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September 1960

DEVELOPMENT OF TITANIUM ALLOY CASTING METHOD

R. V. Carter

AERO-SPACE DIVISION
BOEING AIRPLANE COMPANY
Contract: AF33(600)-36450
AMC Project: 7-656

FINAL TECHNICAL ENGINEERING REPORT

March 1958-May 1960

A commercially feasible process was developed for production of titanium alloy castings for high performance aerospace vehicle applications. The recommended practice utilized a vacuum consumable-electrode arc furnace, a water cooled copper, tilt-pour crucible, expendable rammed graphite molds, and centrifuge casting techniques. The Ti-6Al-4V alloy is the best casting alloy presently available, with as-cast tensile strength in excess of 150,000 psi and excellent surface finish.

METALLIC MATERIALS BRANCH
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NOTICES

This is the final technical engineering report covering all work performed under Contract AF33 (600)-36450 from March 1958 to May 1960. The manuscript was released by the author on May 30, 1960 for publication as an AMC Technical Report.

This contract is a continuation of the work started by National Research Corporation to develop titanium casting fundamentals under Contract AF33(600)-32801, Project 7-216-n.

This contract with Boeing Airplane Company was initiated under AMC Manufacturing Methods project number 7-656, "Development of Titanium Alloy Casting Method." The contract was administered under the direction of Mr. A. H. Langenhelm of the Metallic Materials Branch (LMBML-1), Manufacturing and Materials Technology Division, AMC Aeronautical Systems Center, Wright Patterson Air Force Base, Ohio.

Mr. R. V. Carter, Research Engineer, Aero-Space Division of Boeing Airplane Company was the engineer in charge of the program. The work was supervised by Mr. J. W. Sweet, Chief Metallurgist, Materials and Processes Staff, Aero-Space Division, Boeing Airplane Company.

The primary objective of the Air Force Manufacturing Methods Program is to increase producibility and improve quality and efficiency of fabrication of aircraft and missiles and components thereof. This report is being disseminated in order that the methods and/or processes developed may be used throughout industry, thereby reducing production costs and obtaining "MORE AIR FORCE PER DOLLAR".

Your comments are solicited on the potential utilization of the data and information contained in this report as applied to your present or future production program. In addition, any suggestions concerning additional Manufacturing Methods developments required on this or similar subjects will be appreciated.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER

PRESTON ... HILL, ... USAF

[illegible]

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SECTION A

INTRODUCTION

This is the final report on Contract AF 33(600)-36450. This research and development contract was initiated approximately 1 March 1958 and had the following objectives:

(a) Develop a complete commercially feasible process, on a non-proprietary basis, capable of producing close-tolerance titanium-alloy castings of the type, size, and quality required for aircraft application.

(b) As a practical demonstration of the validity of the developed process, produce and evaluate pilot production quantities of several different casting designs.

(c) Establish procurement specifications, quality control procedures, inspection methods and standards, and design criteria necessary for extensive application of titanium designs.

This program consisted of four phases summarized as follows:

Phase I - Preliminary.	Establish the present state of the art; select components for development as titanium castings.
Phase II - Process Development.	Develop a practicable casting process; investigate melting and pouring procedures, mold materials, mold design, casting alloys, surface treatments, and casting design.
Phase III - Trial Production.	Produce and evaluate test parts; develop quality control methods, inspection standards, procurement specifications, design procedures, heat treatment procedures; establish design allowables by test.

Phase IV - Pilot Production.	Produce pilot production lots of several casting designs in accordance with specifications, etc. developed in Phase III.

Oregon Metallurgical Corporation was selected as subcontractor for this program, and conducted the necessary foundry research and development work.

SECTION B

CASTING PROCESS DEVELOPMENT

MELTING PRACTICE DEVELOPMENT

Because of the extreme reactivity of titanium at and above its melting point, an entirely new melting process has been developed specifically for casting titanium and similar metals. The rapid contamination of titanium at elevated temperature by oxygen and nitrogen and the severe damage to ductility by small percentages of such contaminants requires that all high temperature processing of titanium be done in the absence of air. Also, since molten titanium reacts readily with almost all crucible materials, the problem of containing the heat until enough stock is melted to make a pour has required special attention. The only satisfactory furnace for production casting of titanium was developed previous to this program by the Albany, Oregon experimental station of the U.S. Bureau of Mines. The equipment used in this program is patterned after the Bureau of Mines furnace, with improvements in the mechanisms and controls. Briefly, the furnace consists of a cylindrical tank with a tower for containing and feeding the electrode, a water cooled copper crucible supported on trunnions inside the tank, provisions for centrifuge casting, and the necessary vacuum pumps and controls. A sketch of the vertical axis centrifuge furnace is presented as Figure B1.

Furnace Characteristics and Operation

Two furnaces were used during this program. One was a static casting furnace with provisions for horizontal axis centrifugal casting. The second was a vertical axis centrifugal casting furnace designed and built by the subcontractor to meet requirements developed during this program. Both units operate with the electrode at negative polarity.

All experimental melting and casting was done under a dynamic vacuum. Melting was started by striking an arc between the electrode and a small quantity of sponge or solids placed in the copper crucible or against the skull from a previous melt. Melting power was then rapidly increased to the desired level where it maintained until the electrode was consumed and the molten pool adequately superheated. Upon accumulation of the proper amount of molten metal in the crucible, the power is cut, the electrode is

1. POWER LEAD CLAMPING PLATE
2. WATER COOLED ELECTRODE RAM
3. MICARTA INSULATOR
4. ELECTRODE
5. WATER COOLED VACUUM CHAMBER
6. LIGHT PORT
7. MOBILE VACUUM CHAMBER
8. MOLD SPIN TUB
9. WATER COOLED CRUCIBLE
10. VACUUM PORT
11. VIEW PORT

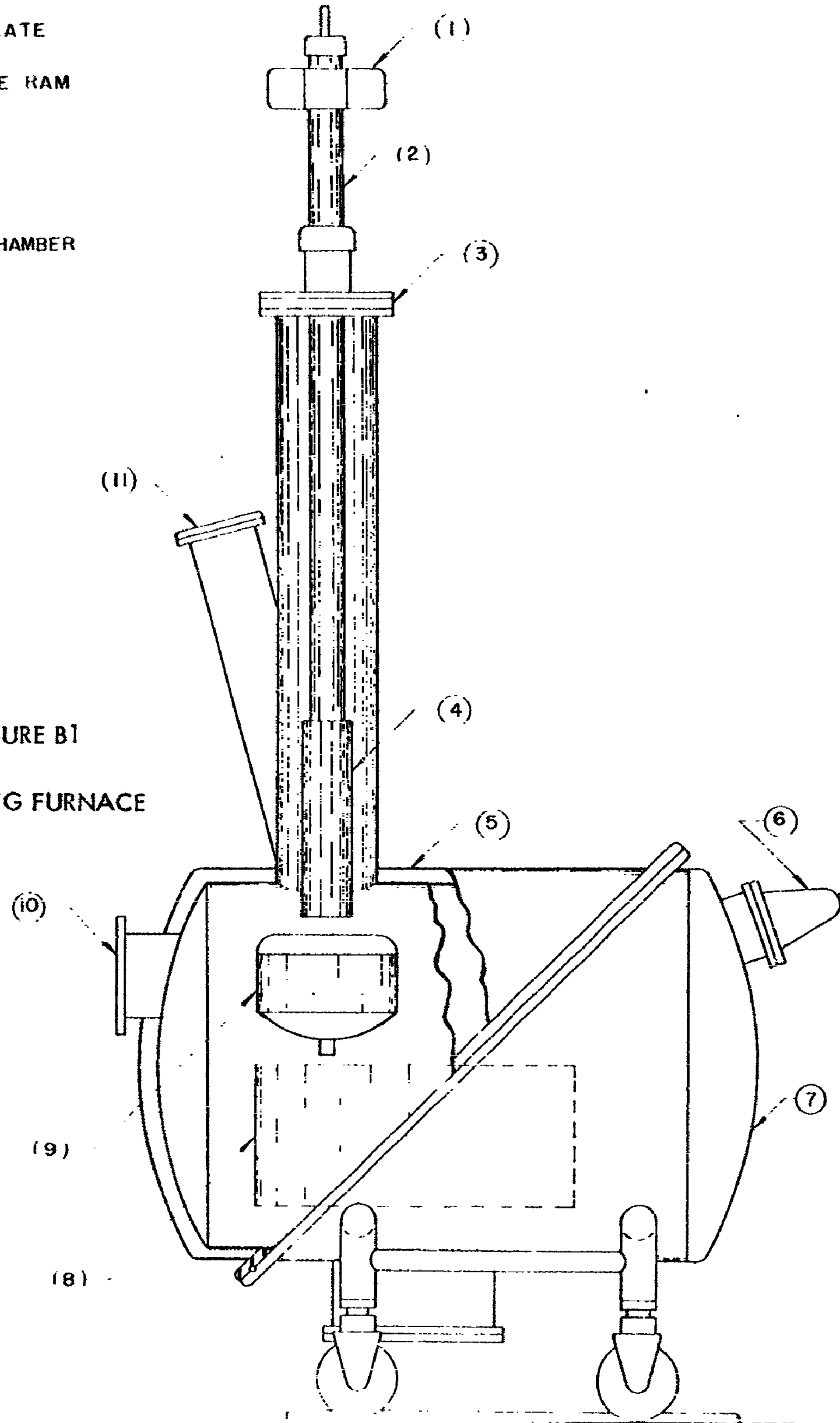


FIGURE B1

CASTING FURNACE

ra; i" · retracted by an ,neumatic cylinder, and the crucible tipped to make the pour. Pouring of the mold is completed in four to six seconds after the arc is extinguished. Table J1 lists the melting conditions recorded for each heat made in this program. The maximum poured weight during this program was 340 pounds.

Cooling of the molds and furnace is usually accomplished by backfilling the furnace chamber with inert gas, or occasionally by allowing slow cool in vacuum.

Electrode Preparation

Electrodes for melting were prepared from ingot, wrought products scrap, or casting recycle material such as gates, risers, and rejected castings. An electrode prepared from ingot requires only the welding of the stub (which is attached to the stinger) to the ingot. The preparation of an electrode from scrap as shown in Figure B2 requires additional fabrication of the electrode by welding.

The general procedure for preparation of an electrode from casting recycle material is as follows. The gates and risers are removed from the castings by power saw, abrasive cut-off, or by oxy-acelylene torch. The material is then cleaned by shot blast. The scrap is segregated to permit control of chemical analysis by blending. The cleaned material is next assembled into an electrode by Heliarc welding in air atmosphere. Figure B2 is a photograph of an electrode of commercially pure titanium which was used to pour experimental castings. This electrode was made from sprues, gates, and risers from previous heats plus a slab of wrought scrap plate which was added to dilute oxygen to an acceptable level. The entire electrode, except the attachment stub, is melted in one pour.

The welds must be large, since they must carry the entire current load being used to melt the electrode. In some instances, inadequate welds have resulted in electrodes beirg prematurely dropped into the crucible. As the consumable electrode is melted, hot spots occasionally occur on the electrode, requiring that the power be reduced. If welding cracking is a problem in fabrication of alloy electrodes, commercially pure weld filler wire can be used to dilute the alloy content in the weld. The electrodes are welded as symetrically as possible to avoid protrusions which could arc to the crucible.

Recycling of Foundry Scrap

It was decided that maximum recycle of gates, risers, and other foundry scrap would be utilized to gain experience on the effects of melting on chemical analysis and the effects of analysis on mechanical properties.

Three series of heats were poured to experimentally de-determine the sources of melting contamination of the cast titanium alloy. The variables in each series were as follows:

Series 1 - Control of melting at the normal operating standards, with electrode preparation by welding in an inert-gas (helium) tank using carbon welding electrode.

Series 2 - Melt under varying furnace vacuum (simulating poor melting practice), with electrode preparation as in Series 1.

Series 3 - Controlled melting as in Series 1, with electrode preparation by cutting and welding (Heliarc) in air atmosphere.

The results of these trials are shown in the series of graphs comparing each of three series of casting conditions. Each of the three casting conditions are plotted on the same graph for comparing the interstitial rise in each controlled series.

Figure B3 illustrates the vacuum control held during the three casting series. The three curves plotted on each graph (Series 1, 2, and 3) are drawn to show the starting vacuum reading, the vacuum reading during the melting cycle, and the vacuum reading directly after pouring. The vacuum is measured in microns of pressure contained in the furnace chamber. It is evident from the "during" melting curve that outgassing occurs from the melting of the ingot and as continued recycling is conducted, the amount of outgassing increases. The "after" pouring reading follows very closely the "during" melting vacuum readings, demonstrating that little gas is liberated by pouring metal into the graphite mold.

The vacuum pressure in Series 2 deliberately varies over a large range as this series was conducted to determine the effect of varied melting conditions. The first recycle heat of the Series 2 tests was started at 50 microns and the remaining heats were varied to complete the recycle experiment. The conditions in the furnace were varied by backfilling to maintain the desired vacuum reading. The second recycle heat in Series 2 illustrates that although the furnace was backfilled to 200 microns, vacuum condition improved during the run due to the continuous pumping of the furnace atmosphere.

The casting trials in Series 3 were conducted to determine the effect of welding the electrodes in air. As the vacuum curve shows, control of atmosphere during the entire series closely parallels Series 1, illustrating that normal vacuum control was held. The "during" and "after" vacuum readings vary over a wide range relative to the initial micron readings, due to welding of the electrodes in air. Because of the method in which the electrode was made for the continuous recycle heats, little welding was necessary. To determine the effect of conventional welding requirements on interstitial contamination, additional welding was performed by welding beacs along the side of the ingot. It is evident from the graphs that outgassing occurred during the melting stage in larger proportion than in the other two series. It was concluded that the welding in air does increase gas evolution during melting.

The series of graphs in Figure B4 illustrate the increase in interstitials in the recycled 6Al-4V. The graphs show carbon, oxygen, hydrogen, nitrogen, and iron content. Each of the series of casting conditions plotted on the same graph illustrates by comparison, the increases in interstitials due to different melting conditions.

The carbon percentage graph demonstrates that in the original heat, carbon increased as the recycle heats continued. Carbon in recycle heat five is low, probably because that electrode was pickled prior to casting. In recycle heat six the carbon content again increases. It is evident that the increase in carbon is a function of the number of times the material is cast in the graphite mold. Melting conditions in Series 2 evidently did not have a separate effect upon carbon increase. The rate of carbon increase is similar to that of Series 1.

The increase in oxygen does not show a great deal of variation, there being a slight increase in all the heats as recycling continued. Poor atmosphere control and welding in air are both detrimental to oxygen control. Since oxygen must be maintained within close limits, the foundry has the option of tight process controls to minimize oxygen pickup during the process cycle or addition of higher purity raw stock to the heat to dilute the contamination to the proper level.

The hydrogen curve illustrates a rapid increase in hydrogen when electrode is fabricated in air by welding with Heliarc.

The increase in nitrogen occurs slowly as recycling continued. In heat five of Series 1, a reduction in nitrogen is noted on the graph. The reason is not known. Series 2 increases in nitrogen are gradual and uniform and increases in nitrogen, therefore, seem to be consistent with uncontrolled furnace conditions.

The increase in iron in recycling titanium does not seem to be separately influenced by furnace conditions. It is expected that the iron content would not increase appreciably as recycling continued. The source of iron contamination was shot blasting of the ingot material for cleaning and, as very little cleaning was necessary for recycling, the contamination level was kept quite low.

Mechanical property tests of each of the recycled heats are reported in Table J2 and are plotted on graphs in Figure B5 . Yield strength, ultimate tensile strength, elongation, reduction of area, and Brinell hardness are included. Each plotted point is based on the average of three tensile specimens tested. Series 1 strength curves show a small increase in strength over the period of recycle heats. The second series strength curves show higher, but consistent strength in recycle heats except for heat four, where the specimens failed without yield.

The Series 3 conditions resulted in a gradual increase in strength as recycling continued.

The ultimate strength curves are generally similar to those shown for yield strengths. The average ultimate tensile strength of the fourth heat of Series 2 dropped to 81,000 psi, with no ductility.

After recycle heat three, the chemical analyses and properties showed greatest variation between the three practices investigated. This indicates that recycling of selected foundry scrap is acceptable if the scrap is properly diluted with new metal.

FIGURE B2

TYPICAL ELECTRODE

FIGURE B3

FURNACE PRESSURES DURING EXPERIMENTAL RECYCLE TRIALS

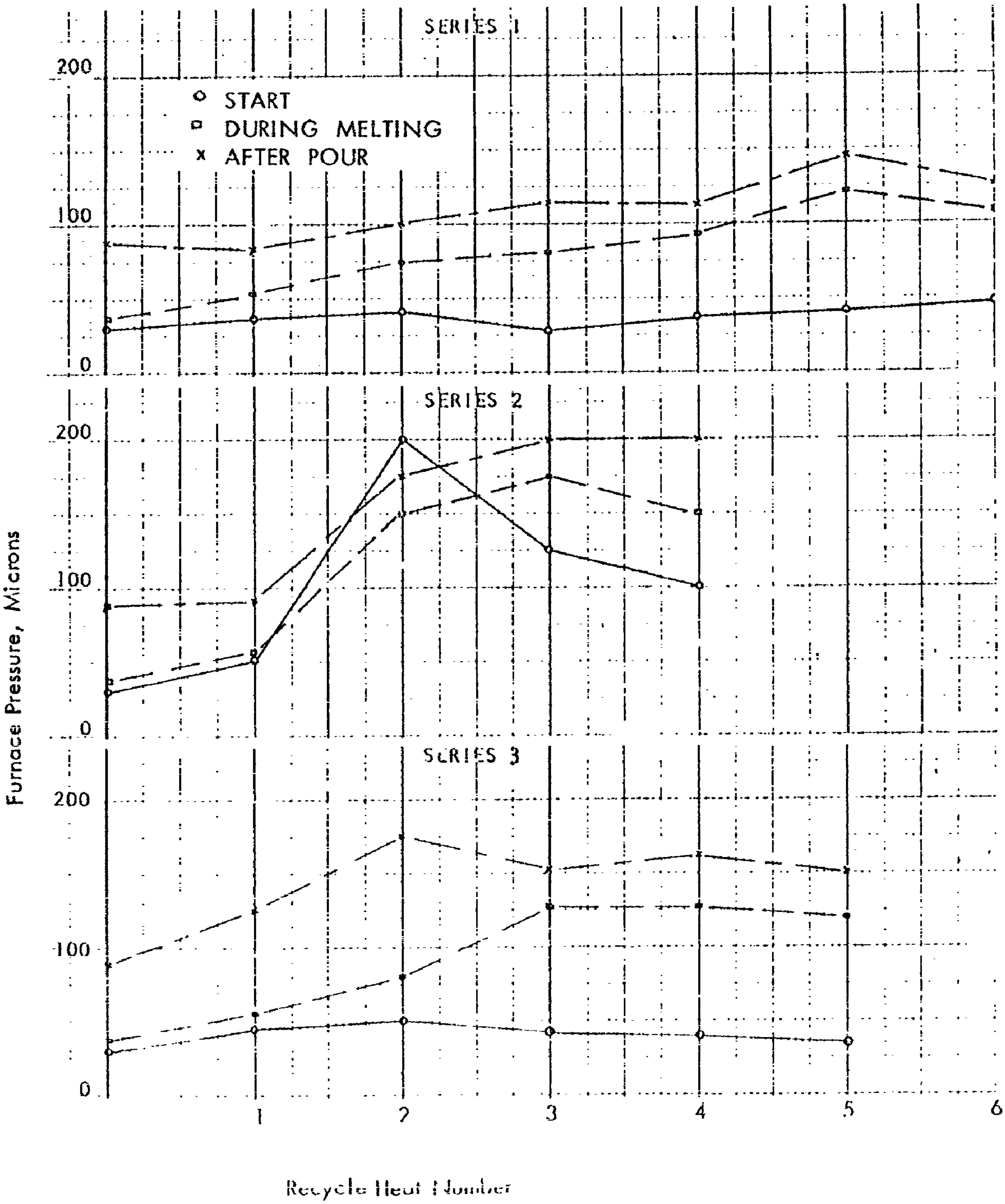


FIGURE B4

INTERSTITIAL ANALYSES OF RECYCLE HEATS

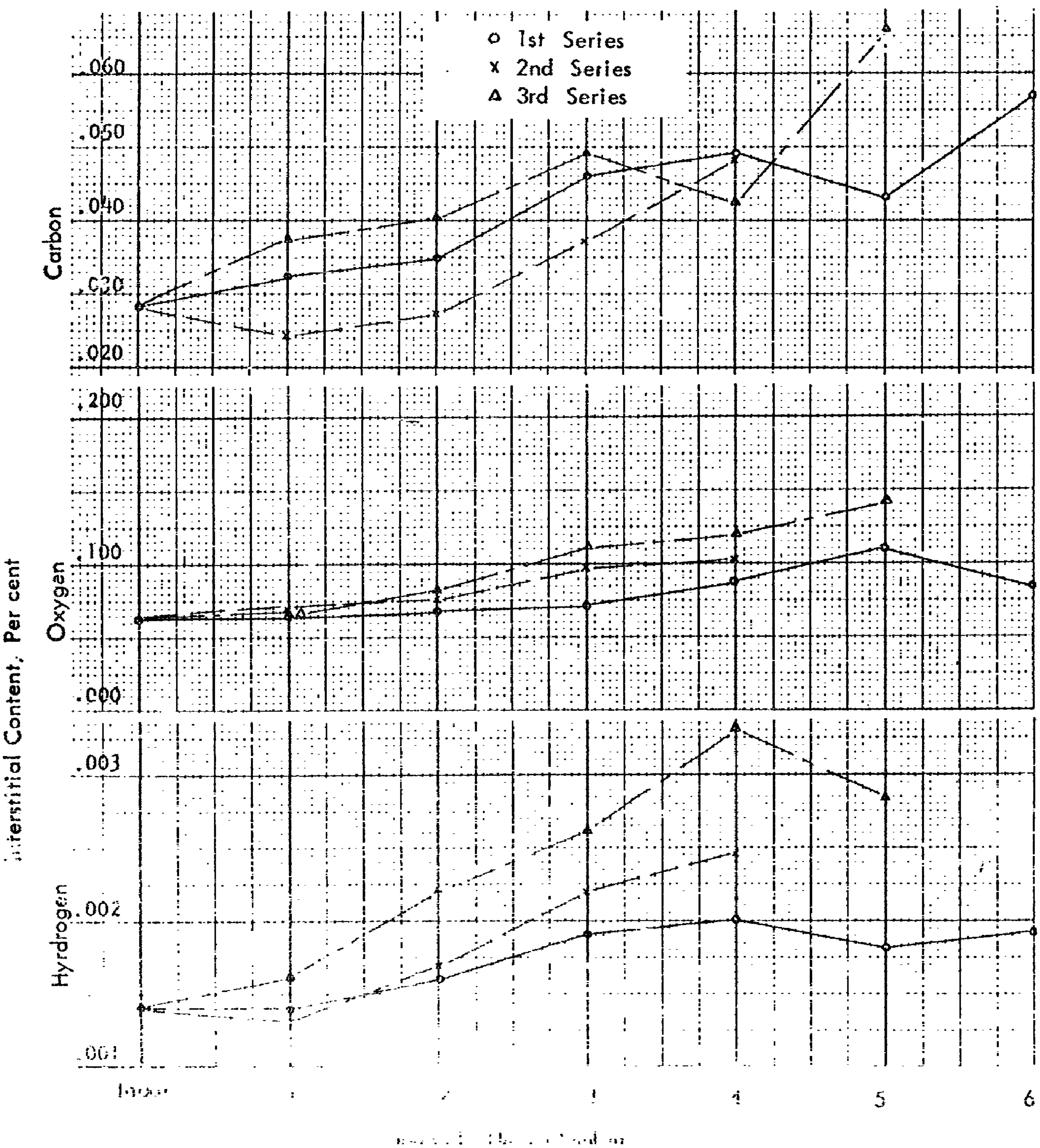


FIGURE B4 (Continued)

INTERSTITIAL ANALYSES OF RECYCLE HEATS

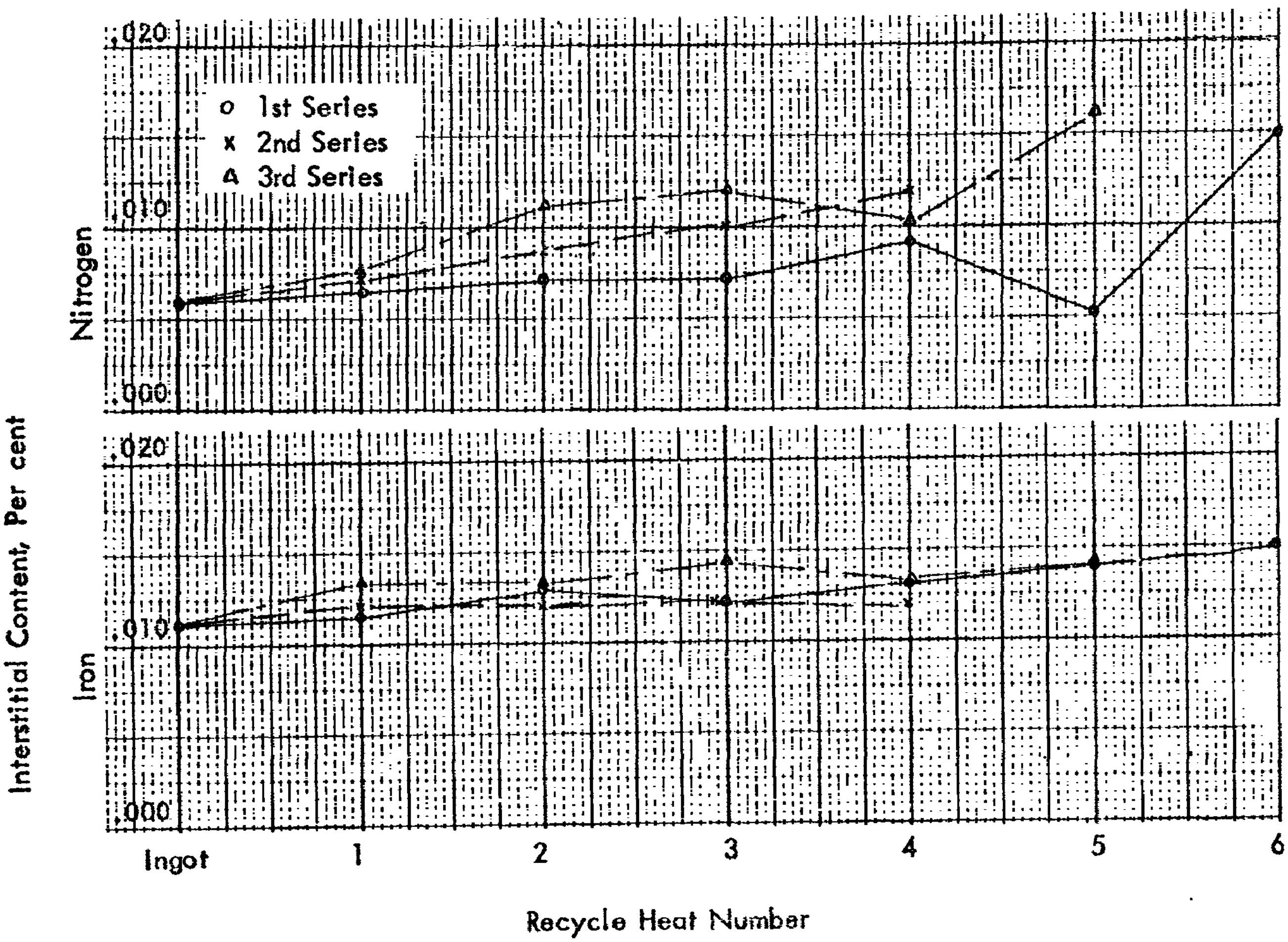
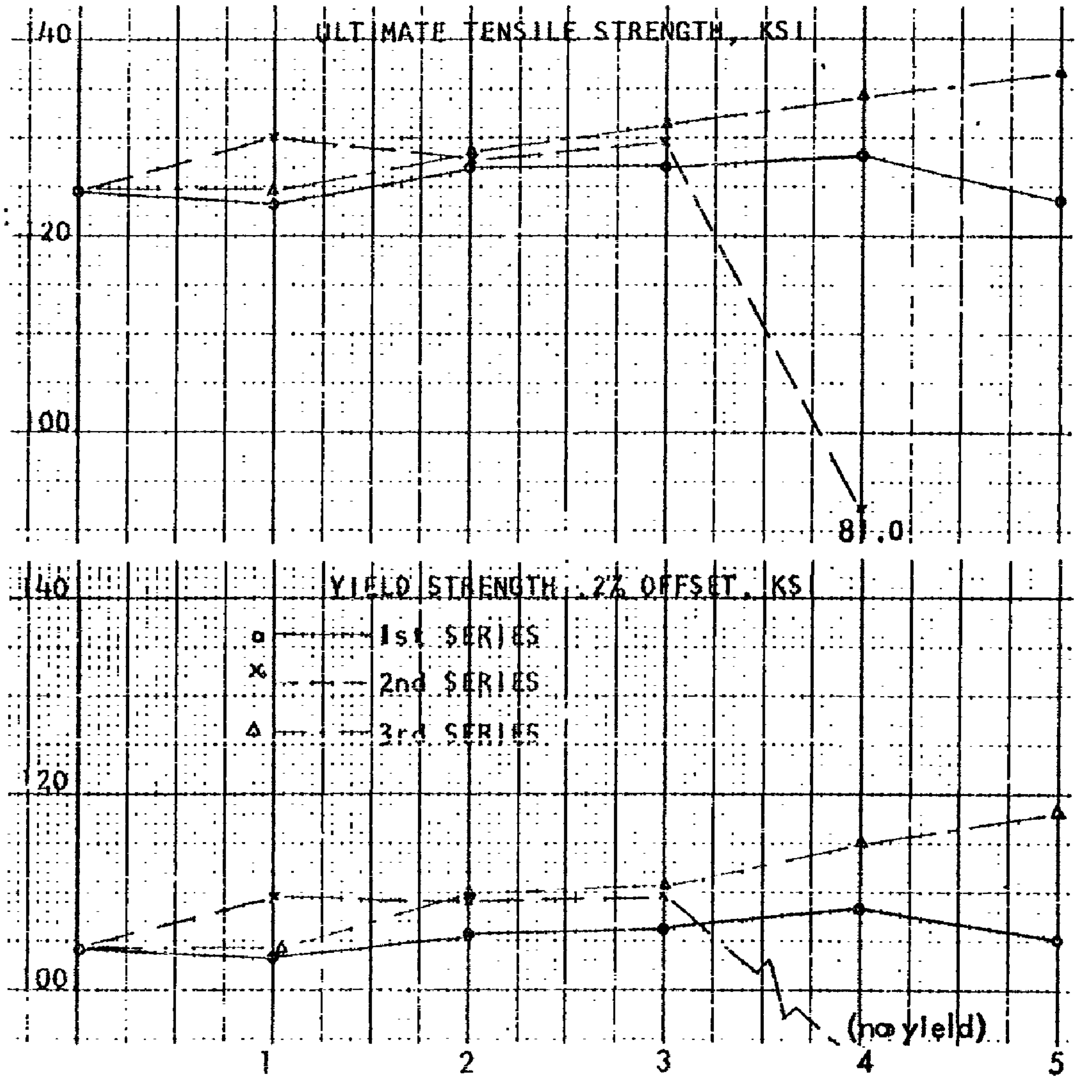


FIGURE B5

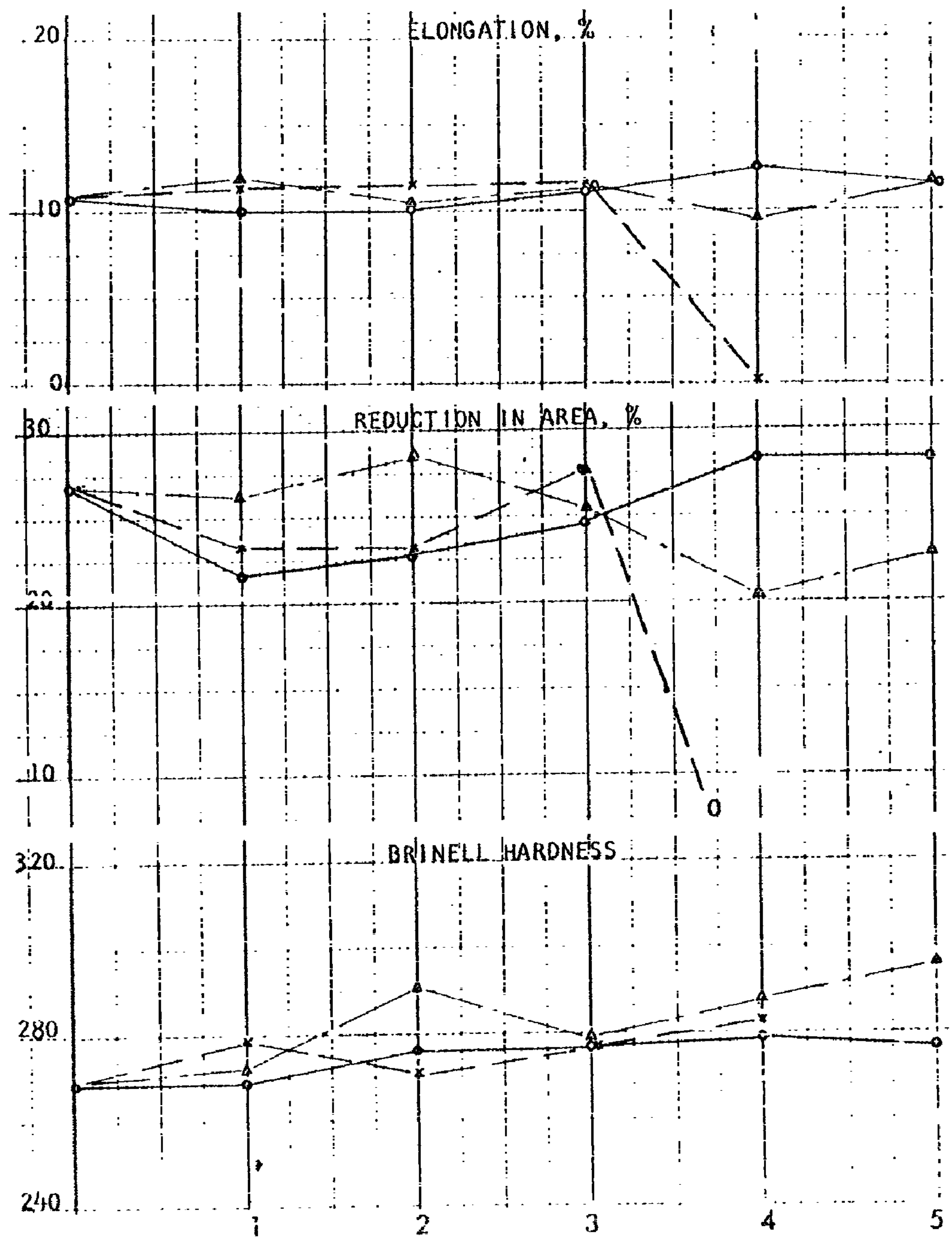
PROPERTIES OF RECYCLED Ti-6Al-4V



Recycle Heat Number

FIGURE B5 (Continued)

PROPERTIES OF RECYCLED Ti-6Al-4V



Recycle Heat Number

MOLD DEVELOPMENT

A major problem in the development of a practical process for casting of the reactive metals has been that of finding a suitable mold. The conventional mold materials used for casting of steels (such as sand, shell, or ceramic molds) are completely unsatisfactory for titanium, since titanium above or near its melting point will violently react with those materials. The only materials which have been found to satisfactorily withstand contact with molten titanium are metals or graphite. Of these, graphite has been the most satisfactory.

Machined Graphite Molds

At the time of initiation of this contract, usable titanium castings of simple geometry had been produced in machined graphite molds. This material was used for much of the early work in this program, such as the first trial casting of the developmental bracket and the first feeding studies. It was soon found to be unsatisfactory for the developmental bracket, because the high strength of the mold would not allow proper contraction of the casting during cooling, and consequently would cause hot tearing in the restricted web area and mold spalling, particularly at corners and restricted areas. Mold life can be extended by use of replaceable mold inserts.

In general, machined graphite molds are useful for simple shapes, where the mold does not restrict contraction of the metal during cooling. Reproduction of surface detail is good, and close dimensional tolerances can be maintained. Some loss of dimensional tolerance capability occurs if mold inserts are used.

Metal Molds

Metal molds are satisfactory for only the simplest of shapes. Any restriction of contraction during cooling of the casting will cause rupturing of the restricted areas. The cost of preparing a metal mold is high.

Rammed Graphite Molds

Shortly before initiation of this program, details were published on research work on rammed graphite mold mixtures carried out by A.L. Feild, Jr. at the E.I. du Pont de Nemours experimental station at Wilmington, Delaware. The mold mixture consisted of powder graphite as a base, corn starch for a green binder, pitch and carbonaceous cement for a high-temperature binder, and water with a wetting agent to provide molding plasticity. Further development of the mold was done by Andes, Norton, and Edelman at Frankford Arsenal. This work provided a starting point for development of a suitable rammed-graphite mold for production casting of titanium.

A total of 133 experimental mold mixtures were prepared and tested during this program. Parameters used in judging the mixtures were mold shrinkage; presence or lack of reaction with titanium; carbon contamination of the titanium; green strength, permeability, and hardness; and general handling and casting characteristics.

All batches were mixed in a Carver Muller, Model I-GF. The general mixing procedure was:

(a) mull graphite (or other base) and starch dry for two minutes,

(b) add pitch and mull for two minutes,

(c) add water and cement and mull for four minutes.

Samples of each batch were hand screened through an eight-mesh riddle for testing. In most cases, molds were prepared from the remaining material for shrinkage determinations and casting trials. Compositions of the various mixes are in Table J3 . Grain size distributions of the graphite base materials are in Table J4.

Two-inch diameter by two-inch length standard American Foundrymen Society briquette specimens and standard A.F.S. tensile specimens were prepared from the screened material. These specimens were hand rammed to a hardness of A.F.S. 80 when mix properties permitted.

After the properties of the green specimens had been determined, specimens were air dried for a minimum of 16 hours at 250°F and then fired. Firing was accomplished by packing the specimens in graphite powder in corrosion resistant steel boxes, and placing the box in an electric-resistance heated furnace at 1200°F. The temperature of the furnace was raised to 1600°F for three hours and the furnace then turned off and allowed to slowly cool. The specimens were removed after the furnace had cooled to 1200°F. After air cooling to room temperature, the specimens were tested using standard foundry sand-testing equipment. The results of tests on the trial mold mixtures are given in Table J5.

Next, rammed molds for casting 5/8-inch thickness by six-inch diameter plates were prepared from the experimental mixtures. These molds were used to determine mold shrinkage during firing and to determine carbon pickup, resistance of the mold to reaction with the titanium, and surface quality of the cast part. Most of the molds were produced using a split core box technique where the pattern halves could be assembled to form the completed mold. Molds were bench rammed to a mold hardness of A.F.S. 80 using a pneumatic hand rammer. The patterns were drawn using a vibrator draw machine.

The molds were partially dried at room temperature and finish dried at 250°F, usually for 16 hours. They were then packed in graphite powder in corrosion resistant steel boxes and placed in an electric-resistance heated furnace at 1200°F. The furnace was then raised to 1600°F, held for three hours, and the power shut off. The molds were removed when the furnace had cooled to 1200°F. The firing cycle required approximately 24 hours. Fired molds were stored at 250°F until about two hours before pouring, when they were assembled. It is desirable to keep the molds hot until they are placed into the casting chamber, to avoid moisture pickup from the atmosphere. This is difficult since the external gating and the mold halves and cores must be manually assembled after the mold is fired. Later in the program, molds for production castings were heated to 1650°F instead of 1600°F, in an attempt to reduce gas porosity defects.

The results of hardness tests on the experimental rammed molds are in Table J5. The shrinkage measurements (made by measuring outside dimensions of molds before and after firing) are given in Table J6.

Carbon contamination adjacent to the surface of Ti-6Al-4V castings produced in rammed-graphite and machined-graphite molds was determined by machining 0.003-inch successive cuts from the face of cast discs and analyzing the cuttings obtained. The edges of the discs had been previously machined so that contamination at the edge would not influence the analyses. Results of these tests are plotted in Figure B6. As shown by this graph, the carbon contamination is high adjacent to the surface, but decreases rapidly as depth increases, and at .025 to .030-inch has leveled off to the base carbon content of the casting. This depth of contamination was confirmed by hardness traverse technique.

Mixtures 7 through 15 were produced to evaluate binders. Observations of interest are that laundry starch provides fired strength, pitch provides fair green strength and best fired strength, carbonaceous cement contributes only to baked strength, and foundry corn flour provides good baked strength but is weak after firing. Starch-pitch and starch-cement combinations provide good green and fired properties.

Mixtures 19 through 29 evaluate the use of raw linseed oil as a substitute for carbonaceous cement. Three and four percent additions of linseed oil produced good molds without detriment to castings poured in these mixtures. However, the mixtures containing linseed oil were difficult to handle because of "stickiness". Costs of the two materials were found to be about equal.

Mixtures 34 through 38 were made with varying amounts of carbonaceous cement and with corn flour as a substitute for laundry starch. Although the tests of the low cement mixtures indicated desirable properties, the molds tended to be weak and broke easily at corners.

Mixtures 39 through 133 were made to investigate substitute materials such as coke for graphite, to test a wetting agent, and to find mixtures that would decrease mold shrinkage.

The addition of "Duponol G" (du Pont), a wetting agent, to the rammed graphite mold mixture caused significant increase in fired tensile strength, but caused stickiness of the mixture making preparation of molds more difficult.

The use of conventional liquid foundry binders in the mixture (Mixtures 61 - 64) severely aggravated the gas porosity problem and caused poor surface quality in the casting. Soluble aminoaldehyde thermosetting resin (a high solid urea type of water soluble binder), and a phenol-formaldehyde water dispersed binder were used. In conventional foundry practice, these are used mainly as core binders. It is probable that the gas porosity and surface quality problems were the result of incomplete removal of volatiles during firing of the molds, and that modified firing practice including higher firing temperature could be developed for these binders.

Mixtures 71, 72, and 73 were made using "Slurry" (a petroleum residual available from Union Oil Company, Los Angeles) in place of water. As in other series, the percentages of pitch were varied. These mixtures exhibited low green strength making pattern withdrawal difficult, particularly with complex molds. Mixtures 74, 75, and 76 also included Slurry, but no starch or cement. These mixtures also exhibited low green strength. Additional mixtures were made without starch, cement, or Slurry; with varying amounts of pitch and water; and with additions of coke flour.

Some of the mixtures made contained coke as a substitute for granular graphite in an effort to reduce mold cost. However, coke was unsatisfactory because of severe reaction with the molten titanium, apparently because of high sulfur in the coke.

Mixtures 1 and 17 were considered the best of those tested. They handled well during ramming, provided good casting surfaces and had desirable strength levels. Mixture 17, with less moisture than mixture 1, had superior flowability and produced the better casting surface of the two but because of its lower green and fired strength, required more careful handling of the mold. Mixture 17 was selected as the most satisfactory mold material and was used for the pilot production phase.

Shell Graphite Molds and Cores

A partially successful program was conducted to develop a shell process for making graphite molds and cores. The resulting shell was used primarily for cores, and was satisfactory except when exposed to a large volume of metal or when a sharp corner of the core was exposed to metal on both sides, in which cases penetration of metal into the shell occurred.

The experimental shell graphite mixes used in this work are listed in Table J7. The mixture selected as best and used in production of Phase IV castingsis mixture 4.

The mixtures which contained calcined coke as a substitute for granular graphite produced excellent surface finishes but sometimes caused reaction with the molten titanium, apparently because of sulfur in the coke.

The investment cycle found to be best was 8 seconds, with a one minute cure. Variation in investment time directly causes variation in thickness of the shell. Curing longer than one minute does no harm but was unnecessary. After a one minute cure, the shell was quite strong and was durable enough to be handled without undue breakage. Investing and curing are accomplished at 350° F. At temperatures above 350° F, the shell adhered tightly to the pattern and was difficult to remove. Various parting agents were tried but did not eliminate the stickiness problem at high curing temperatures.

Air pressure used to force the mixture into the corebox was found to be an important factor in producing good shells. To obtain consistently strong and dense shells, it was necessary to use an air pressure of 20 - 25 psig. A problem was experienced in some trials, because of the rapid set-up of the mixture. During the build-up of the shell, a bridging of the initial layer over parts of the corebox was observed, particularly over sections that had re-entrants such that the mixture entering did not impinge directly on all portions of the corebox. Venting along the parting line of the corebox aided in reducing this problem. When molds or cores containing bridged areas were fired and used, metal penetration occurred into the bridged portions of the mold.

Shell cores were experimentally used to core the cavities in the Sway Brace Case, the Torsion Fitting, and the Flap Track Link, and to form the pockets in the Developmental Bracket. These experiments demonstrated that the shell cores are not suitable adjacent to heavy sections or to form sharp fillets, because of penetration of metal into the core. The heavier volume of metal around the shell apparently does not permit the initial chilled skin to remain in place next to the core wall. Consequently, molten metal remains in contact with the shell and penetrates into it.

Coreboxes were machined from aluminum or block graphite. The shells prepared in graphite coreboxes were equal in quality to those made in the conventional aluminum coreboxes. Graphite coreboxes were preferred for experimental work because of the ease of making dimensional changes. The graphite and aluminum boxes were initially prepared for investing by application of a silicone parting compound (grease) and then spraying with a silicon-water emulsion to facilitate shell removal. The silicon-water emulsion was re-applied before each investment cycle.

The shell graphite process was further studied to determine if complete molds could be produced in multiple stacks. A corebox was prepared to make multiple molds for casting discs. The pattern equipment consisted of two 1/2" x 9" x 10" aluminum plates separated by a 3/4" x 1" frame work around three sides to make the box. The cavity for the casting was a 5/8" x 6" diameter disc, half of the disc on the interior of each of the box halves. A central 1" diameter core was also located to provide the sprue in each of the molds. The graphite material was invested from the bottom of the box in the shell core machine. The completed mold was then fired at 1650°F in the standard manner. The shell molds, when stacked together, formed a complete 5/8" x 6" diameter disc with one-half of the disc in the cope section of each mold and one-half of the disc in the drag section; the parting line of the casting being between the two surfaces of the molds. The sprue was centrally located to permit a single gate at the bottom to feed the entire stack of castings. Twelve 5/8" x 6" diameter discs were to be cast in a single stack. Two attempts were made to pour the stack of molds. The first attempt failed because of severe mold reaction between titanium and coke molds. The second pour was partially successful but insufficient metal was poured to fill the entire set of plates and only ten of the twelve discs filled. The second series of molds was made of granular graphite material. There was no penetration into the graphite material and the castings were relatively clean with no surface burning.

Conclusions reached as a result of the shell mold studies are as follows:

(a) The shell molding process offers excellent potential for production use.

(b) At the present stage of development, shell graphite molds or cores are not suitable for shapes with relatively large volume concentration or with sharp fillets, because penetration of metal into the shell occurs in these areas.

(c) The feeding distance in shell graphite molds appears to be approximately 1.5 times that typical of rammed graphite molds.

Investment Molds

The initial experiments with investment casting techniques were conducted with a proprietary investment mold developed by Misco Precision Company, Muskegon, Michigan.

The results of the first investment casting trial are shown in Figure B7 . The castings had good reproduction of detail, but rough surface and some surface burn-in. The major defect was the severe gas porosity in the casting. Figure B8 is a print of the x-ray of the tensile test specimens and clearly shows the extreme porosity.

Figure B9 is a photograph of a casting made in another type of investment mold which was made with a graphite primary coat. Gas porosity was extensive throughout the castings, but surface finish was excellent. The mold was centrifugally cast in the vertical axis centrifugal furnace in an attempt to eliminate the gas porosity problem. The ingates into each of the molds broke and complete mold filling did not occur. The threaded portions of the test bars showed evidence of reaction between the mold material and the metal.

Castings made in a third type of Misco Proprietary investment mold showed severe surface reaction and gas porosity. The primary surface of this mold was composed of graphite and zirconium oxide. The type of binder used is not known. The photograph in Figure B10 illustrates the severity of reaction.

A general observation in connection with experimental casting of these molds is: to obtain a gas free casting, a binder that does not retain oxide materials must be used to prevent reaction and subsequent gas in the castings.

Additional investment casting trials were conducted using molds developed by Oregon Metallurgical Corporation. The program was aimed at producing an experimental mix that would not react with the metal and that would produce gas-free castings. The mixtures tried are listed in Table J8. Casting trials were conducted on only those mixtures that showed promise as an investment material.

Castings were poured into simple bar molds made from mixtures 11, 14, 15, and 16.

The molds made from mixtures 11 and 15 exhibited violent reaction with the molten titanium, only about half the metal remaining in the mold. It is believed that moisture in the second coat caused the reaction. The mold made from mixture 14 also reacted violently, with no metal remaining in the mold. This is believed due to the oxides and silicates in the second coat.

Mold mixture 16 was used to make four trial castings with no evidence of reaction. A problem of mold-face porosity was caused by bubbles in the mixture and resulted in rough surface on the casting. It is expected that further development of the process (such as mixing of the ingredients in a vacuum chamber and mechanical vibration during investment) would solve this problem.

In general, the development of a satisfactory investment mold for casting of titanium appears feasible if based on the use of graphite.

Recycling of Mold Materials

The object of this study was to determine if mold materials could satisfactorily be reused to make new molds and, if so, to establish suitable preparation methods to obtain proper grain size and distribution in the recycle materials.

The process for reclaiming the rammed graphite molds involves crushing, pulverizing, and screening. The crushing operation was to reduce the size of mold fragments broken from the castings to approximately 1/2-inch size for feeding to the pulverizer (a hammer mill) which then reduced the material to the proper grain size for making new molds. In some instances when crushing machined graphite, a large proporation of fines were produced and screen classification was necessary to separate the useful portion from the fines.

To establish a procedure for obtaining material of proper grain size from the pulverizer, several samples were processed using different rotor speeds and screens, these being the variables most effective in adjusting grain size. Table J9 is a tabulation of grain size distributions of the test samples. The rotor speed of the pulverizer was varied between 14000 and 6070 RPM. The higher rotor speeds produce larger proporations of fines. The rotor speed of 6070 RPM combined with the 1/8-inch mesh herringbone screen produced the lowest percentage of fines.

The present stage of reclamation of the pulverized graphite mold material involves a screen classification process to obtain the desirable portion of the pulverized material. The material as recovered from the pulverizer can be used in two different ways. The first is to use that material which will pass through the No. 20 screen of a vibratory shaking unit. The distribution of the material is listed as Sweco No. 20 in Table J4. This material was somewhat coarse, but produced acceptable molds where fine surface finish was not essential. The most satisfactory combination of classified material has been found to be 60 percent Sweco No. 20 and 40 percent Sweco No. 40 mixed together and used with the standard mix ingredients. This combination contains a higher portion of fines than is normally desired in general foundry molding practice, but has been found to be satisfactory for the rammed graphite mold practice.

FIGURE B6

CARBON CONTAMINATION DEPTH IN Ti-6Al-4V CASTINGS

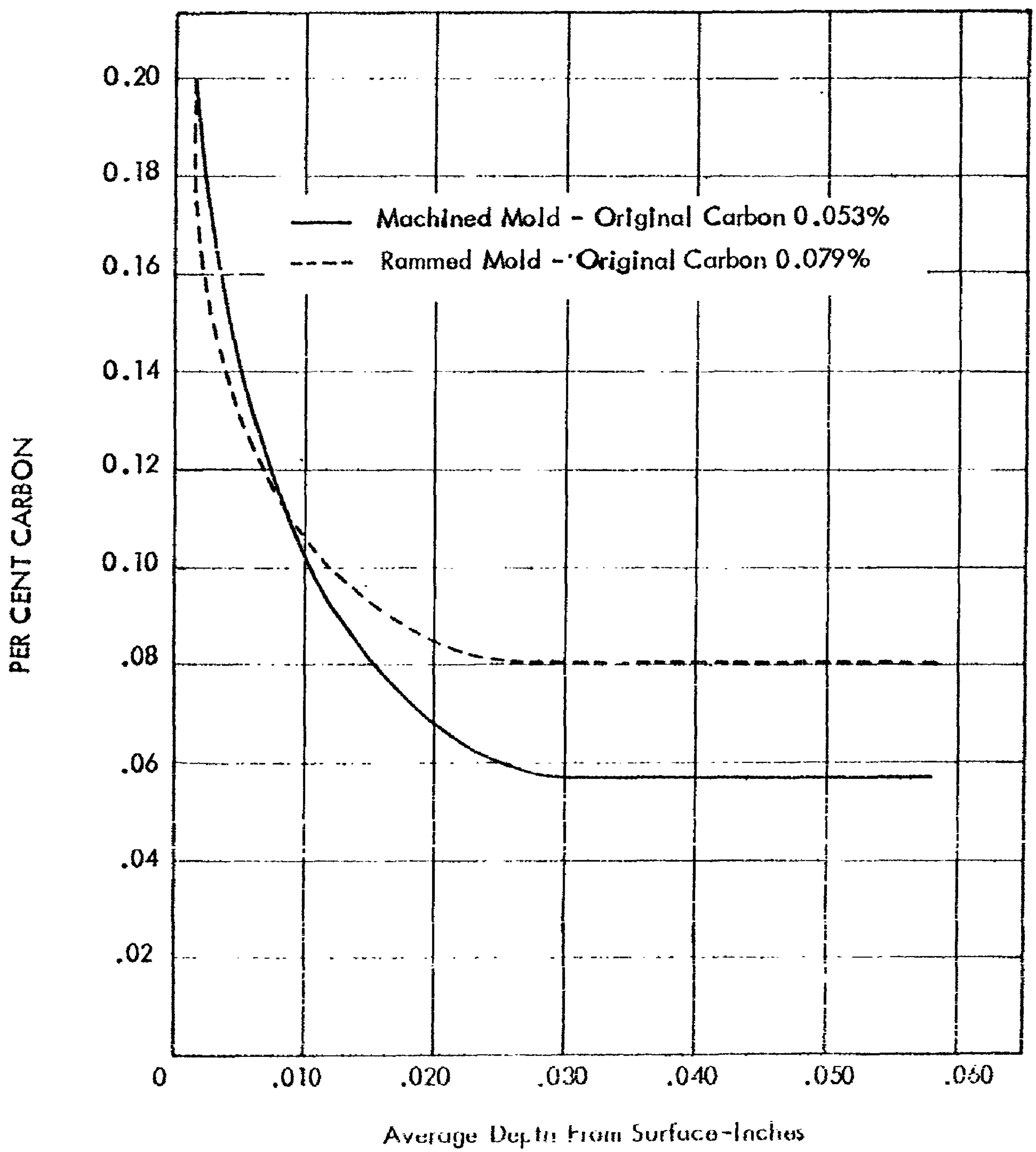


FIGURE B7

INVESTMENT CASTING

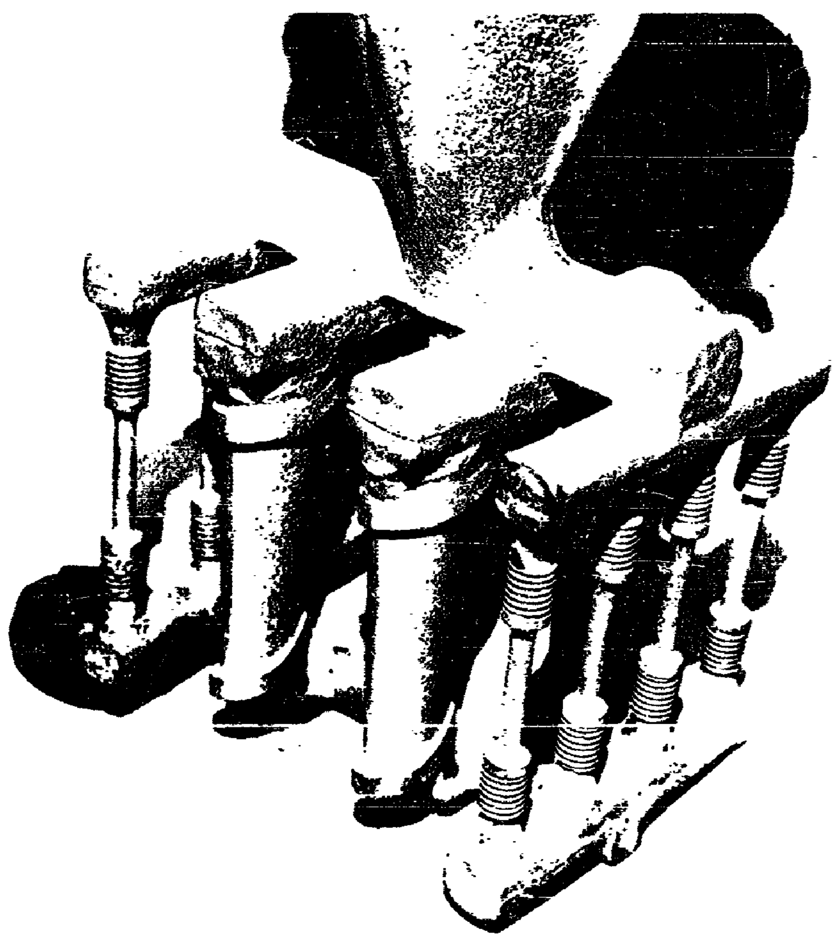


FIGURE B8

X-RAY OF INVESTMENT CASTING

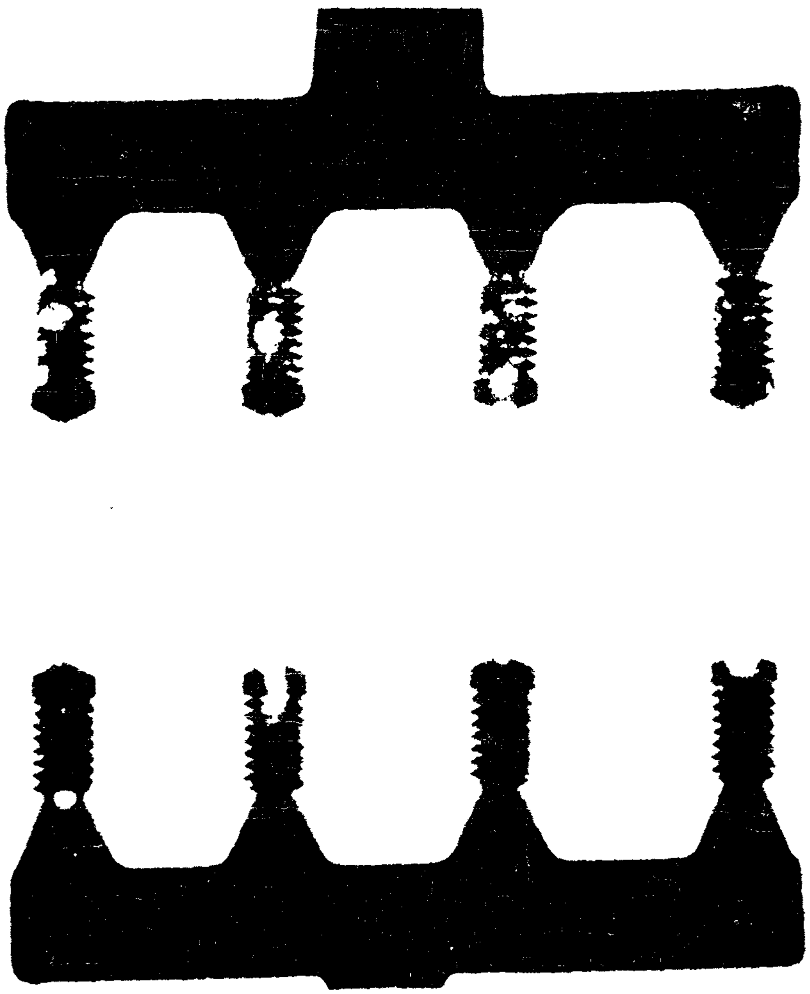


FIGURE B9

INVESTMENT CAST Ti-6Al-4V

FIGURE B10

INVESTMENT CAST Ti-6Al-4V

FEEDING STUDIES

Feeding Distance in Flat Sections Cast in Machined-Graphite Molds

An early study in this program consisted of the casting of Ti-6Al-4V titanium alloy into a series of round, flat discs of various diameters, thicknesses, and riser sizes, using machined graphite molds. The purpose of the study was to become familiar with the feeding characteristics of titanium alloy castings.

The specific objectives of the study were:

(a) to determine minimum riser diameters required to prevent under-riser shrinkage porosity,

(b) to determine the "edge effect", or soundness contributed by faster cooling adjacent to the disc edge,

(c) to determine feeding distance changes caused by risering variations,

(d) to measure the total effective feeding distance contributed by the riser and by edge effect.

Plate diameters of five and six inches were cast, with thicknesses from 3/8 to one inch in 1/8-inch increments. Riser diameters were equal to their heights and were varied from one to 2 1/2 inches. In all cases, the risers were concentric to the plates. A typical casting heat is shown in Figure B11. One inch gates were used. All molds for this series were machined from graphite block. A typical mold setup is shown in Figure B12.

After casting, the plates were x-rayed and examined for under-riser shrinkage, shrinkage beyond the riser, and soundness adjacent to the edge and riser. The total soundness is expressed as "T" and is equal to D/t where D is the sum of the sound distance measured radially from the edge of the riser and from the edge of the plate, and t is the thickness of the plate.

The results of the study are tabulated in Table J10.

After the first three trial pours, it was established that bottom gating, as shown in Figure B11, produced the best casting detail. This general setup was used for making all subsequent static pours of this type.

Examples of extreme conditions of shrinkage observed are illustrated in Figures B12, B13, and B14. These illustrations are photographic prints made directly from x-ray films.

The following was concluded from this study:

(a) Feeding distance in flat sections (no taper) in unheated machined-graphite molds does not exceed 1T for consistently sound castings.

(b) Riser diameter at its junction with the casting must be not less than two times the casting thickness, to prevent under-riser shrinkage in castings made in unheated machined-graphite molds.

(c) Bottom gating provides casting detail superior to top gating.

Feeding Distance In Tapered Sections Cast in Machined and in Rammed Graphite Molds

A second feeding distance study was conducted to evaluate the effect of taper on soundness of cast titanium discs. In this study, both rammed-graphite and machined-graphite molds were used. All discs were tapered such that thickness increased from edge to center, and were cast in edge thicknesses of 1/8 to one-inch in 1/8-inch increments. The following types of static molds were used:

(a) unheated machined-graphite,
(b) unheated rammed-graphite,
(c) heated machined-graphite,
(d) heated rammed-graphite.

The results obtained on study of x-rays of the castings made in unheated machined-graphite and rammed-graphite molds are presented in Tables J11 and J12. The parameter "T" (defined on page B30 is plotted against taper for various disc edge thicknesses in Figures B15 through B17. Figure B18 relates the taper required for sound castings to the edge thickness of the discs, for castings made in machined or in rammed-graphite molds.

The results obtained in similar trials using heated machined-graphite molds are in Table J13. These tests were made using discs of 1/8 to one inch edge thicknesses with zero, one, three, five, and seven-degree tapers. The mold temperature at the time of pouring varied from 210 to 355 degrees fahrenheit. The parameter "T" for the heated molds is plotted against taper for various edge thicknesses in Figures B19 through B21, along with the "T" values obtained from the similar tests of unheated machined-graphite molds.

A similar series of trials was conducted using heated rammed graphite molds. The mold temperature at the time of pouring varied from 200 to 400 degrees fahrenheit. The results obtained are tabulated in Table J14 and plotted in Figure B22 to B24.

The following observations were made from this study:

(a) Increased taper in unheated machined-graphite molds improves soundness primarily by increasing the edge effect. Increased taper in unheated rammed-graphite molds improves soundness primarily by increasing riser effect. Less taper is generally required in rammed-graphite molds than in machined-graphite molds, for equivalent soundness.

(b) Shrinkage porosity in cast titanium appears as distinct voids rather than as cloudy low-density areas on the x-ray film. Microshrinkage has not been observed.

(c) In cast tapered discs of 1/8-inch edge thickness, riser feeding distances were greater in machined-graphite molds, however, for all other thicknesses tested the rammed graphite molds provided the [illegible]

(d) Increasing the amount of taper progressively improves feeding distances in rammed molds. In the case of machined-graphite molds the feeding distance decreases until taper exceeds three or four degrees, and then increases.

(e) The effectiveness of taper decreases as the section thickness is increased.

(f) The tapers required to cast sound sections have been established in relation to thickness, and are shown in Figure B18 in graphical form for machined and rammed-graphite molds.

(g) The use of heated molds did not appreciably improve the feeding of cast Ti-6Al-4V alloy but did decrease the gas porosity problem, apparently because of reduced moisture pickup during mold assembly.

Feeding Distance in Shell Graphite Molds

The experimental castings of plates in shell graphite molds exhibit greater areas of soundness than castings in the other mold materials. The initial casting of the plates was primarily for determination of carbon contamination from the shell graphite material. Due to excessive distortion of the shells during casting, the plates were not used for carbon contamination studies. X-rays of these plates revealed only small dispersed shrinkage areas, as contrasted to general heavily dispersed shrinkage in previous castings produced in rammed graphite and machined graphite in the 5/8" plate thicknesses without taper. There was evidence of gassing occurring in two of the four plates cast in the heat. The second experimental casting of shell graphite plates was made with a supporting arrangement to prevent sagging about the periphery of the plate. The casting experiment was not successful due to inadequate support on the surface of the cope, resulting in mold rupture. The chilling effect was sufficient to prevent loss of metal through the cracks in the molds even though the plates were much thicker than desired, because of the mold deformation. It appears that slight tapers in plates cast in shell graphite molds would greatly extend feeding distance, because the absence of an effective amount of chilling permits the metal to solidify in a slower and more directional manner toward the casting risers.

Feeding Distance In Centrifuge-Casting

A comparative study of feeding distance in centrifuge-cast discs was conducted using 1/2-inch thickness by six inch diameter disc molds mounted on a central sprue. Four plates were cast in machined-graphite molds in each of six heats. The casting setup is shown in Figure B25.

The object of the study was to determine the effect of ingate size and centrifuge speed on the feeding distance. The data obtained are in Table J15.

The feeding characteristics in these discs were not significantly different from the similar discs which were statically cast, except the edge effect on soundness was somewhat less in the centrifuge-cast plates. There was not an appreciable difference in soundness when rotation speed was increased.

It was noted that the portion of disc which was forward of the gate during centrifuging had improved soundness over the trailing section. A second group of centrifuge-cast discs were made with the gates at the trailing edge. This modification did not improve casting soundness.

Several casting trials were made to investigate gating techniques in centrifuge casting. Molds were prepared to produce 1/4 by three by five inch plates, and were arranged so that the plate mold could be filled either from the leading or trailing edge, by reversing the direction of rotation of the centrifugal casting apparatus. A photograph of a typical casting produced during these trials is shown as Figure B26. When the centrifuge was rotated counterclockwise the plate molds were effectively "top filled", and were "bottom filled" when rotated clockwise. A comparison of surface qualities of castings produced at various rotation speeds (200, 700, and 1600 rpm) and directions demonstrated considerably superior surface quality in the "bottom filled" plates at all centrifuge speeds. Comparison of x-ray quality showed little difference in clockwise or counterclockwise rotation at low rotation speed (200 rpm) but considerable advantage in "bottom filling" at the higher rotation speeds.

The centrifuge casting of up to twelve 1/2-inch thickness by five inch diameter discs in a single pour was investigated to determine the practicability of the proposed multiple centrifuge casting technique. A machined-graphite mold setup was prepared as shown in Figure B27. Figure B28 is a photograph of a typical trial heat, showing the arrangement of molds, gating, and central sprue. The gates were one inch in diameter from the sprue to the two inch diameter ingates feeding the casting.

Examination of the X-rays of these plates revealed that the gating size was not sufficient to provide soundness in the discs. The locations and sizes of the shrinkage voids in the twelve discs were very consistent. Additional trials were made using three-cavity mold setups such as shown in Figure B29. Larger and smaller diameter gate and ingate diameters were tried with some improvement in soundness but complete absence of shrinkage porosity was not obtained.

There was no evidence of turbulent metal flow on the casting surface, except for a very slight surface ripple near the ingate. As the radius at this junction was increased, the surface ripple appearance decreased. The entire set of castings had consistently good surface finish.

FIGURE B11

TYPICAL FEEDING STUDY ARRANGEMENT

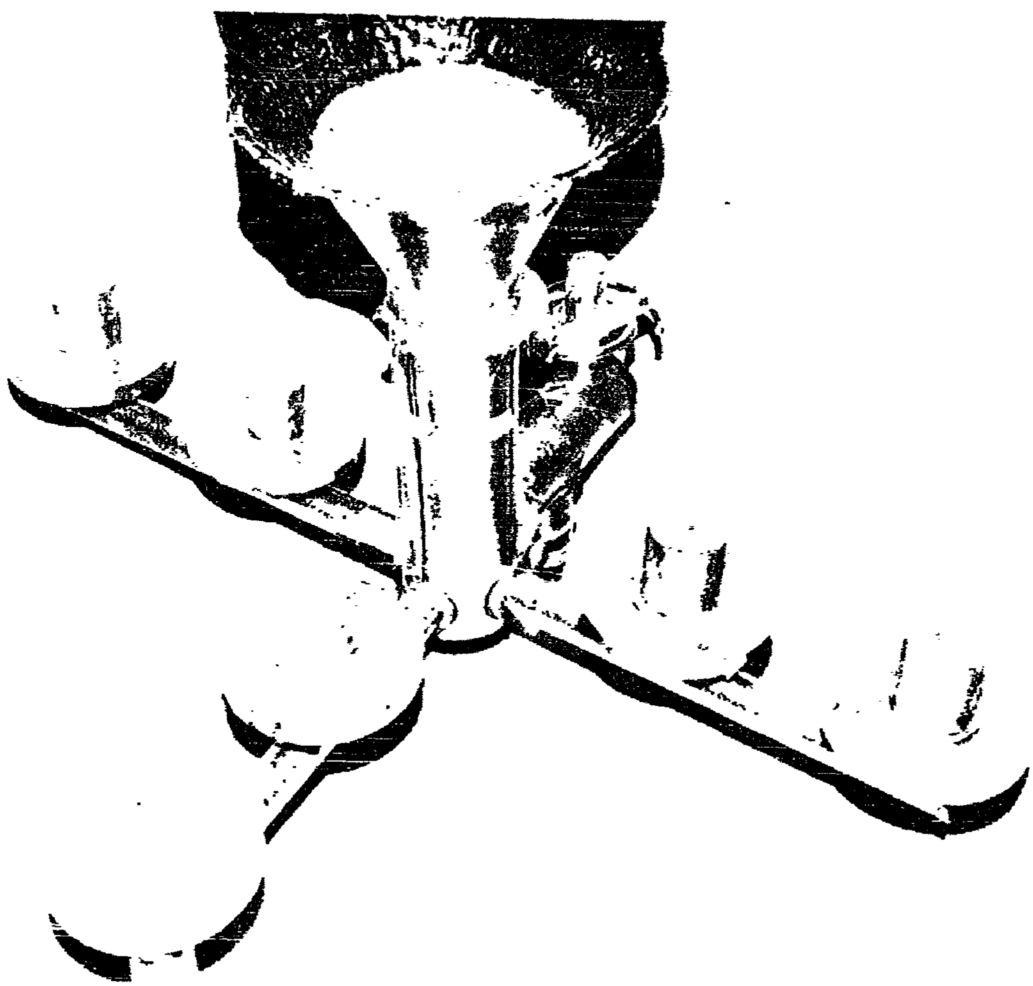


FIGURE B12a

GENERAL DISPERSED SHRINKAGE - FEEDING DISTANCE EXCEEDED GREATLY

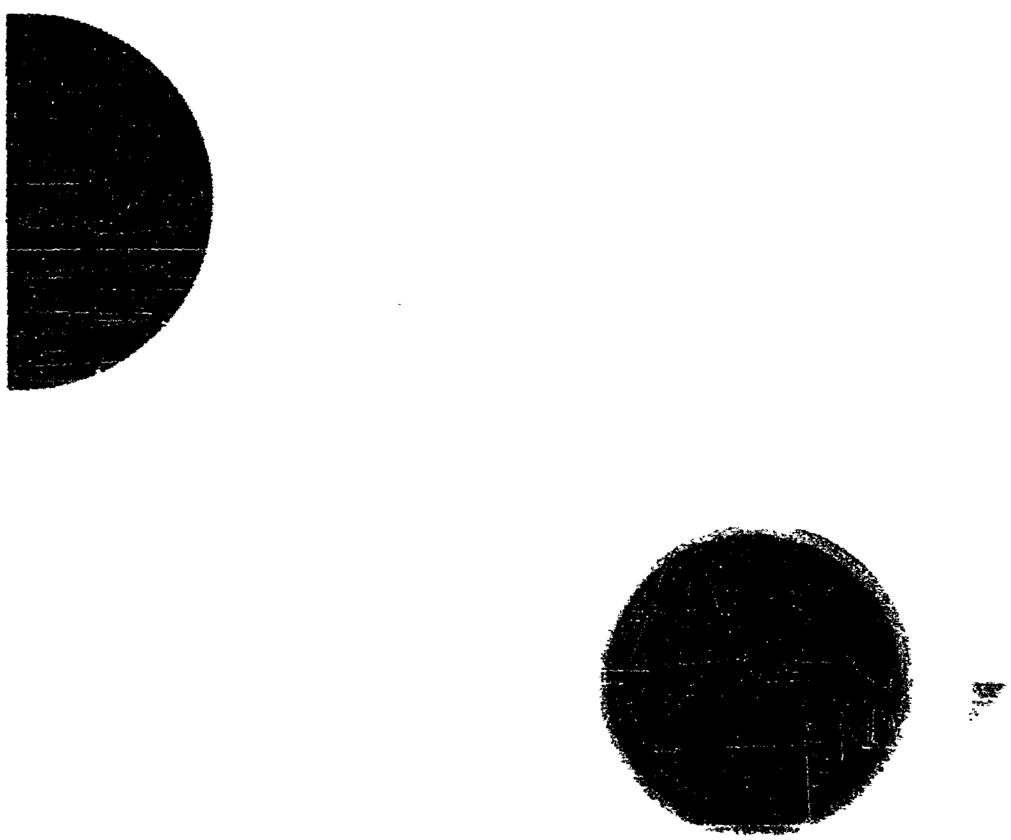


FIGURE B12

TYPICAL PLATE MOLD SETUP

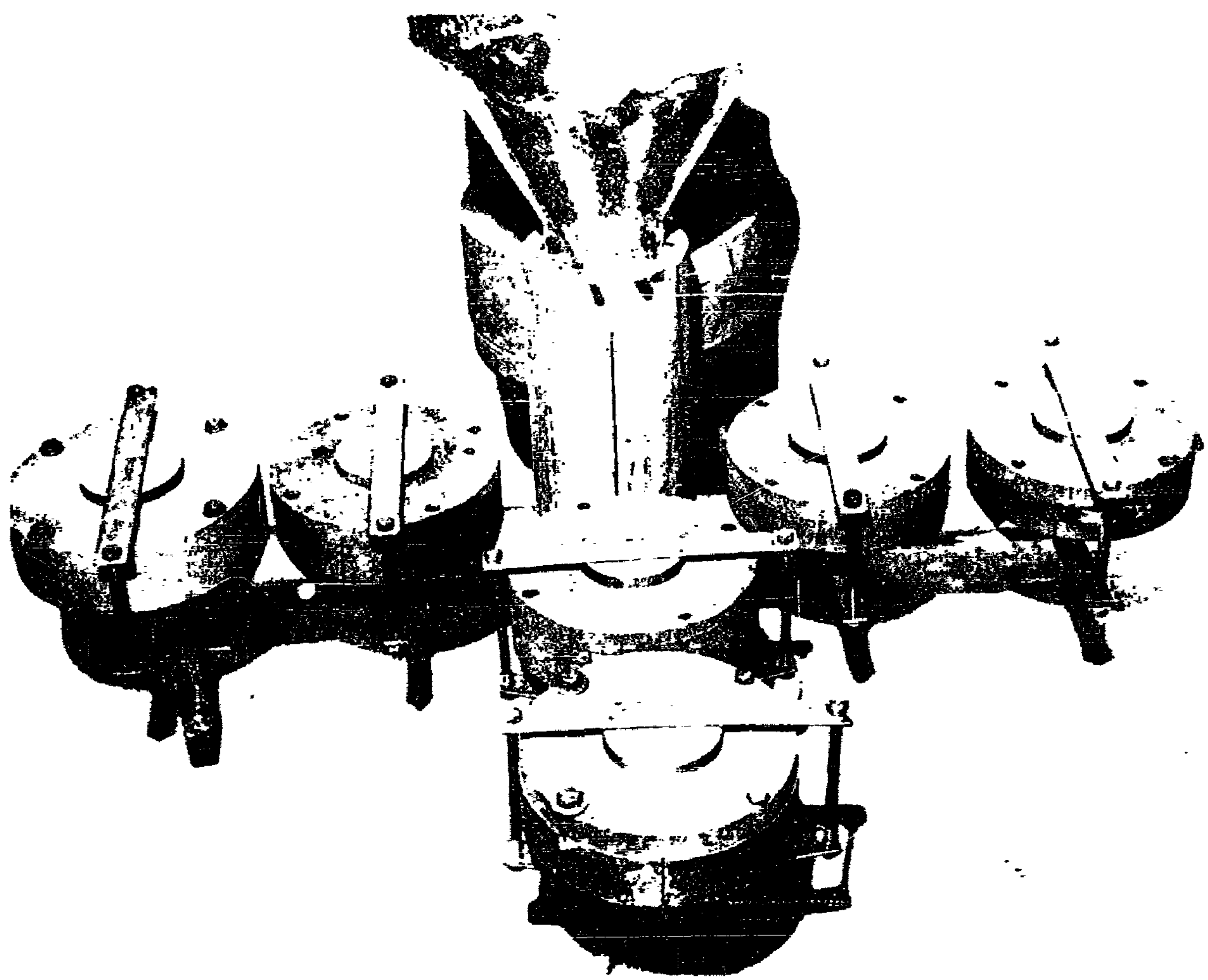


FIGURE B13

SHRINKAGE IN SLIGHTLY EXCEEDED
FEEDING DISTANCE

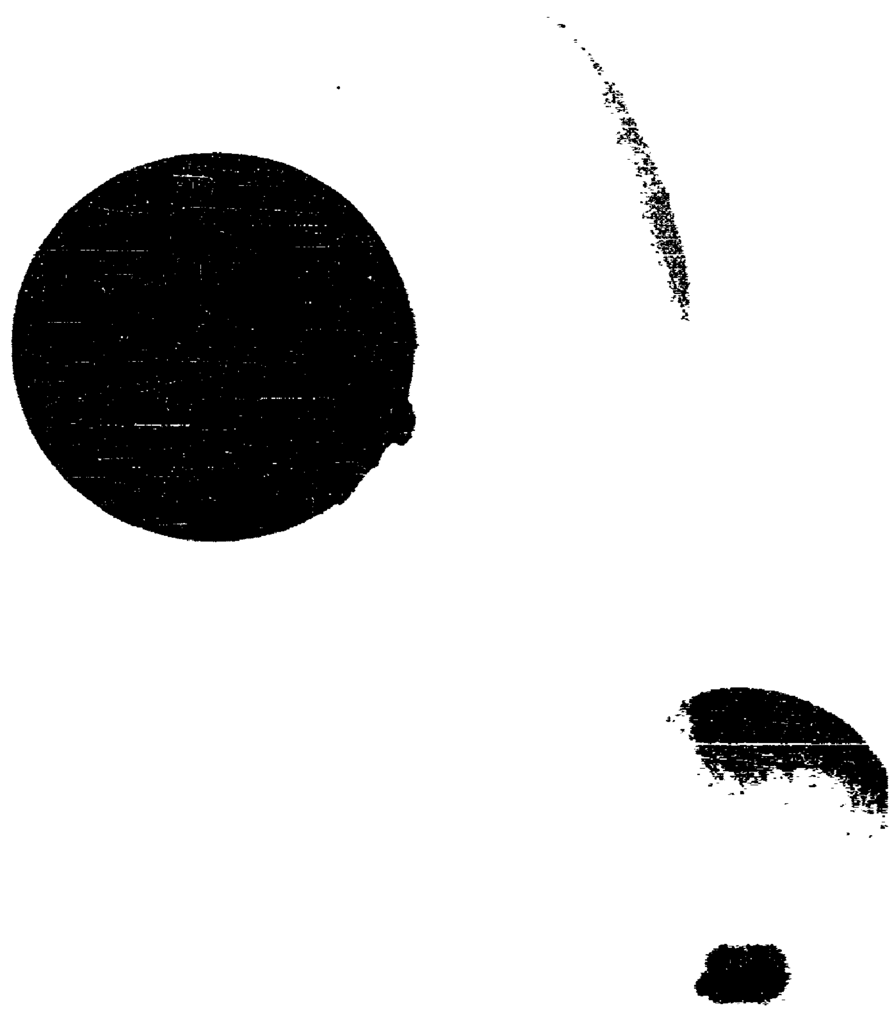


FIGURE B14

FEEDING REQUIREMENT SATISFIED

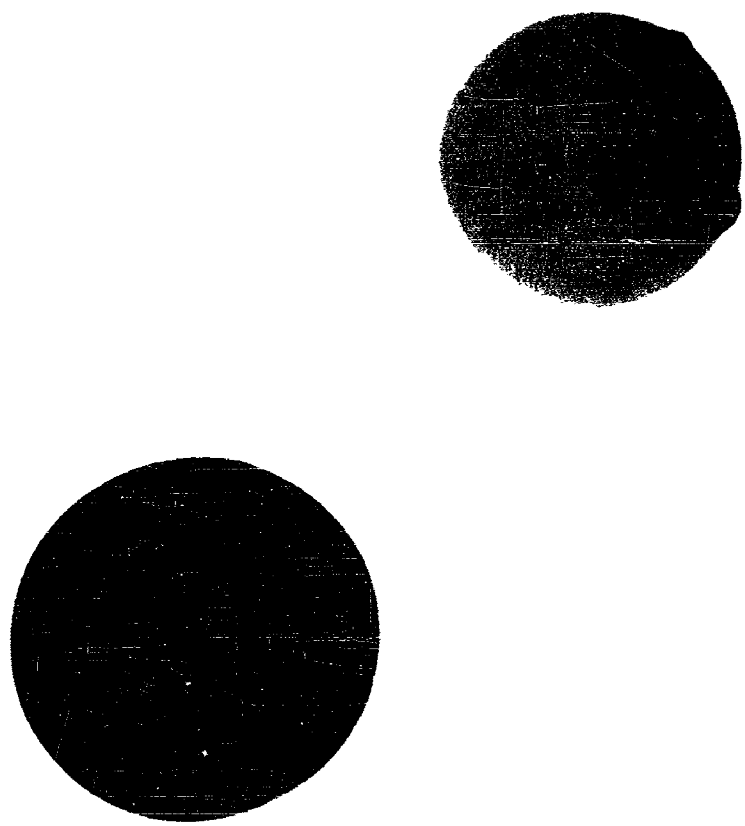


FIGURE B15

FEEDING DISTANCE IN 6" DIAMETER DISCS

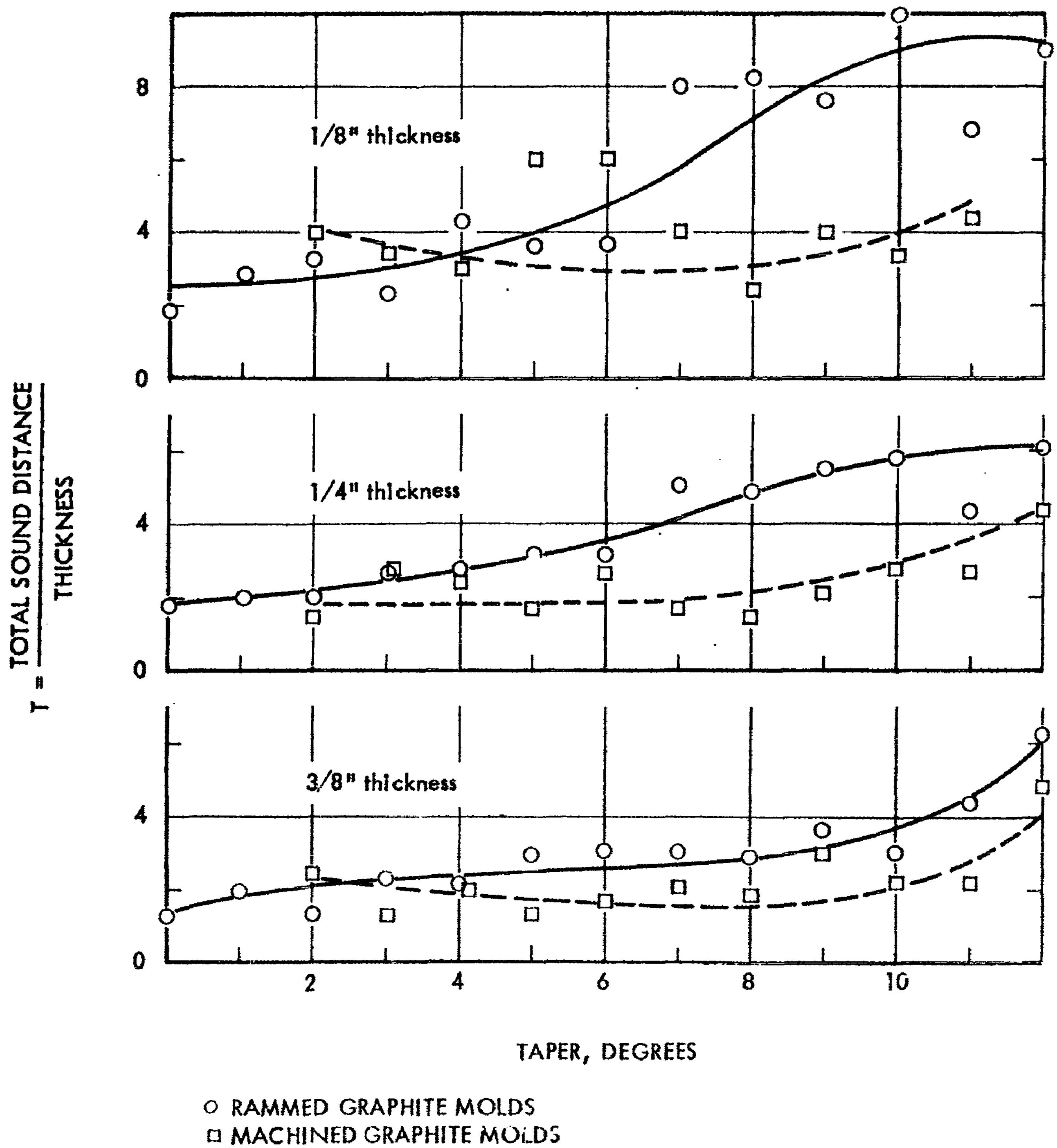
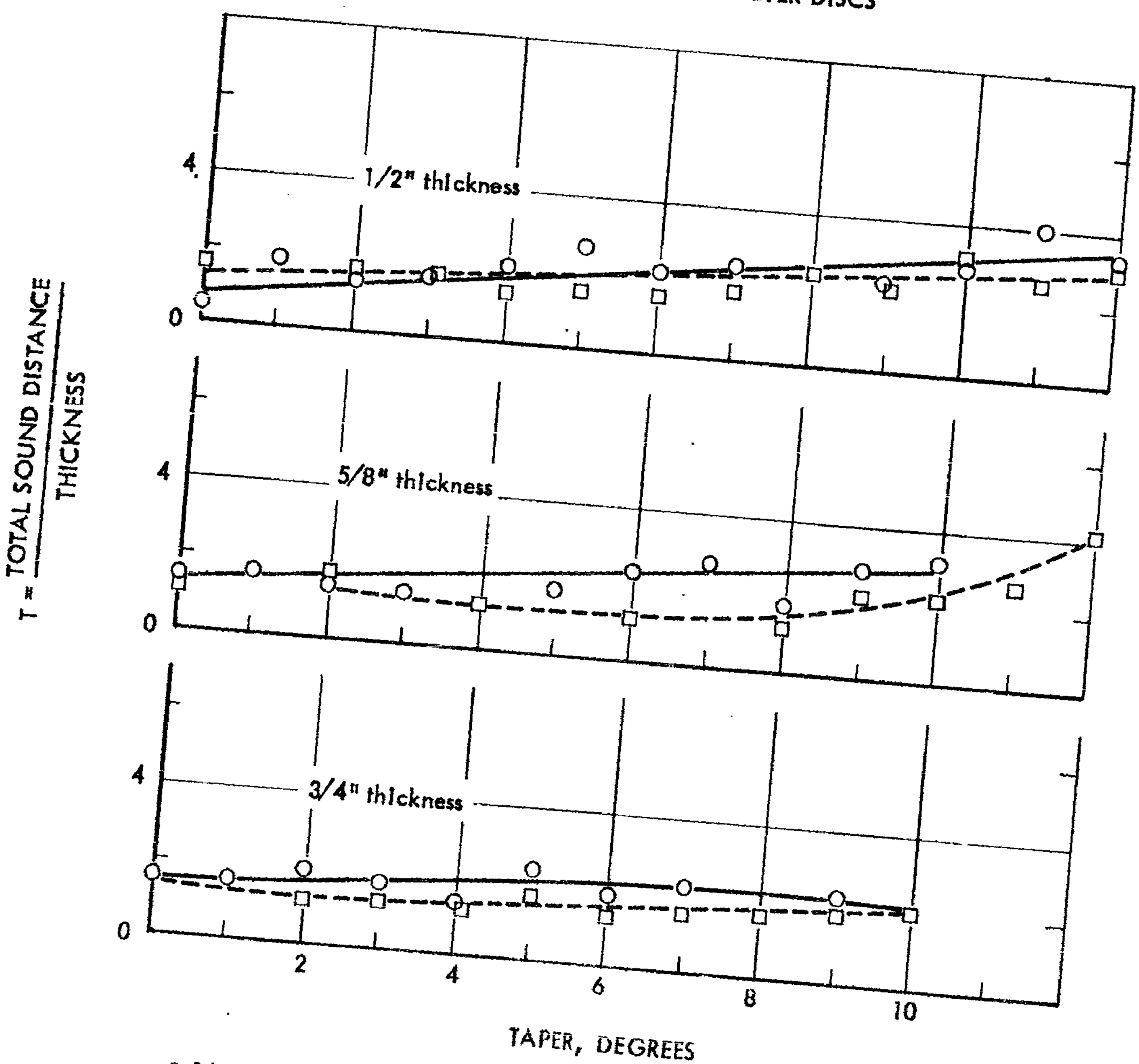


FIGURE B16

FEEDING DISTANCE IN 6" DIAMETER DISCS



○ RAMMED GRAPHITE MOLDS
□ MACHINED GRAPHITE MOLDS

FIGURE B17

FEEDING DISTANCE IN 6" DIAMETER DISCS

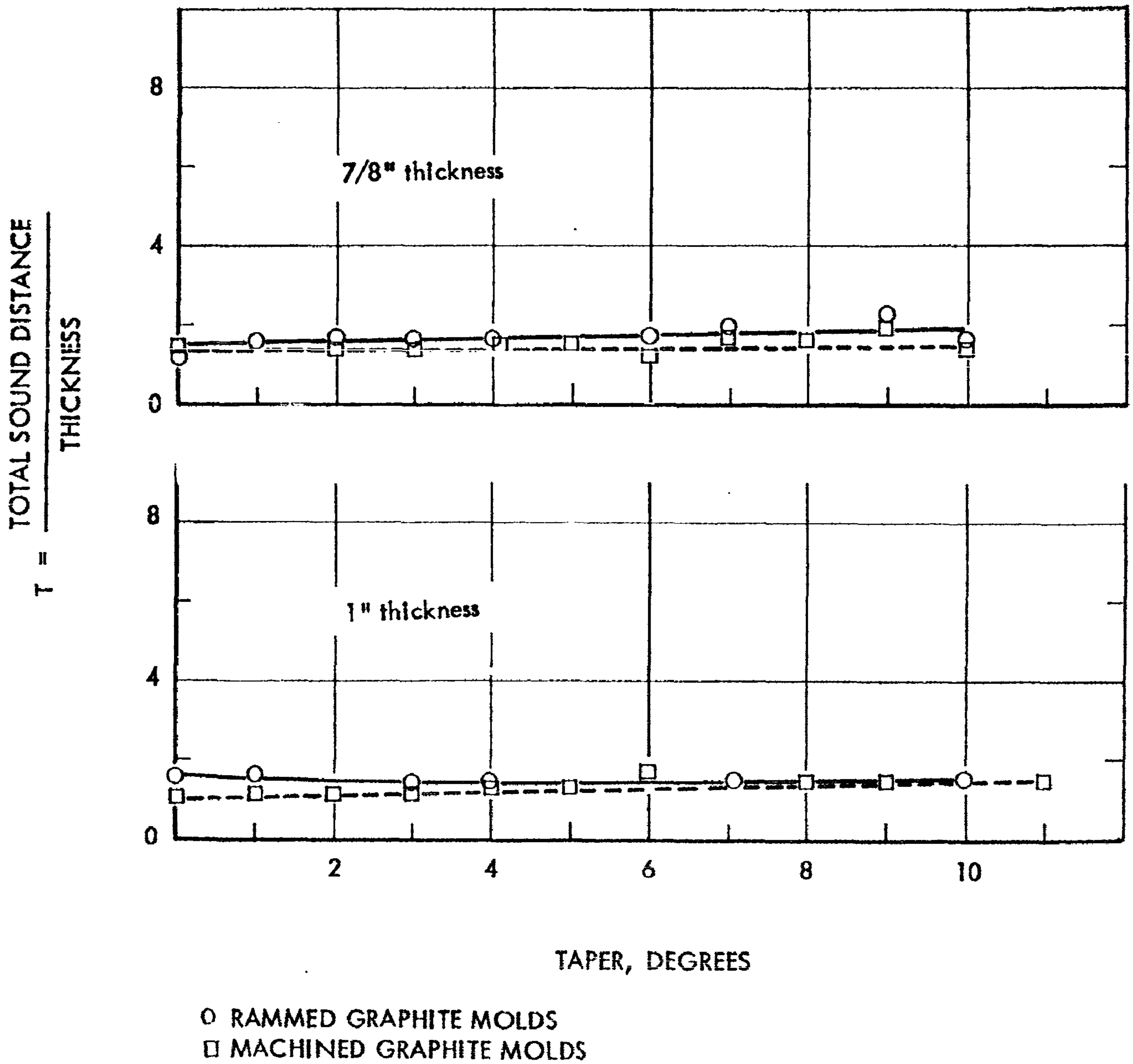


FIGURE B18

TAPERS REQUIRED TO CAST SOUND 6" DIAMETER DISCS

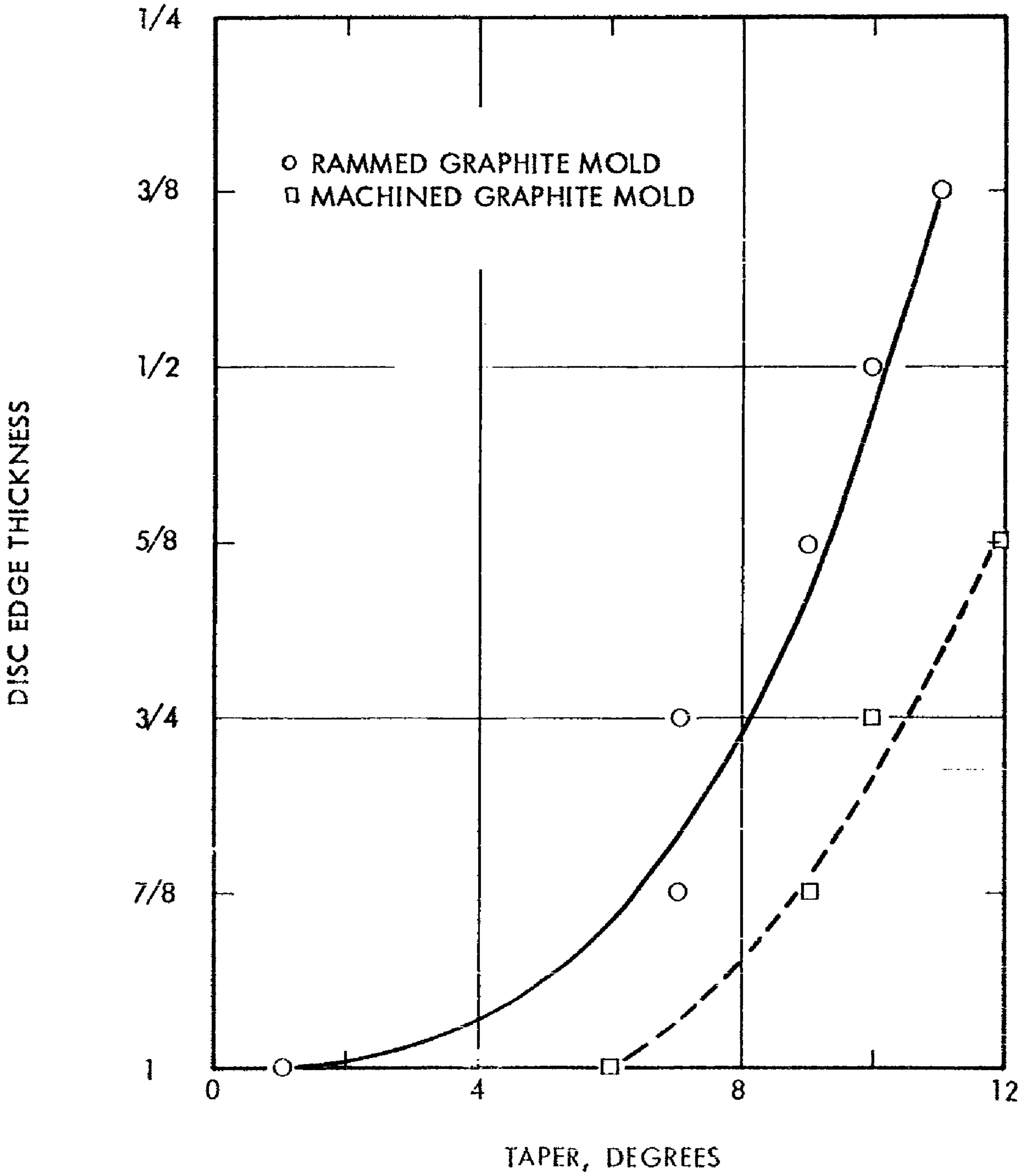


FIGURE B19

FEEDING DISTANCE IN 6" DIAMETER DISCS

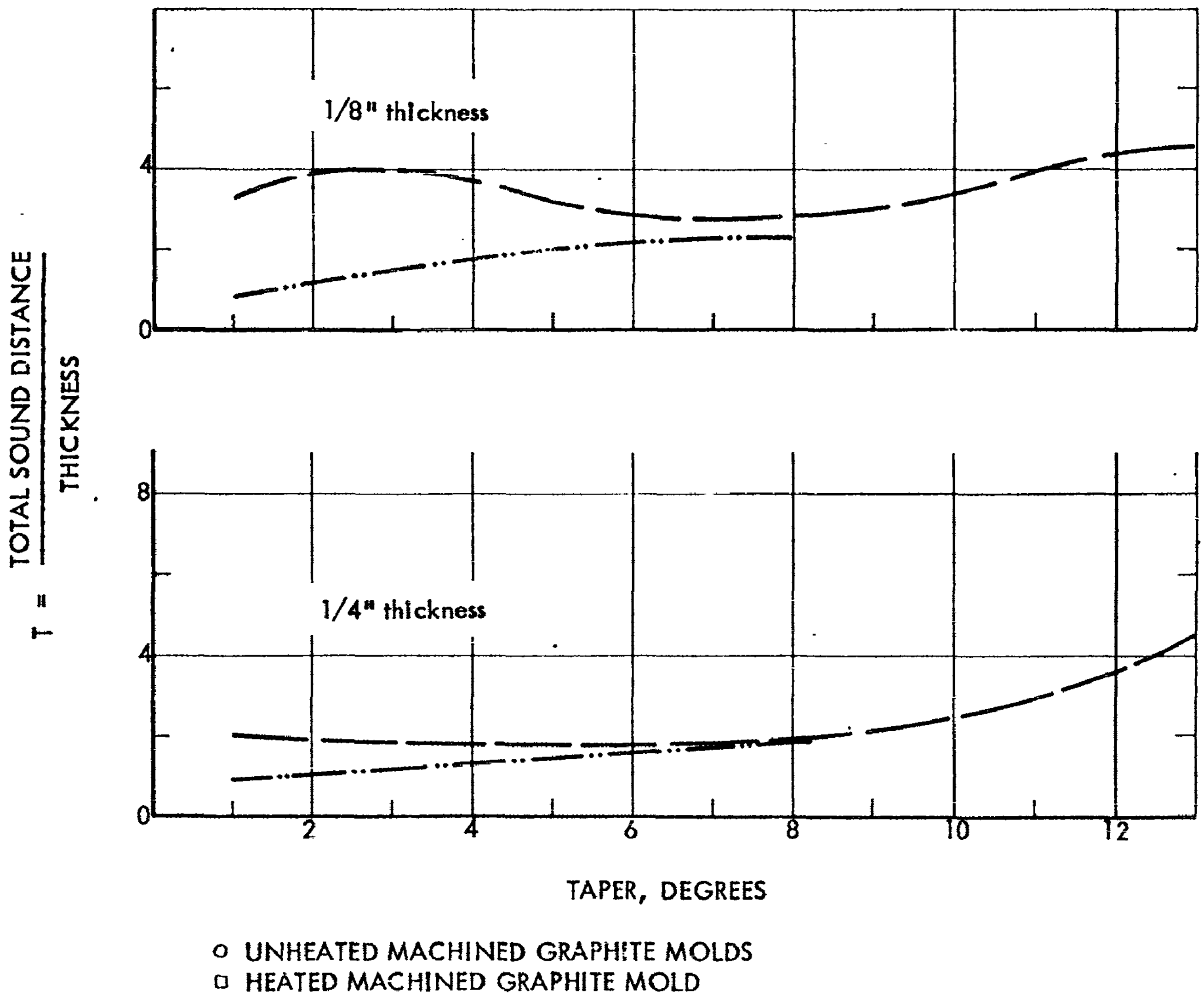


FIGURE B20

FEEDING DISTANCE IN 6" DIAMETER DISCS

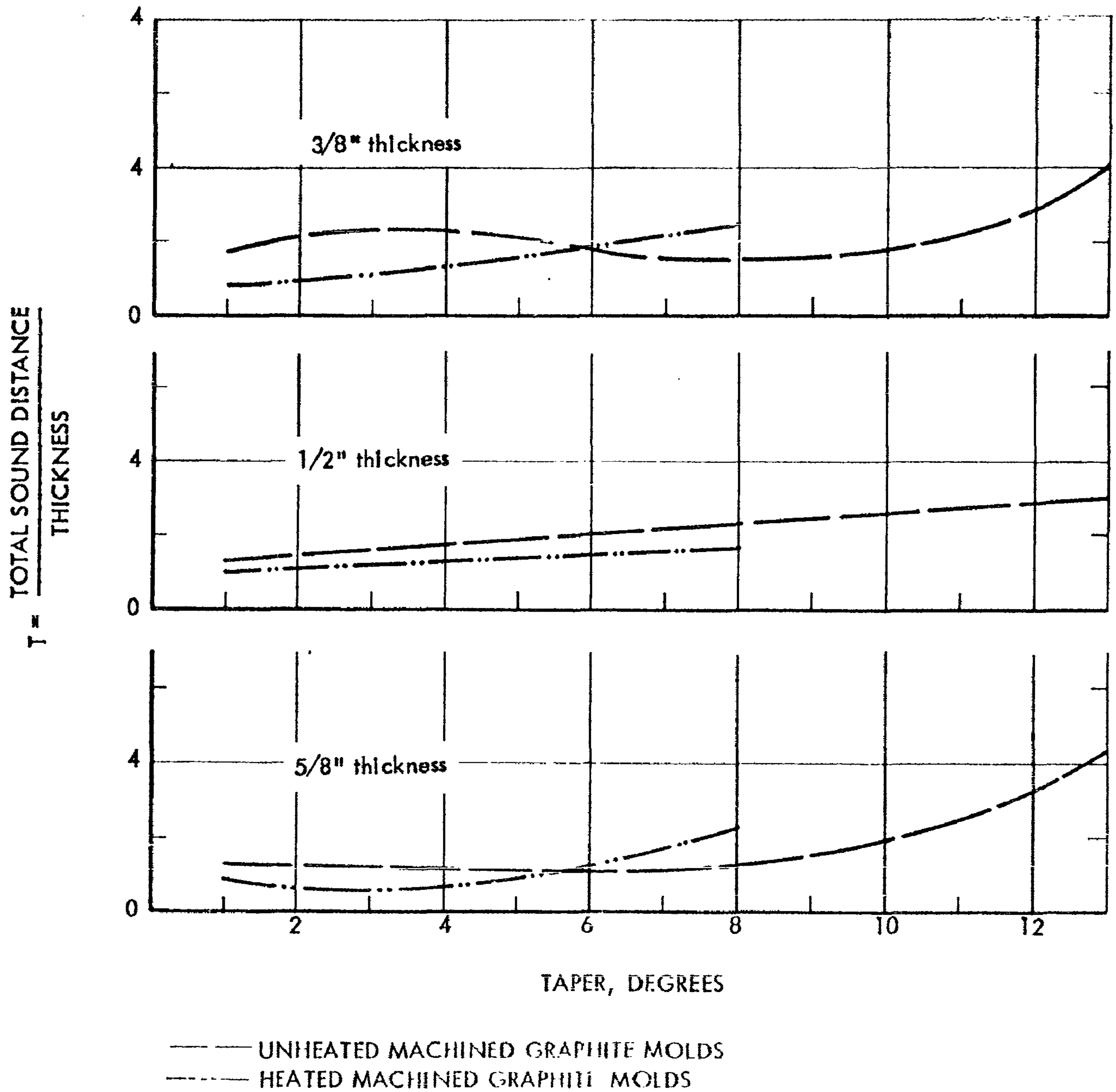


FIGURE B21

FEEDING DISTANCE IN 6" DIAMETER DISCS

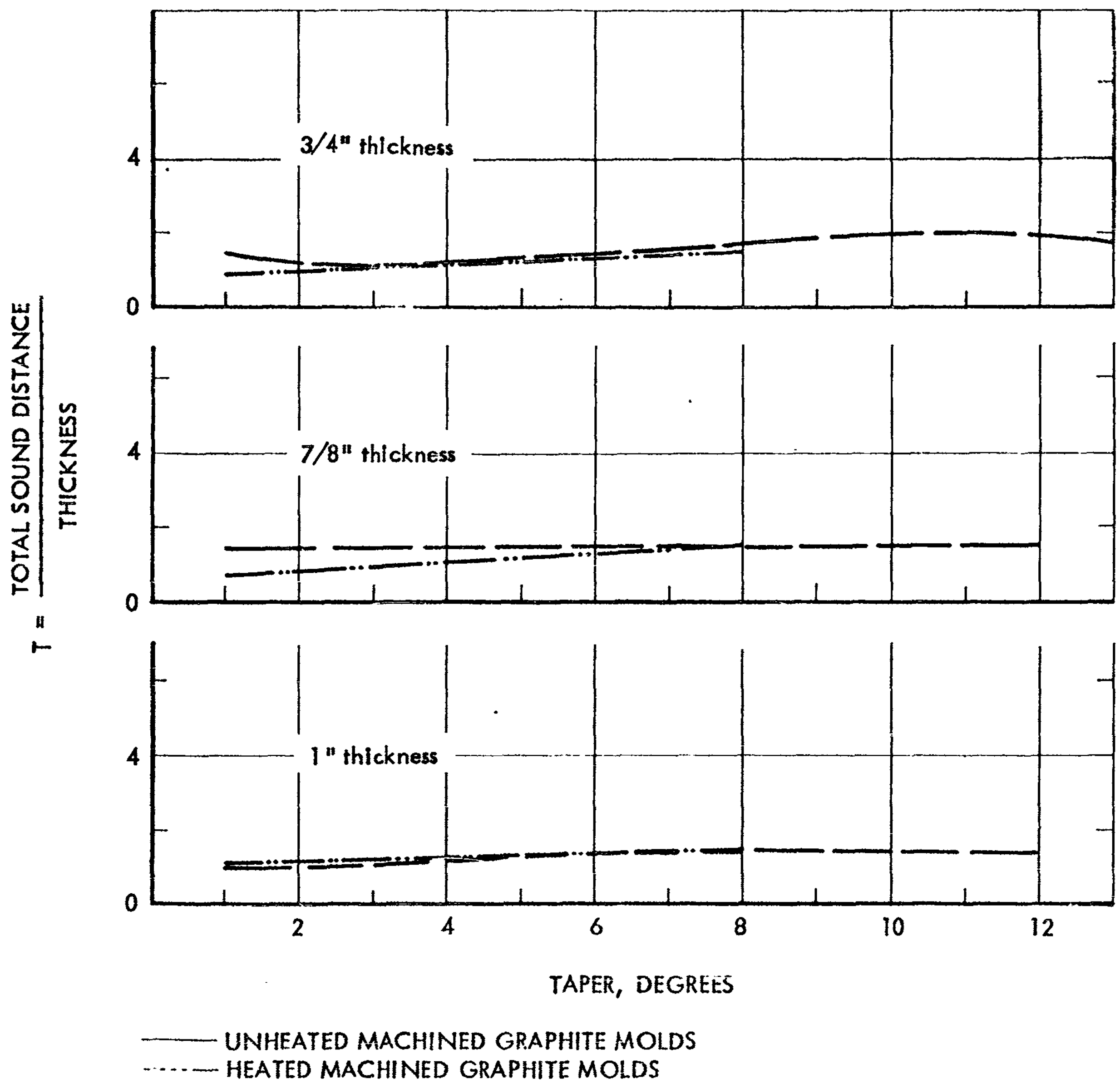


FIGURE B22

FEEDING DISTANCE IN 6" DIAMETER DISCS

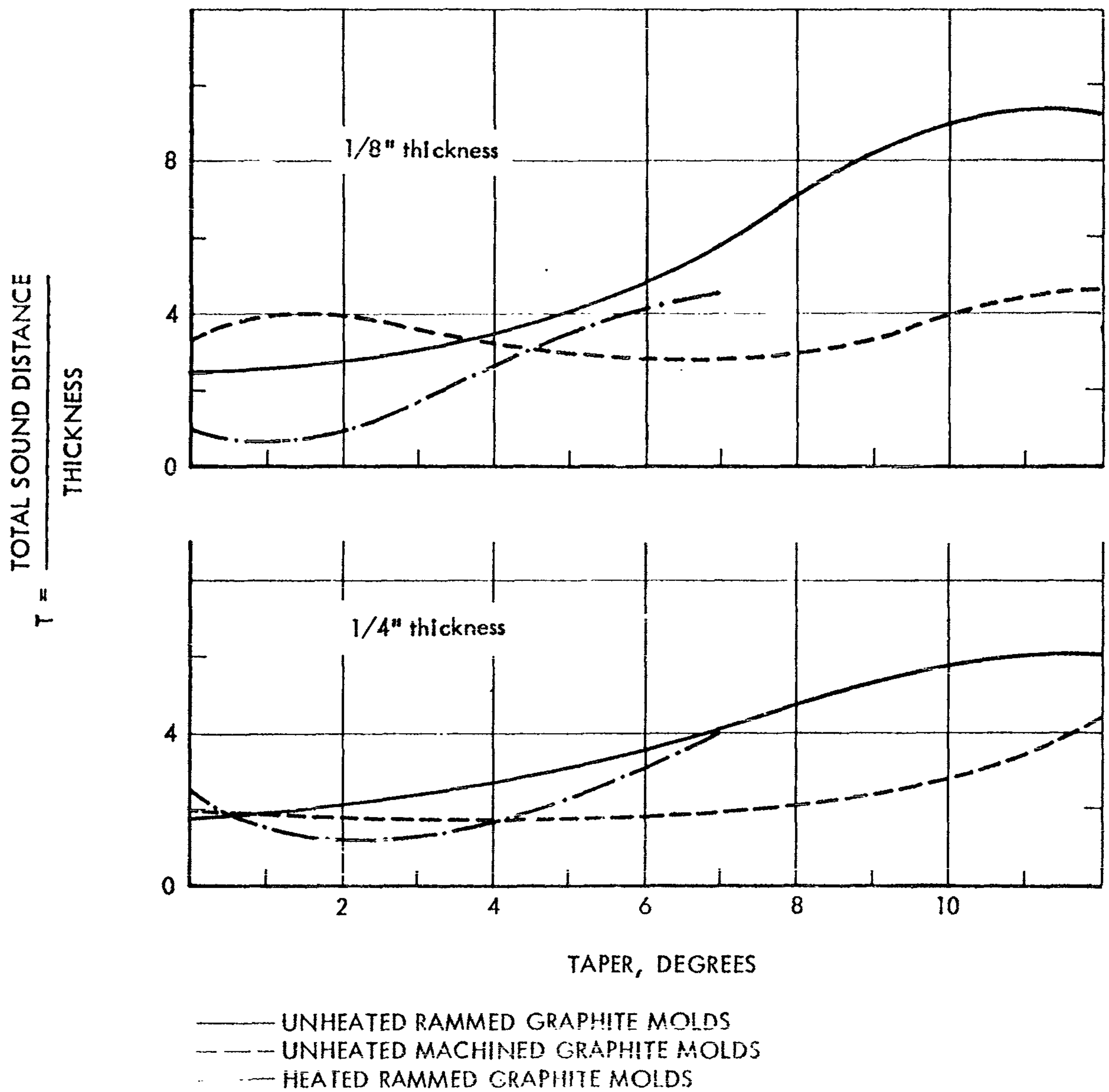


FIGURE B 23

FEEDING DISTANCE IN 6" DIAMETER DISCS

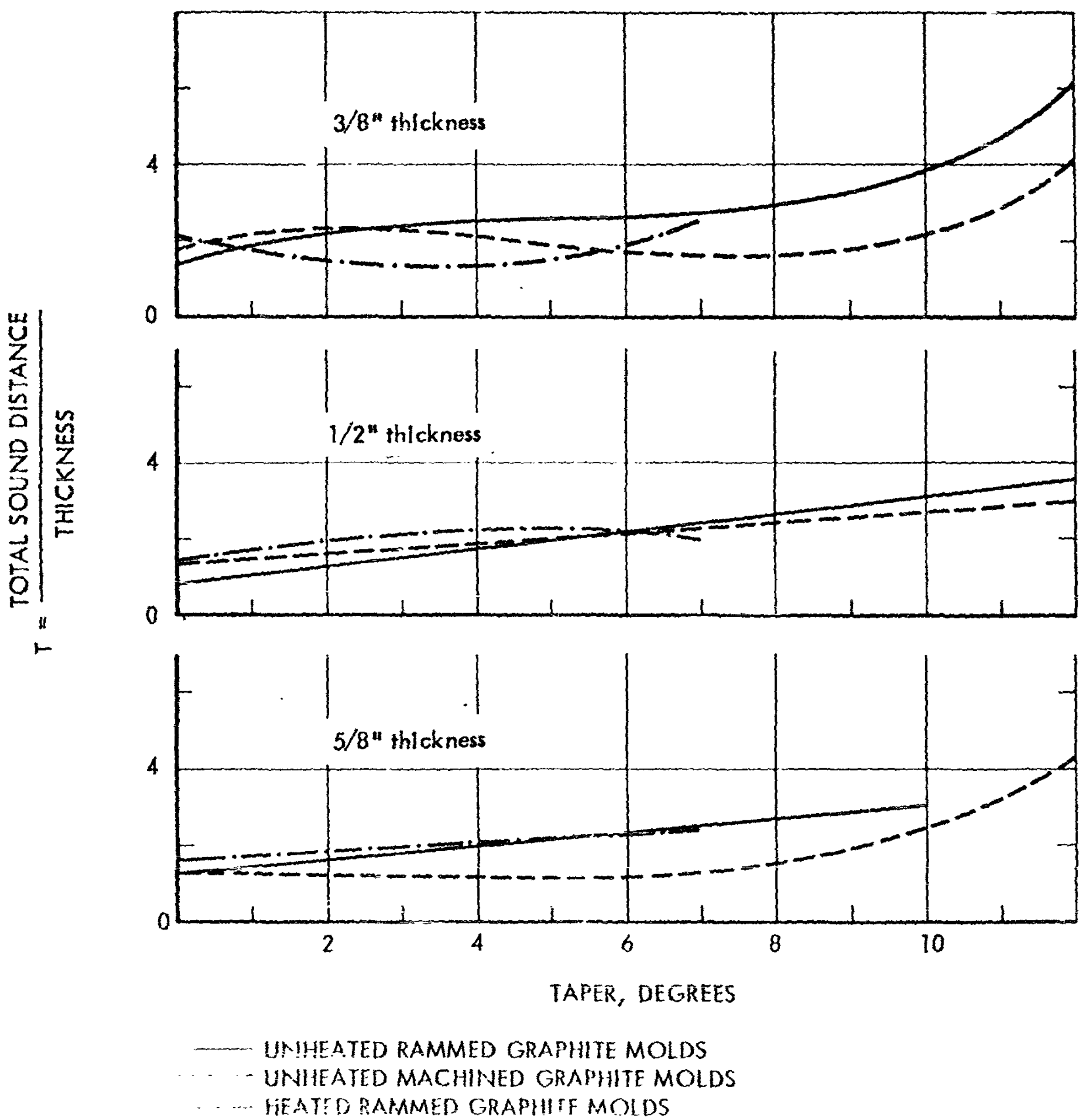
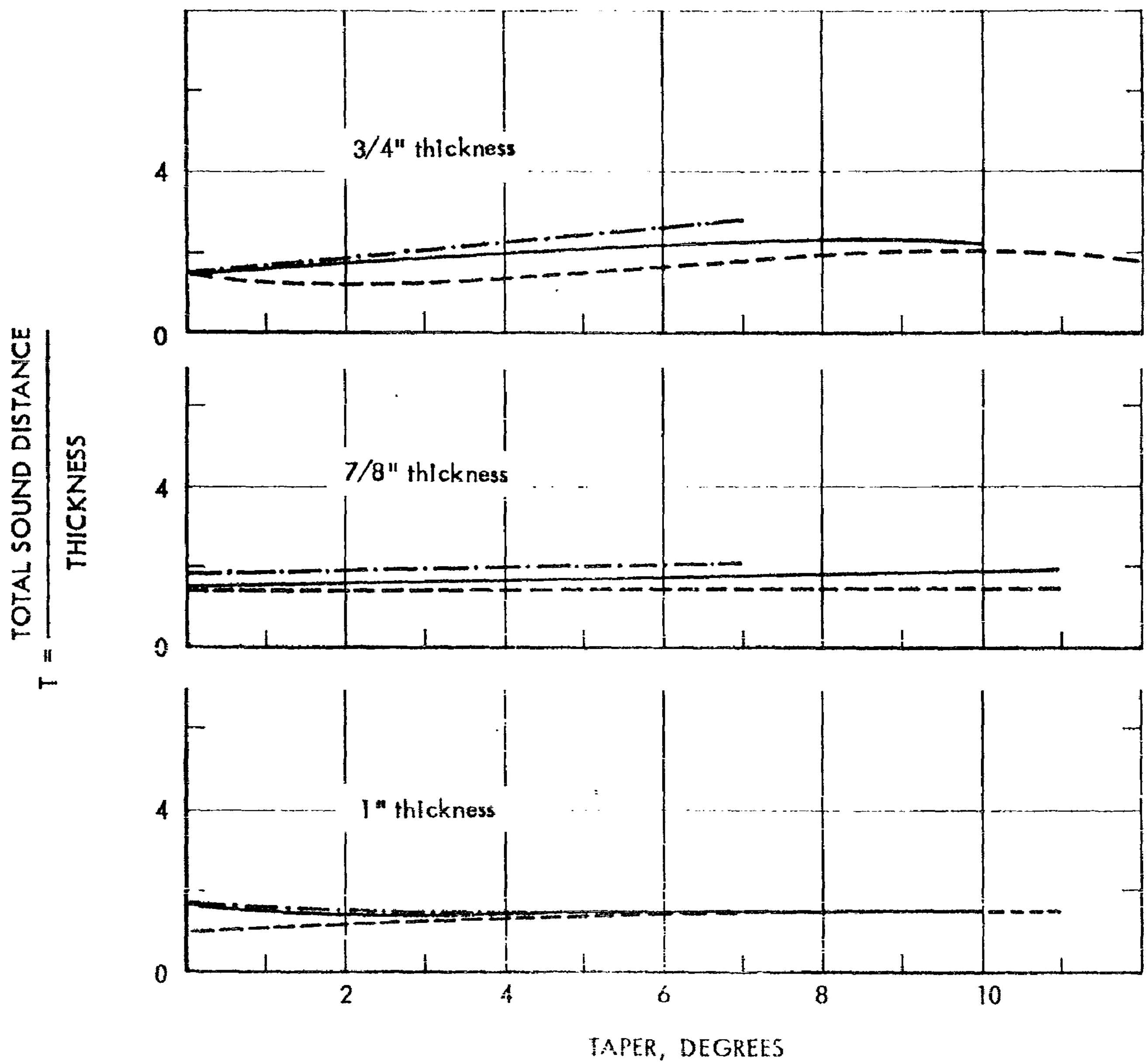


FIGURE B24

FEEDING DISTANCE IN 6" DIAMETER DISCS



——— UNHEATED RAMMED GRAPHITE MOLDS
— — — UNHEATED MACHINED GRAPHITE MOLDS
— · — · HEATED RAMMED GRAPHITE MOLDS

FIGURE B 25

TYPICAL SETUP FOR CENTRIFUGED PLATE CASTING TRIALS

FIGURE B26

CENTRIFUGALLY CAST PLATES

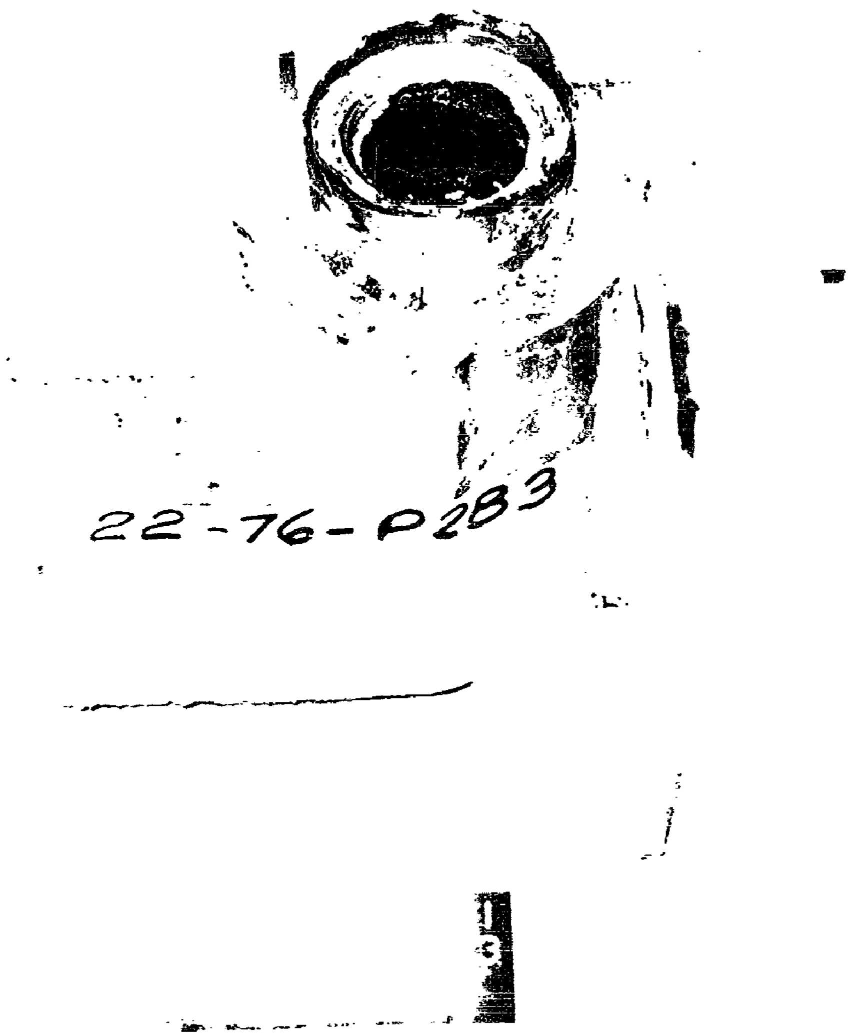


FIGURE B27

TYPICAL MOLD SETUP FOR CENTRIFUGALLY CASTING DISCS

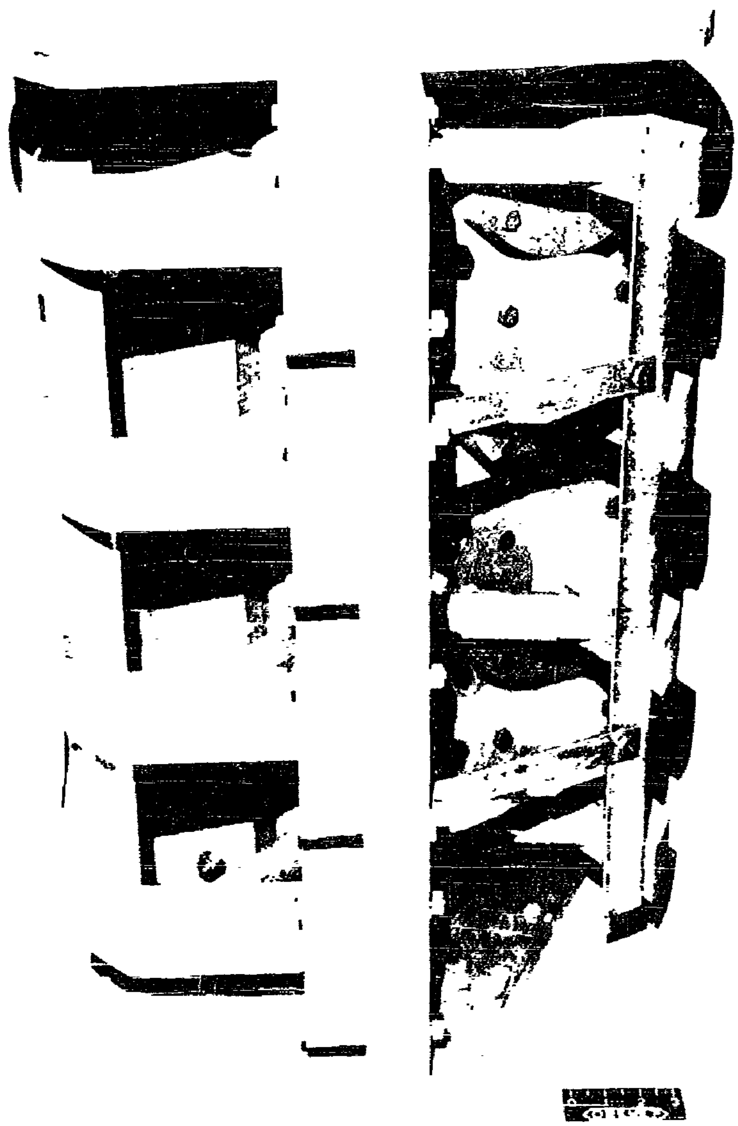


FIGURE B28

CENTRIFUGALLY CAST DISCS

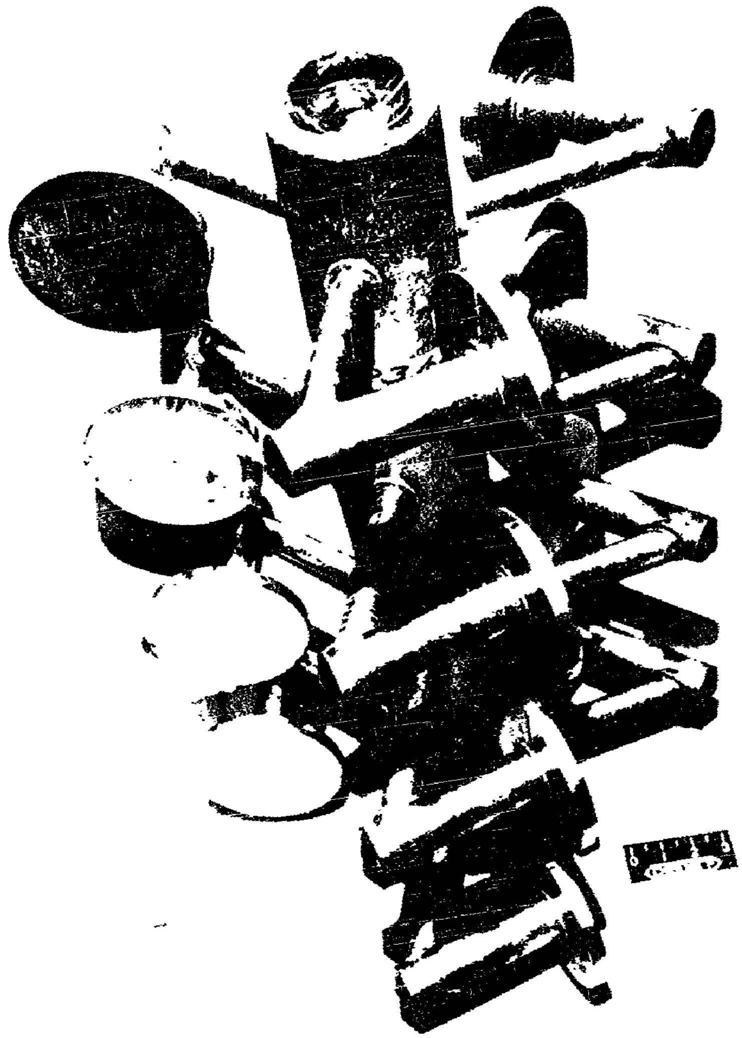
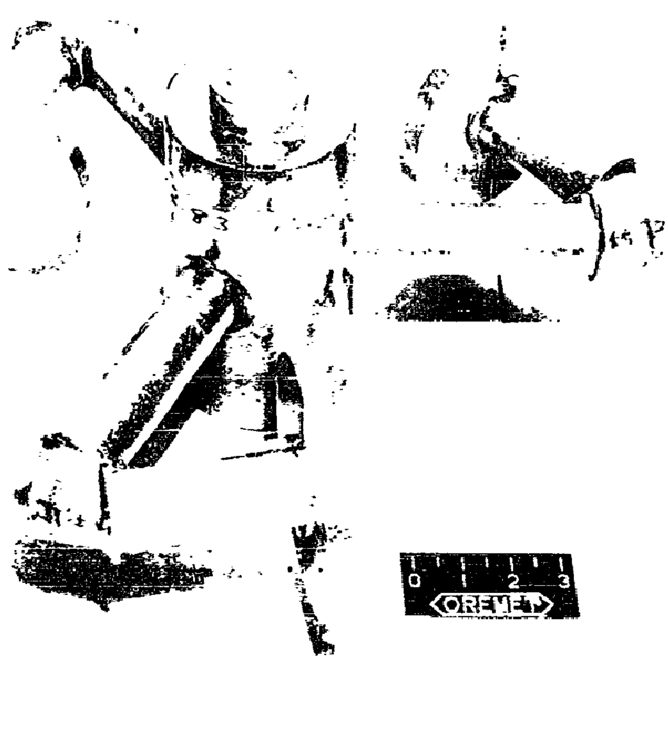


FIGURE B29

CENTRIFUGALLY CAST DISCS



SURFACE TREATMENT OF TITANIUM CASTINGS

Removal of Gates and Risers

Gates and risers were removed from the castings by oxy-acetylene torch cutting, power hack-sawing, and abrasive cut-off wheel. Of these the use of the abrasive cut-off wheel was found to be the most satisfactory. The oxy-acetylene torch cut-off increases oxygen contamination of the foundry scrap and requires excessive hand grinding to clean up the casting. Although power sawing produces a satisfactory cut, the abrasive cut-off wheel can trim closer to the casting and is much faster than sawing. The cost of the abrasive discs was compensated by lower labor cost compared to power sawing.

Grinding and belt sanding of cast titanium was used for primary cleaning. Rough grinding to remove material at gates, risers, and flash points was the most effective method of metal removal. Aluminum oxide wheels were used and are operated at approximately 3,030 surface feet per minute. All castings were hand held.

The grinding belt was used for finishing the cast titanium to remove rough grinding marks and for slight blending and flash removal. Material removal was fast and efficient, with metal removal efficiency increased by using a white-tallow base belt lubricant. Belt operating speed was 1100 surface feet per minute with average belt life of 8 hours. The belts were made of silicon carbide abrasive bonded to heavy cloth. The most efficient sanding was accomplished using a ribbed hard rubber wheel at the point of pressure contact. The ribbed-rubber wheel gives maximum life to the sanding belt coupled with efficient metal removal.

Using present methods of grinding, there has not been any evidence of grinding damage of cast surfaces. An attempt was made to damage a cast titanium specimen by poor grinding techniques. The experiment consisted of hand finishing the specimen on a grinding belt using abnormally high hand pressures. Microstructural examination of the surface did not reveal any discontinuities in the ground surface. The experiment resulted in destruction of the grinding belt.

Cleaning of Castings

The use of a shot type abrasive was not suitable for cleaning castings. Shot blasting does not adequately remove surface oxides or fused graphite. The shot provided a surface deformation action whereas titanium castings require an abrasive that will produce a cutting action to remove the surface contaminants.

Grit blasting of castings with an angular abrasive material was a satisfactory method of cleaning. The angular grit cleaning material produced a cutting action and readily removed surface oxides and graphite from titanium alloy castings. The most satisfactory cleaning material of those used has been a chilled iron blasting grit. The material continually breaks up to produce new cutting edges and as used, a finer surface finish was obtained. Adding a small quantity of new material at frequent intervals maintains the cleaning action and surface finish at acceptable standards. A detrimental effect of using the sharp cast iron material is the coating of the cleaned part with finely divided iron particles, which later rust with detriment to appearance. A second although not serious effect of the use of iron shot is possible slow build-up of the iron level in chemical analysis of the cast titanium due to use of shot blasted scrap. This effect is not serious as additions of new material dilute the iron to acceptable levels. If necessary, surface contamination by iron dust can be removed by light pickling of the scrap.

Other types of grit used were "malleabrasive" grits of various grain sizes. The malleabrasive grit is more ductile than the chilled iron grit and wears by deformation rather than by breakdown. The wearing action causes the sharp angular structure to become round and ineffective in removal of surface oxides and fused material. The material gradually performs as shot in reduced cleaning effectiveness.

Sand blasting of cast titanium has been effective in producing a fine surface finish with small metal removal rate. Three types of sands that have been used are Garnet sand, Banding sand, and Flint sand obtained from Idaho Garnet Company, Spokane, Washington, and Ottawa Silica Company, Ottawa, Illinois.

The Garnet sand is the tougher abrasive and holds up well during use. Metal removal is slow, therefore, primary cleaning of surfaces with this material is not recommended. The material used was fairly coarse and did not give a fine appearing surface finish.

The Flint sand and Banding sand provided a relatively fine surface finish. These were used as a secondary cleaning medium to remove any iron contamination caused by the initial cleaning with the chilled iron grit. The Flint and Banding sands have rapid breakdown characteristics and, after one hour's use the major portion of the abrasive is reduced to fines.

Abrasive tumbling has not been found an acceptable method of cleaning cast titanium. The abrasive material evaluated was Tumblex "a" No. 3, an Alundum material. The cast titanium specimens were tumbled in the abrasive media for 24 hours to determine the effectiveness in surface cleaning. At the end of 10 hours, no removal of the oxide discoloration layer on the cast surface was evident. Surface roughness was reduced at 16 hours with an acceptable product at 24 hours. The flash and burrs on the specimen were not removed during the tumbling cycle but instead had a polished appearance. It should be noted that this was a limited study and more favorable results might be obtained through more trials using other equipment and abrasives.

<u>Chemical Removal of Surface Material</u>

A satisfactory acid solution and processing techniques were developed for chemical removal of surface material from the castings. Fatigue tension tests were used to determine the necessity of this step and to establish the amount of material which should be removed.

The chemical removal solution developed is as follows:

Nitric Acid	15 to 25 oz./gallon
Hydrochloric Acid	5 to 9 oz./gallon
Ratio HNO_3/HCL	2 to 3
Free Hydrofluoric Acid	3 to 8 oz./gallon
Acetic Acid or ...	3 to 4 oz./gallon
Oxalic Acid (option)	[illegible] to 4 oz./gallon
Disodium [illegible]	[illegible] oz./gallon
Wetting [illegible]	[illegible] adjust surface tension to [illegible]
"[illegible]	[illegible]
[illegible]	

This solution may be maintained until 20 ounces of titanium per gallon of solution has been dissolved. It can be operated at 90°F to 130°F to adjust metal removal rate, which varies from .0003 to .0015 inches per minute over this temperature range. To maintain a reasonably constant specific removal rate, the temperature should not vary more than five degrees from nominal during the removal operation.

Before being chemically cleaned or pickled, the castings must be abrasive blasted to remove any mold particles or oxidation. During chemical removal several dimensions on the parts should be frequently spot checked for thickness control. After pickling, the castings must be water rinsed.

A series of tension-tension fatigue tests were conducted to establish the proper amount of surface removal depth. Specimens were 1/2-inch gage diameter and were tested in the following conditions:

(a) As-cast, with normal abrasive cleaning,

(b) As above plus chemical removal of .005-inches per surface,

(c) Same as (a) plus chemical removal of .010-inches per surface,

(d) Same as (a) plus chemical removal of .015-inches per surface.

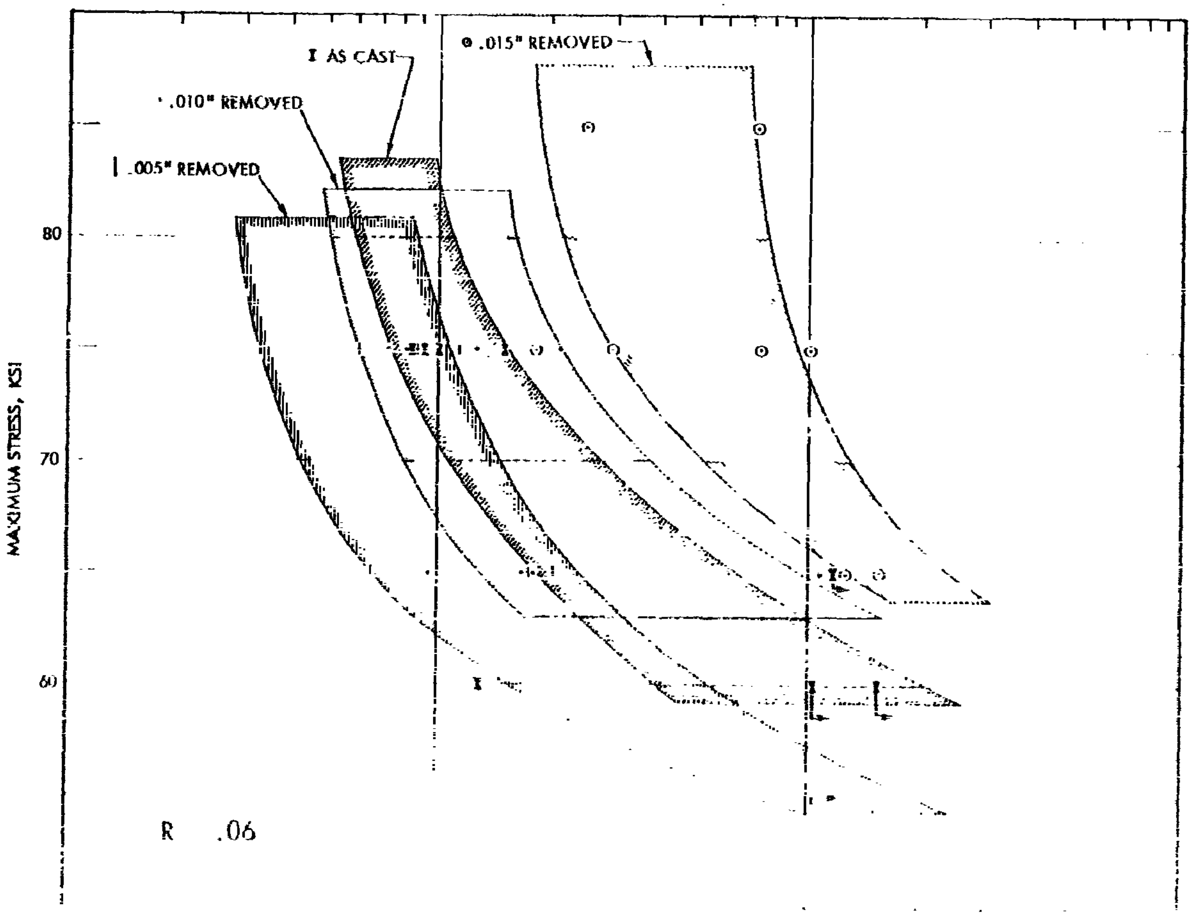
The specimens were tested in a conventional Sonntag SF - 10U universal fatigue testing machine at 1800 cycles per minute and a stress ratio of R = .06. The specimens were all from the same heat, were x-ray inspected, and the acceptable specimens selected to randomize quality.

The results of the fatigue tests are tabulated in Table J16 and illustrated by S - N curves in Figure B30. In general, removing only .005 inches per surface damaged fatigue life, removing .010 inches per surface restored the fatigue life to that of the as-cast condition, and removal of .015 inches per surface provided significant improvement over the as-cast condition.

It is recommended that, in titanium alloy casting applications requiring best fatigue properties, .015-inches per surface be chemically removed using the solution and process described.

FIGURE B30

FATIGUE PROPERTIES OF AS-CAST AND PICKLED Ti-6Al-4V CAST SPECIMENS



SECTION C

ALLOY DEVELOPMENT

Development of Ti-6Al-4V Alloy

Early in this program, it was necessary to choose an alloy for use in casting trials, mold development trials, and other work which could not be delayed until alloy development studies were completed. Because of the general acceptance of the 6Al-4V titanium alloy for wrought products, that alloy was chosen for these studies with the intention of substituting a more suitable casting alloy when one was found. As discussed in the portion of this report which discusses general alloy development, a casting alloy significantly better than Ti-6Al-4V was not found.

A series of approximately 440 heats of Ti-6Al-4V was studied to establish effect of analysis on mechanical properties, practical analysis limits, practical guaranteed minimum mechanical properties, and correlations of processing variables with resulting interstitial levels.

First, frequency distribution bar charts (histograms) were prepared to show the distributions of oxygen, nitrogen, hydrogen, carbon, iron, aluminum, and vanadium which were characteristic of the equipment and practice developed in this program. The histograms are presented as Figures C1 through C7 . Much of the early work in the program was done without concentrated effort to maintain close control of chemical analysis, since other variables received the main focus of attention. As a result, a fairly wide spread of analyses was obtained which proved of benefit in studying effects of analysis on properties.

As shown in Figure C1 , the oxygen content varied from .08 to .37 per cent and averaged approximately .21 per cent. This high oxygen range is the result of recycling of foundry scrap, since from .02 to .05 per cent oxygen is picked up during each melt and recycling of material from previous heats compounds the pick up. Because of the economic necessity to use foundry and other titanium alloy scrap in the casting process, high interstitial oxygen contamination has been a problem. To maintain oxygen at acceptable levels, it is necessary to occasionally discard a portion of the normal foundry scrap (gates, risers, etc.) and dilute the oxygen content by adding low-oxygen sponge or electrode stock to the heat. Therefore, the amount of oxygen that can be tolerated as a maximum in titanium alloy castings has a significant bearing on the cost of the final product.

For study of effects of each specific element on mechanical properties, the analysis ranges of the other alloying and interstitial elements were restricted to closer-than-normal tolerances, to minimize obscuring the effects of the element in question by effects of scatter of the other elements. In the case of oxygen, only those heats were used which were within the following analysis limits:

Nitrogen	.021 - .032 per cent
Carbon	.10 per cent maximum
Hydrogen	.010 per cent maximum
Aluminum	5.8 - 6.2 per cent
Vanadium	3.8 - 4.2 per cent

This left 135 heats within these analysis limits having mechanical properties available, with oxygen ranging from .07 to .37 per cent. Oxygen was then plotted against ultimate tensile strength (Figure C8) and against reduction of area (Figure C9) as scatter diagrams. As shown in the figures, increased oxygen increases strength with fair correlation and decreases ductility with considerable scatter in individual values. As also may be noted in the scatter diagram for oxygen versus reduction of area, average reduction of area decreases as oxygen is increased, but the minimum reduction of area does not appear to decrease in the range of oxygen covered (i.e. up to about .25 per cent oxygen). Next, to establish the allowable production maximum for oxygen, all heats which fell in the normal analysis range (Al 5.5 - 6.5, V 3.5 - 4.5, N .07 max., C .10 max., H .015 max., Fe .30 max.) except for oxygen were separated into groups according to oxygen content, as follows:

Group A	less than .16 per cent oxygen
Group B	.16 - .21 per cent oxygen
Group C	.21 - .26 per cent oxygen
Group D	.26 - .31 per cent oxygen

Histograms for ultimate strength, elongation, and reduction of area were then plotted for these groups and are presented as Figures C10, C11, C12 and C13. Averages and standard deviations (σ) were computed for each curve using the conventional statistical analysis method for the "normal" frequency curve. (It should be noted that the histograms for mechanical properties are not "normal" distributions but are skewed slightly toward the high-value ends of the curves, resulting in conservative minimum properties since the standard deviation is slightly enlarged by the high values which are not undesirable except for this influence). Two standard deviations were subtracted from the average values for each curve to establish "minimums" for this study. Design allowable minimums are discussed later in this report. This analysis method is explained in the appendix. As is shown by the histograms and the scatter diagrams, the average and minimum values for ultimate strength are increased as oxygen increases, but for both elongation and reduction of area the averages decrease but the minimum values either remain fairly constant or actually increase due to lesser amounts of scatter in all properties as oxygen is increased. As a result it is advantageous to allow .25 per cent as a maximum for oxygen in titanium castings compared to the .20 per cent maximum usually allowed in wrought products. The minimum ultimate strength is increased without loss in ductility. Consequently, .25 per cent has been established as a maximum for oxygen in the specification for Ti-6Al-4V castings.

The scatter diagrams for nitrogen show that it strengthens Ti-6Al-4V considerably without detriment to ductility, and that the correlation between analysis and properties is better for nitrogen than for oxygen. It may be desirable to establish a minimum as well as the present maximum analysis value for nitrogen to take advantage of its strengthening effect. This was not done since nitrogen independently is difficult to control but as is shown in Figure C16, tends to be high when oxygen is high. Since recycling of foundry scrap is desirable, oxygen content will normally be near the high limiting value, and nitrogen will be also maintained at a relatively high value. As a result, the minimum design values established for Ti-6Al-4V during this program may possibly be increased as more production experience is gained with heats approaching the higher analysis limits for oxygen and nitrogen.

The scatter diagrams and analysis comparisons for aluminum and vanadium show negligible effect of analysis on strength or ductility for the composition ranges typical of the process. For these histograms, ranges for the other elements were selected to the following limits:

for study of aluminum,

Vanadium	3.8 – 4.2 per cent
Oxygen	.13 – .25 per cent
Carbon	0 – .10 per cent
Hydrogen	0 – .01 per cent

for study of vanadium,

Aluminum	5.8 - 6.2 per cent
Oxygen	.13 - .26 per cent
Carbon	0 - .10 per cent
Hydrogen	0 - .01 per cent

The study of carbon showed that increasing carbon provides slight strengthening effect with no significant effect on ductility over the normal analysis range.

Considering past experience with wrought alloys, the normal analysis distributions characteristic of this process, the economics of using foundry and other scrap in the casting process, and the influence of analysis on mechanical properties, the following analysis limits were established as controls for production castings of the Ti-6Al-4V alloy:

Aluminum	5.5 - 6.5 per cent
Vanadium	3.5 - 4.5 per cent
Oxygen	.25 per cent maximum
Nitrogen	.07 per cent maximum
Carbon	.10 per cent maximum
Iron	.30 per cent maximum
Hydrogen	.015 per cent maximum.

A brief study of the effect of grain size of cast Ti-6Al-4V as affected by cooling rate during solidification consisted of pouring a heat of Ti-6Al-4V into four tensile coupon molds, made of rammed graphite, shell graphite, machined graphite, and copper. A macro-photograph of the sectioned coupons is shown as Figure C17. The properties of tensile tests of these coupons were as follows:

Mold Material	U.T.S. psi	Y.T.S. (.2%) psi	Elong., %	R.A., %	Notch * Tensile Strength
Machined Graphite	135,000	116,000	7.6	13.0	205,000
Rammed Graphite	135,000	115,000	7.6	13.0	194,000
Shell Graphite	137,600	120,000	5.5	10.1	198,000
Copper	137,500	118,000	7.1	8.3	205,000

* K_t = 3.37 Heat No. 22.3 - F251

It was concluded that the various molds had insignificant effect on mechanical properties.

The as-cast properties of the heats of Ti-6Al-4V are tabulated in Table J17.

Elevated temperature properties of as-cast Ti-6Al-4V were determined and presented in Table J18 and Figure C18.

Several attempts were made to improve the strength and ductility of the Ti-6Al-4V alloy by heat treatments. The first trials were attempts to modify the cast structure by cycling through the beta-alpha transformation temperature. Next, attempts were made to homogenize the structure by longer solution times than are used for forgings. Neither of these treatments produced improvement over conventional heat treatments. In general, greater strength with concomitant lower ductility was obtained at higher solution temperatures and lower aging temperatures. As solution temperatures were progressively reduced to 1550° F and aging temperatures were increased to 1100° F in attempting to obtain better ductility, ultimate strength increase over the as-cast condition was in the order of 15,000 psi with an accompanying loss of ductility to about one half the as-cast ductility values. Furnace cooling from 1500° F to 1000° F followed by air cooling resulted in reduced ductility with no increase in strength, as compared to as-cast properties.

Further attempts to improve the ductility of cast Ti-6Al-4V consisted of annealing for two to eight hours at 1000°F to 1200°F. Although the results were erratic, the annealing at 1150°F was generally slightly beneficial to ductility without affecting strength. At the other temperatures tried, no advantage in annealing was found. If annealing of Ti-6Al-4V castings is desired as a stress relief or for other reasons, the 1150°F treatment is recommended. The carbon, oxygen, nitrogen, iron, and chromium analyses of the heats used for the annealing treatment investigation were studied to determine if there was a correlation between the amounts these elements and the tendency for ductility to be increased or decreased by annealing. Such correlation was not found.

A heat treatment was developed which simultaneously increased strength and ductility by significant amounts, however the heat treatment was considered too difficult or impossible to accomplish on cast shapes.

The heat treatment consisted of holding at 1900°F for 30 minutes, quenching to 1250°F in less than six seconds, hold at 1250°F for 8 hours, air cool to room temperature, heat to 1500°F and hold for 2 hours, furnace cool at not more than 5F per minute to 1000, and air cool. This treatment provided approximately 3000 psi strength increase with an increase of reduction of area of 5 per cent. A further solution and aging treatment consisting of 1650°F for 20 minutes, water quench, 1000°F for 4 hours, and air cool resulted in a strength increase over as-cast of 19,000 psi with reduction of area loss of 3.5 per cent.

The results of all heat treatment trials on the Ti-6Al-4V alloy are in Table J19.

Development of Casting Alloys Other Than Ti-6Al-4V

The purpose of this portion of the work was to develop titanium casting alloys with properties superior to those of Ti-6Al-4V.

The as-cast mechanical properties of the experimental alloys are in Table J20.

Since the experimental alloys were produced from new sponge and high purity alloying elements, the carbon, oxygen, and nitrogen contents are generally lower than normally present in the Ti-6Al-4V heats which were produced from recycled foundry returns. Consequently, in some instances the experimental alloys are of lower strength and higher ductility than would be expected if they were used in normal production.

Several elements that can be alloyed with titanium to strengthen the alpha phase without producing the beta phase in the room-temperature microstructure are: aluminum, silicon, carbon, oxygen, nitrogen, tin, and zirconium. Since alpha alloys do not respond to heat-treatment, they have good weldability. Also because of the relatively small temperature difference between the liquidus and solidus of alloys of titanium and these elements, it would be expected that these alloys would have good fluidity in the sense of ability to run a thin section without cold shuts or misruns; and also have good feeding characteristics in the sense of enabling risers to feed relatively long distances without shrinkage porosity. Hence, it was hoped that an alpha alloy would be found useful as a low-strength weldable alloy of good castability.

Elements known to be soluble in beta titanium and which tend to make the beta phase stable and strengthen it are: vanadium, manganese, chromium, iron, columbium, molybdenum, nickel, and hydrogen.

Alloys containing manganese, chromium, iron, and nickel undergo a eutectoid transformation from the beta phase to alpha and form inter-metallic compounds as the alloys are cooled to room temperature. In general, as the rate of transformation increases, the transformation temperature and the alloy content of the eutectoid composition decreases for alloying elements toward the right side of the periodic table and having greater differences in atomic diameter as compared to titanium. With the elements vanadium, columbium, and molybdenum, which are not as far to the right of titanium in the periodic table and have atomic diameters more nearly equal to that of titanium, the eutectoid transformation has not been found to occur.

The 5Al, 2 1/2Sn alloy and the 8Al, 2Cb, 1Ta alloys were tried because they were well-known standard alpha alloys at the time.

The 6Al and 8Al alloys were tried because investigations by others had indicated that aluminum strengthens titanium in additions up to approximately 8 per cent.

The 2Cu and the 6Al - 2Cu alloys were tried because the equilibrium diagram for Ti-Cu indicates that Ti_2Cu can be precipitated from alpha titanium. It was hoped that age hardening could be obtained in these alloys and that in the second alloy, additional solid solution hardening would be obtained. The 3Mo - 1/2Be alloy was tried for this same reason.

The 6Al - 1Si alloy was tried in a follow-on of work performed at Watertown Arsenal.

Where a high ductility [illegible] alloy is desired, Ti-2Cu (alloy 41) appears to have properties [illegible] to unalloyed titanium

To stabilize the beta phase sufficiently so that no alpha is present at room temperature, approximately 15 per cent vanadium or 12 per cent molybdenum [illegible] V and Ti 12Mo alloys [illegible] these relatively large additions, it was believed that vanadium would be preferred to molybdenum because of density considerations.

To gain additional hardening by means of the eutectoid reaction, a Ti-15Mo-6V-2Ni alloy was cast. In an attempt to speed up the eutectoid reaction rate, a Ti-5Mo-6V-2Ni-2Al alloy was cast and tested.

To investigate the possibility of decreasing the required aging time of the B 120 VCA type of alloy by changes in the aluminum content, the following alloys were cast:

Ti-13V-11Cr
Ti-13V-11Cr-1.5Al
Ti-13V-11Cr-2.5Al
Ti-13V-11Cr-4Al

Considering as-cast properties only, the following alloys had properties similar to Ti-6Al-4V:

5Al-2.5Sn (Alloy 6)
13V-11Cr-1.5Al (Alloy 11)
13V-11Cr-2.5Al (Alloy 12)
13V-11Cr-4Al (Alloy 13)
5.5Al-5.5V-.5Fe-2Sn-.25Cu (Alloy 16)
7Al-3Mo (Alloy 19)
6.5Al-3.5Mo-1V (Alloy 29)
6Al-1Si (Alloy 47)
6Al-6V-2Sn (Alloy 49)
2Al-9Zr-13Sn (Alloy 50)

The following alloys could be expected to be in the same properties class as Ti-6Al-4V, if at the normal interstitial levels:

4Al-3Mo-1V (Alloy 27)
8Al-8Zr-.5Cb-.5Ta (Alloy 45)
6Al-1Si (Alloy 47)
6Al-4V-.5W (Alloy 55)
6Al-4V-.5Ta (Alloy 56)

Since these alloys did not appear to be superior to the 6Al-4V alloy, work on these alloys was discontinued. It appears that the alloys of the following types may be superior to Ti-6Al-4V:

4Al-4Sn-8Zr-1Fe-1V-1Cr (Alloy 60)
4Al-4Sn-8Zr (Alloys 59 and 64)
4Al-4Sn-8Zr-1.5Fe-1.5V-1.5Cr (Alloy 105)
4Al-4Sn-8Zr-.5Fe-.5V-.5Cr (Alloy 106)
4Al-4Sn-8Zr-2V (Alloy 108)
4Al-4Sn-10Zr-2V (Alloy 110)
4Al-6Sn-8Zr-2V (Alloy 111)
6Al-4Sn-8Zr-2V (Alloy 112)

Additional study will be required to determine the best range of elements for this type of alloy.

The results of mechanical property tests on heat treated experimental alloys are given in Table J21.

Most of the beta and alpha-beta alloys could be strengthened by solution treat and age type of heat treatments. However the increase in strength was accompanied by loss in ductility. In general, at any given strength level an as-cast alloy can be found that is as strong and is more ductile than an alloy that was strengthened by heat treatment. Therefore, hardening heat treatments are not recommended for the cast titanium alloys.

Near the end of the program, alloys which appeared to be good candidates were further screened by a heat treatment to test "thermal stability". This consisted of heating for up to 80 hours at temperatures from 600 to 1000°F. The following were embrittled by these treatments and were eliminated from further consideration because they would not be suitable for service in this temperature range:

13V-11Cr-1.5Al (Alloy 11)
8V-5Fe-1Al (Alloy 15)
4Al-8Sn-8Zr-1Fe-1V-[illegible] (Alloy 60)
4Al-4Sn-8Zr-1.[illegible] (Alloy 105)
4Al-4Sn-8Zr-[illegible] (Alloy 106)

The 6Al-4V, [illegible] (alloy 108) alloys [illegible] is strengthened [illegible]

The chemical analyses of all heats in this program are given in Table J22.

The following conclusions were reached as results of the alloy development studies:

(a) At the present stage of development, unalloyed titanium and Ti-6Al-4V are suitable for "standard" casting alloys.

(b) Ti-2Cu has ductility superior to unalloyed titanium which has been hardened to the same strength level through interstitial additions.

(c) The properties of an alloy of titanium containing four to six per cent aluminum, four to six per cent tin, eight to ten per cent zirconium, and two to four per cent vanadium are slightly better than those of Ti-6Al-4V. Additional work is needed to establish the best composition and interstitial levels of this type of alloy.

FIGURE C1

OXYGEN ANALYSIS DISTRIBUTION IN CAST Ti-6Al-4V

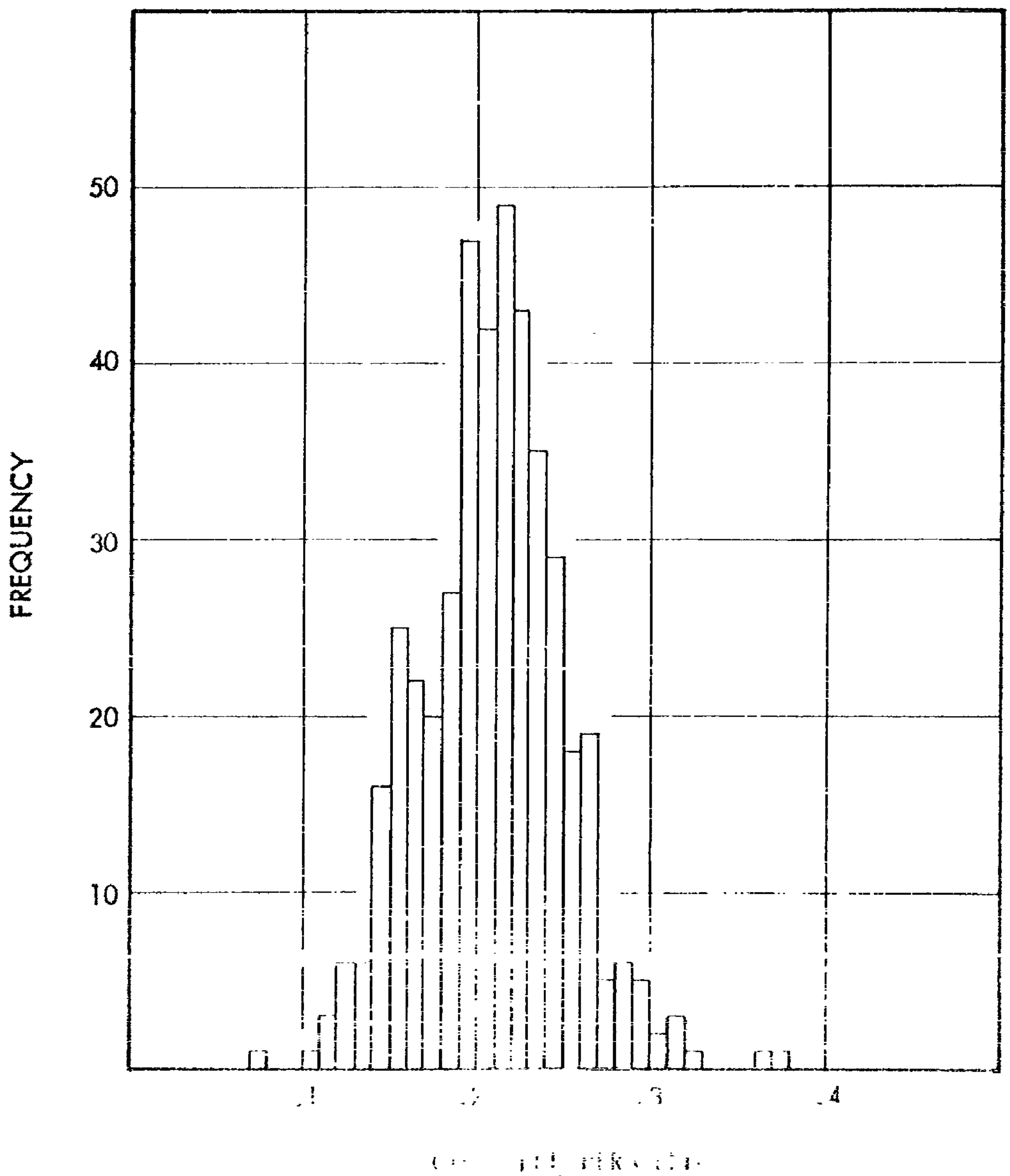


FIGURE C2

NITROGEN ANALYSIS DISTRIBUTION IN CAST Ti-6Al-4V

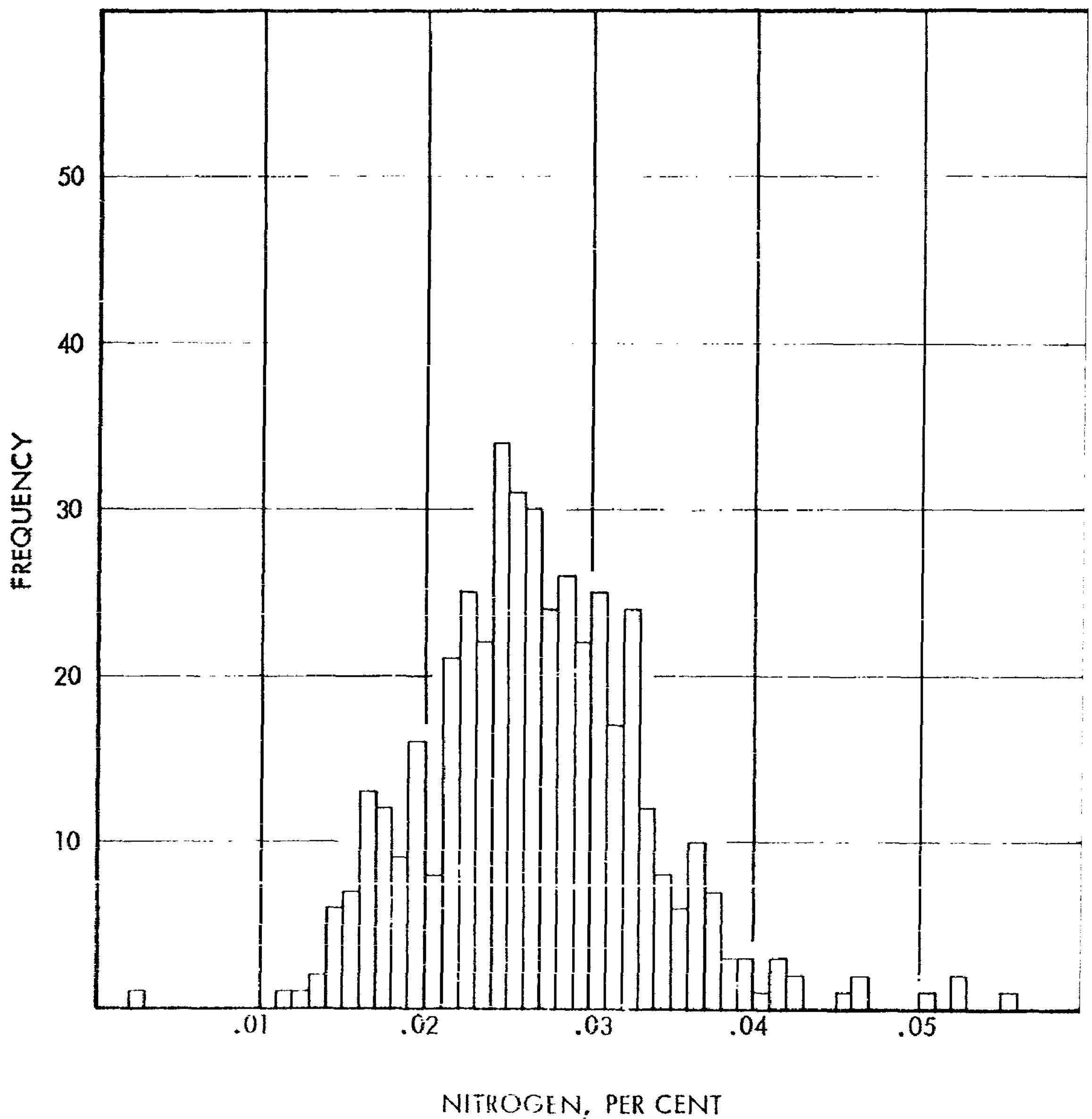


FIGURE C3

HYDROGEN ANALYSIS DISTRIBUTION IN CAST Ti-6Al-4V

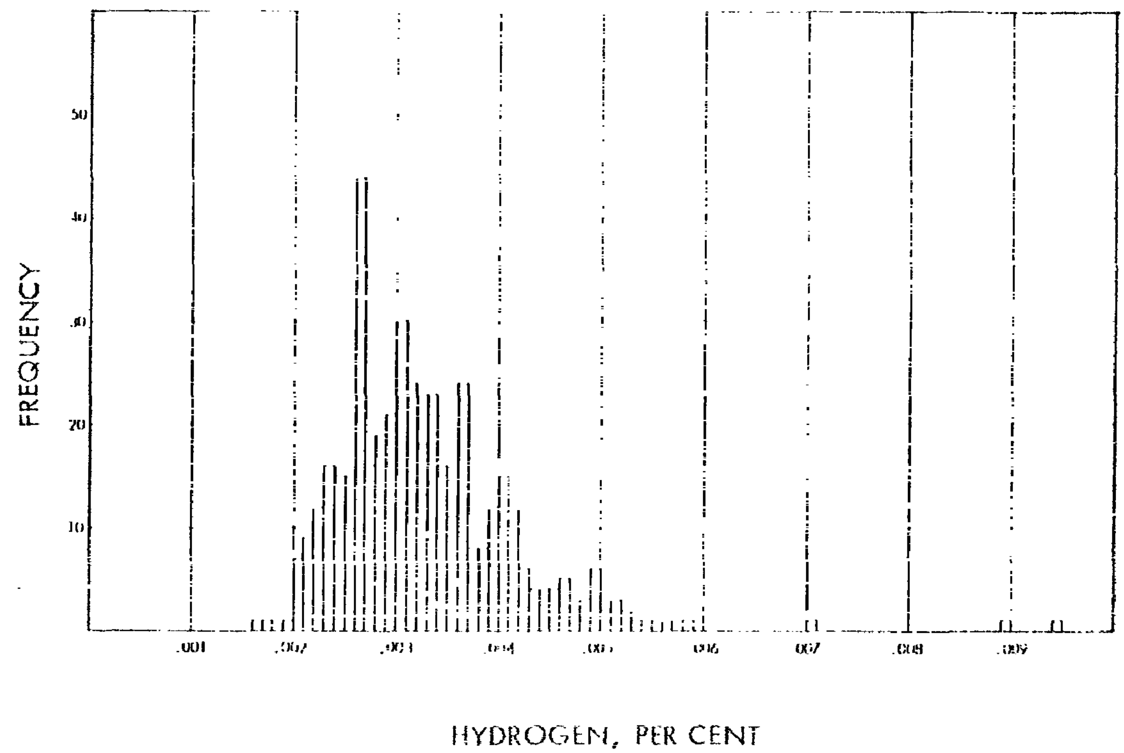


FIGURE C4

CARBON ANALYSIS DISTRIBUTION IN CAST Ti-6Al-4V

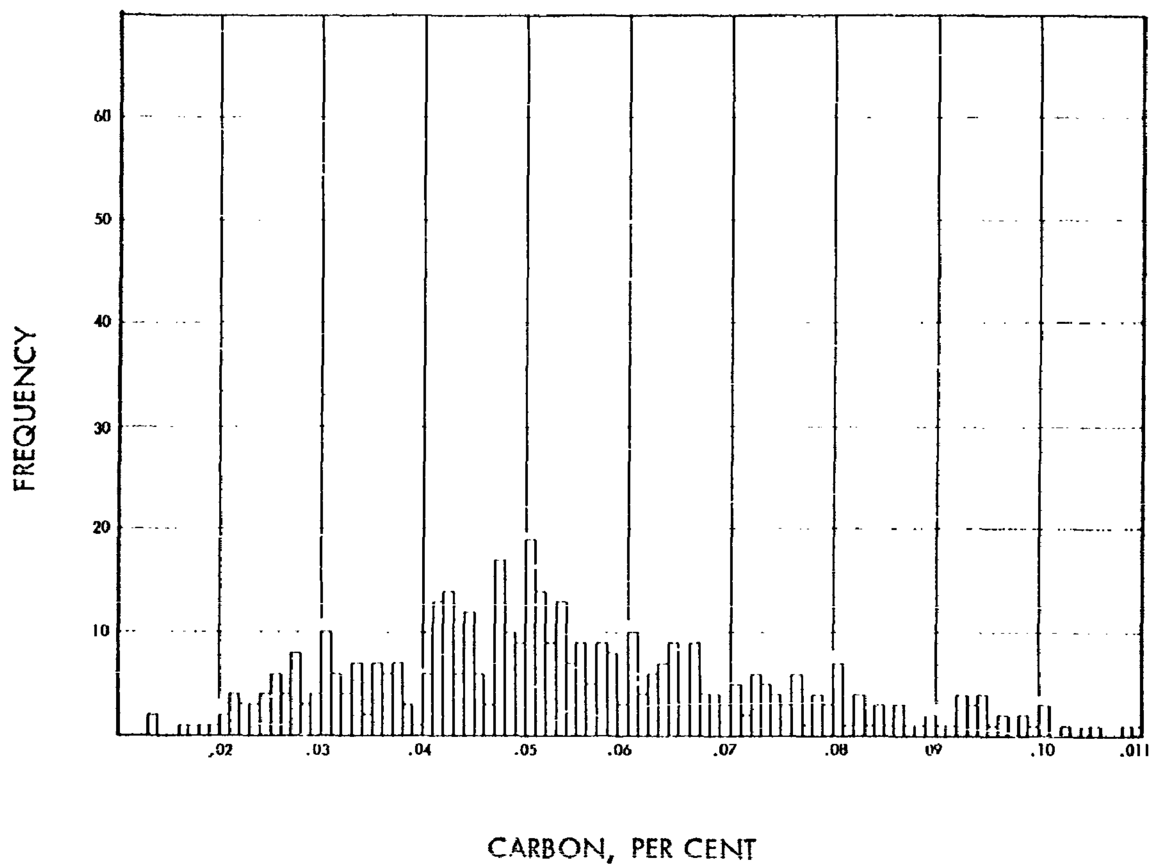


FIGURE C5

IRON ANALYSIS DISTRIBUTION IN CAST Ti-6Al-4V

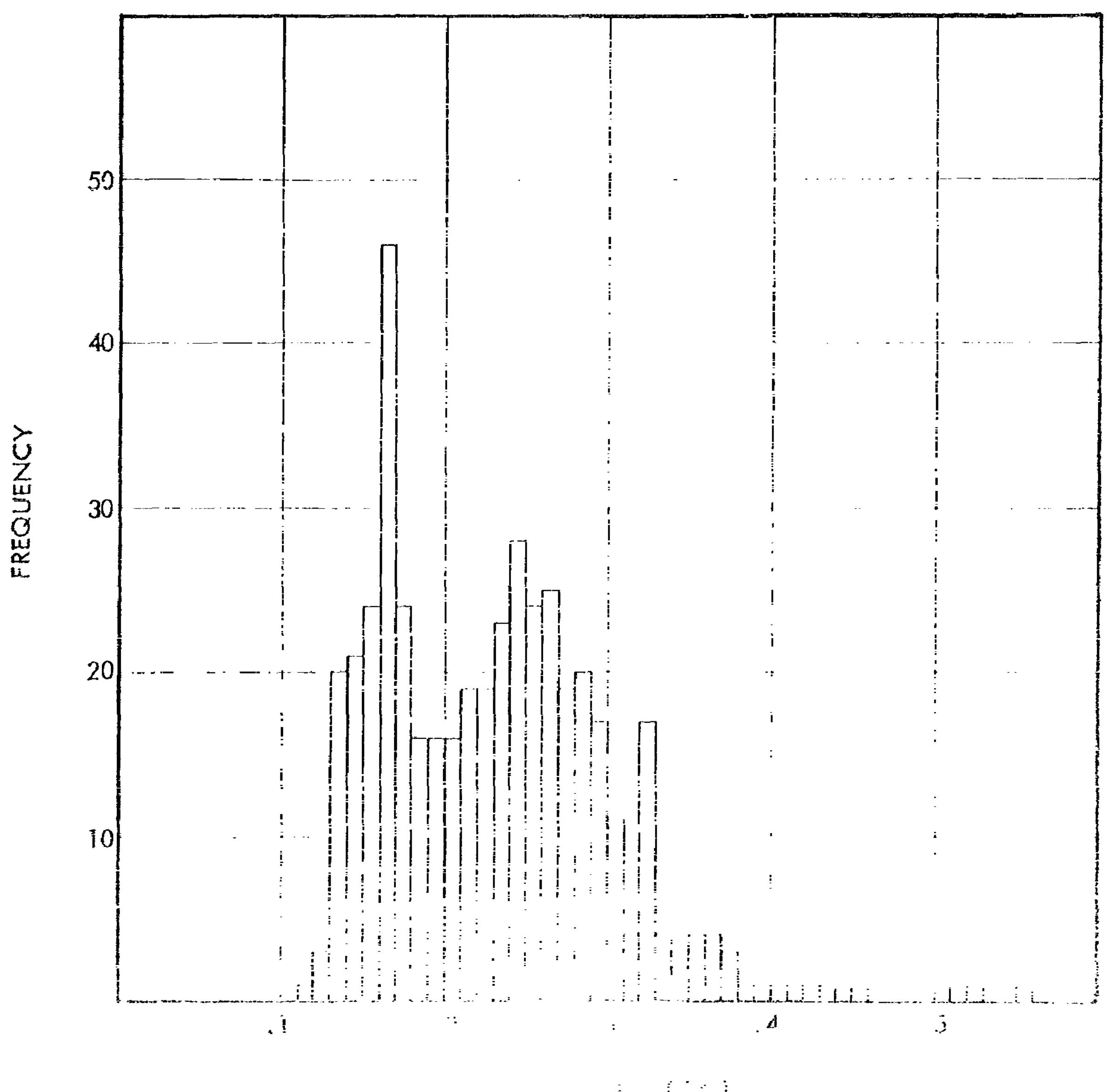


FIGURE C6

ALUMINUM ANALYSIS DISTRIBUTION IN CAST Ti-6Al-4V

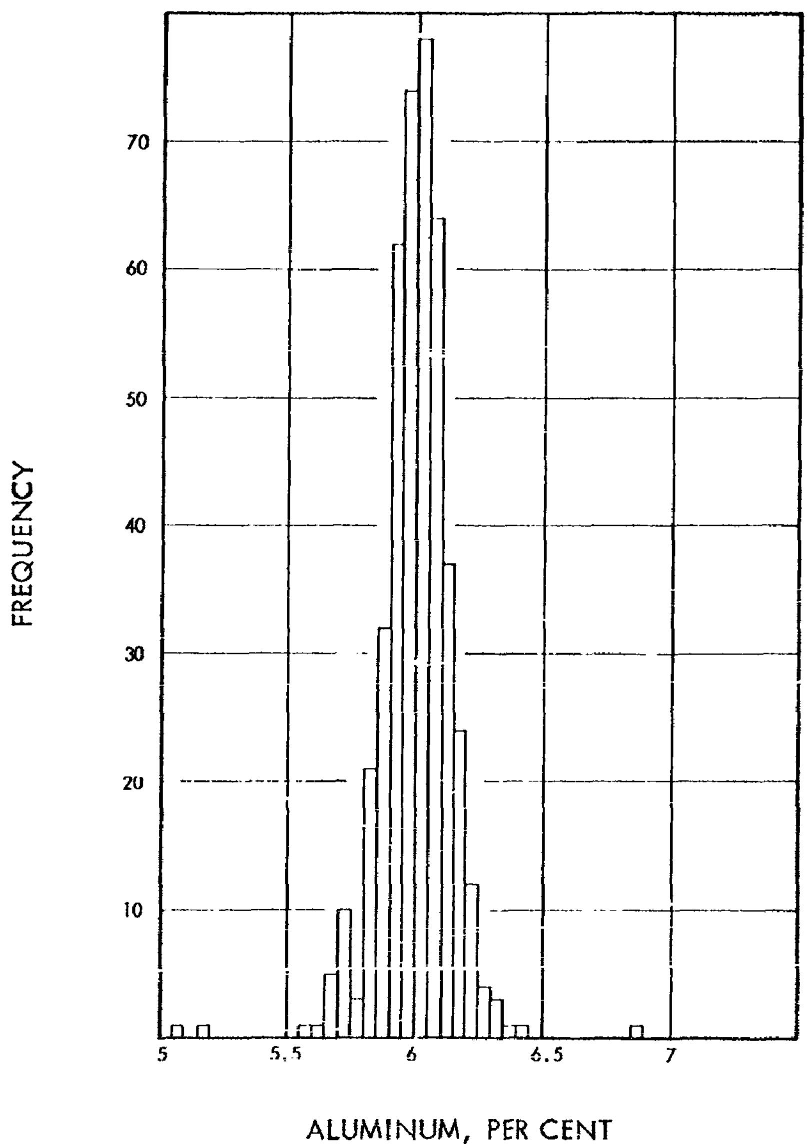


FIGURE C7

VANADIUM ANALYSIS DISTRIBUTION IN CAST Ti-6Al-4V

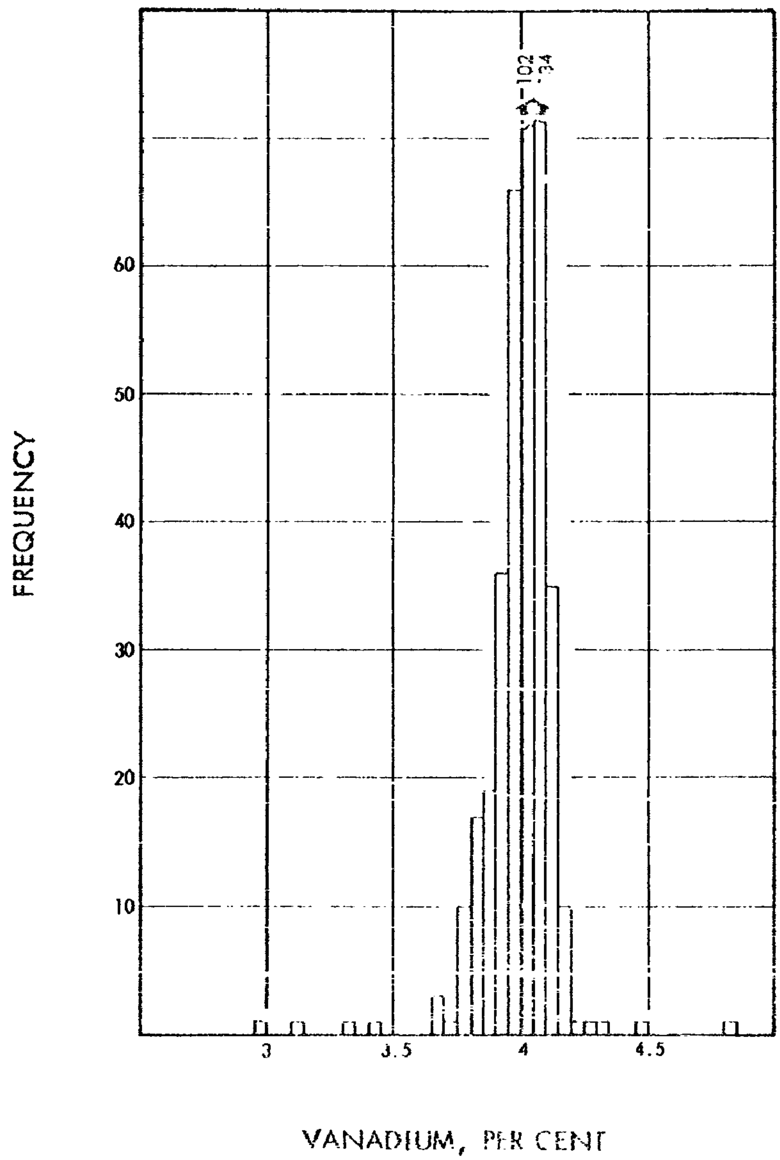


FIGURE C8

SCATTER DIAGRAM - OXYGEN VS. ULTIMATE STRENGTH

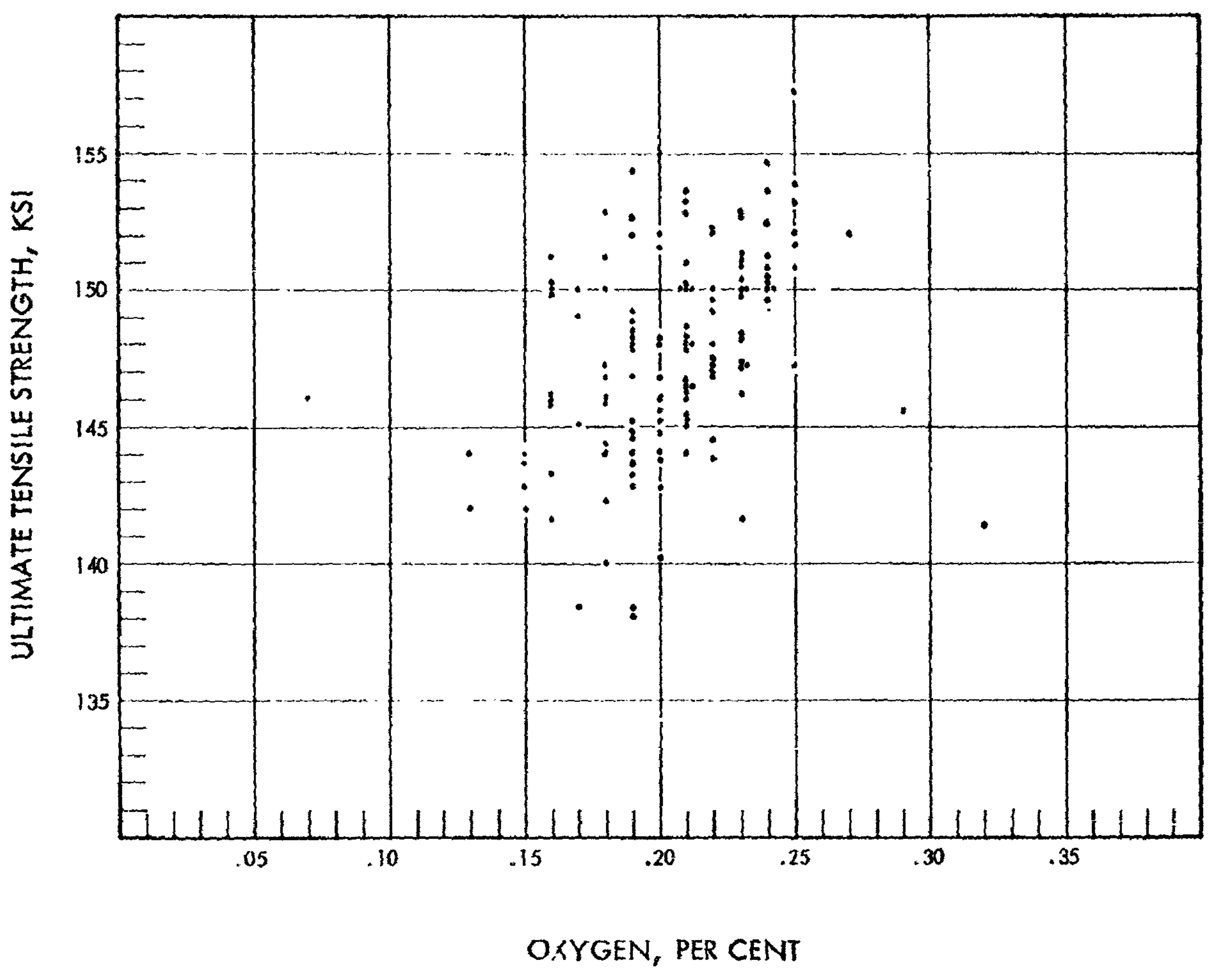


FIGURE C9

SCATTER DIAGRAM - OXYGEN VS. REDUCTION OF AREA

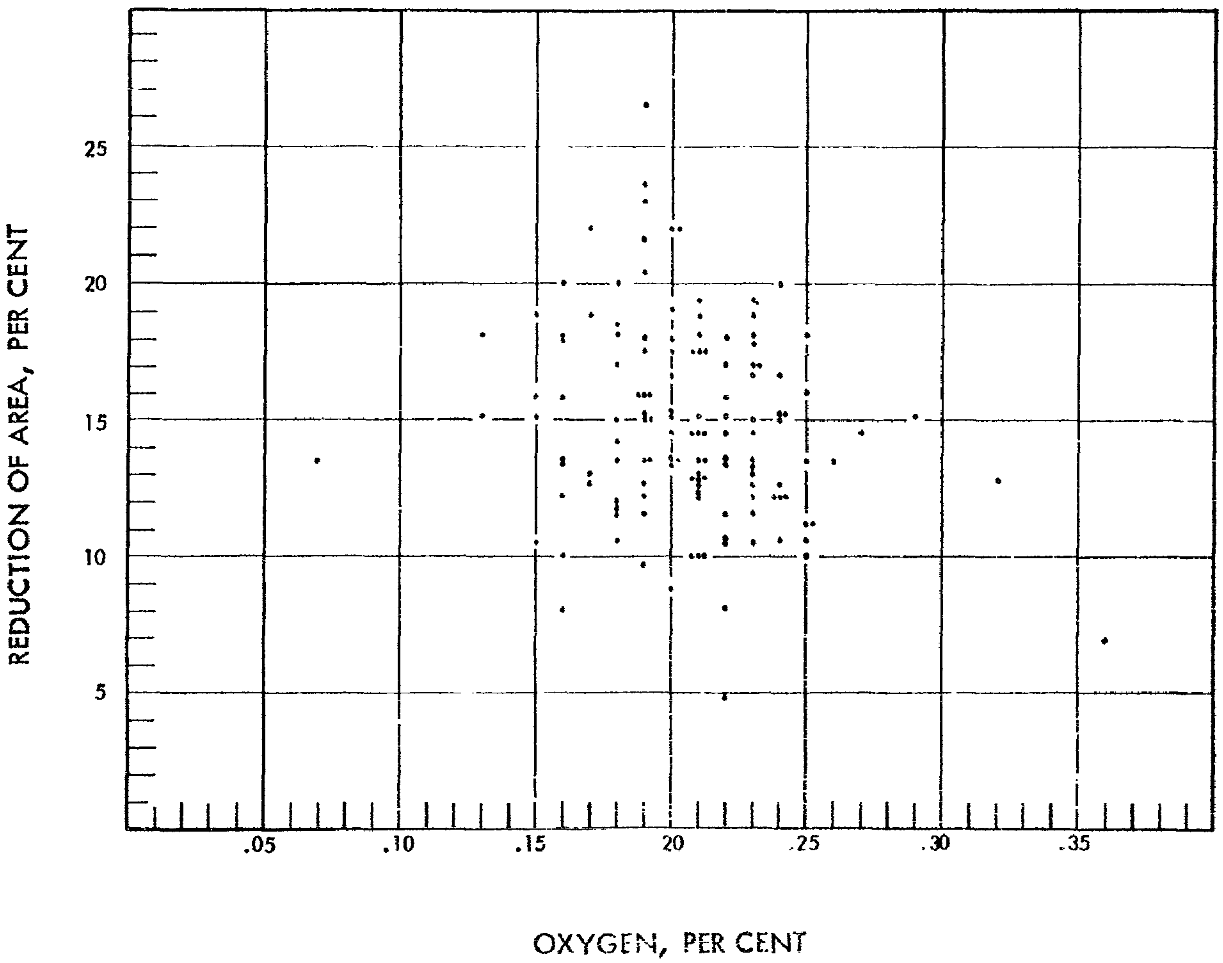


FIGURE C10

FREQUENCY DISTRIBUTIONS FOR ULTIMATE STRENGTH FOR VARIOUS OXYGEN RANGES

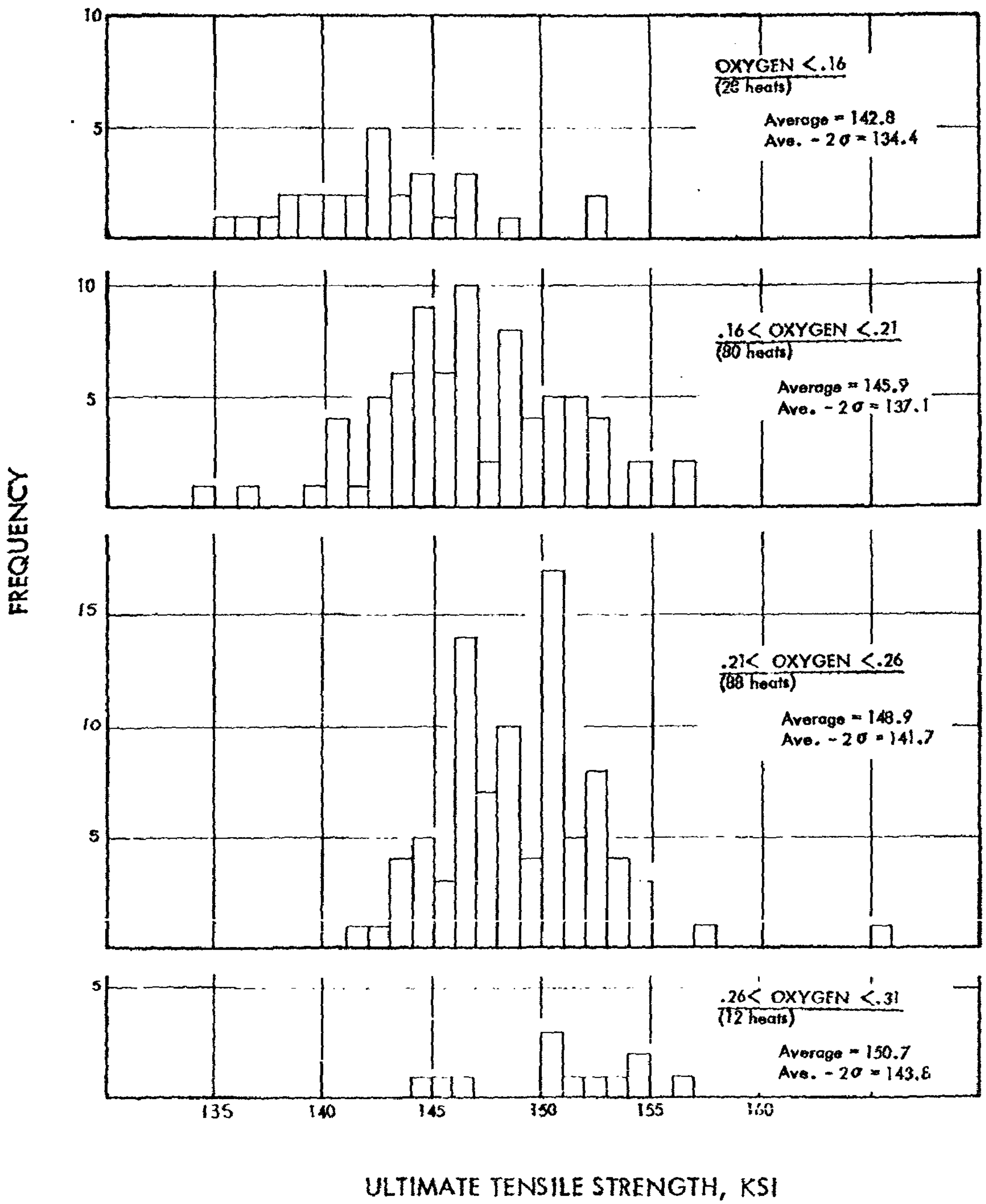


FIGURE C11

FREQUENCY DISTRIBUTIONS FOR REDUCTION OF AREA FOR VARIOUS OXYGEN RANGES

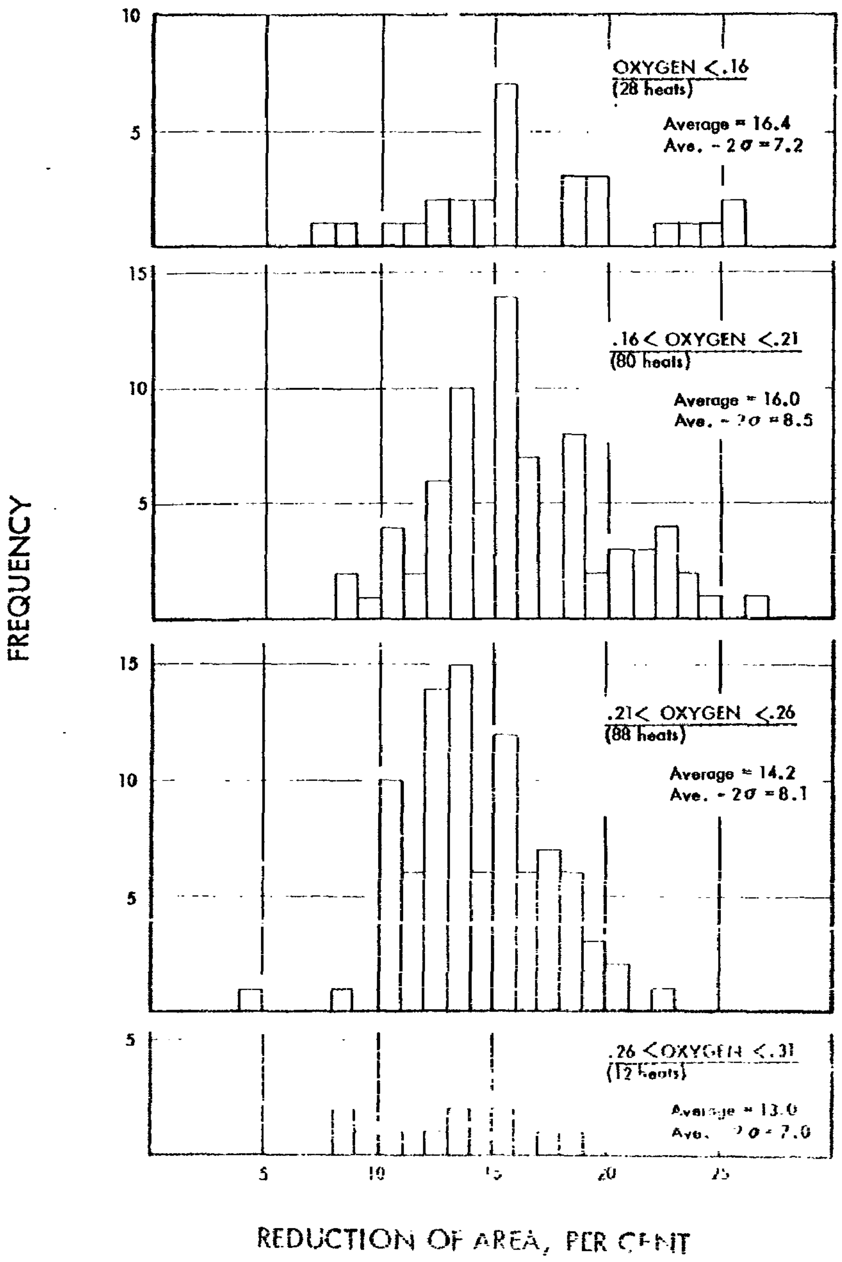


FIGURE C12

FREQUENCY DISTRIBUTIONS FOR ELONGATION
FOR VARIOUS OXYGEN RANGES

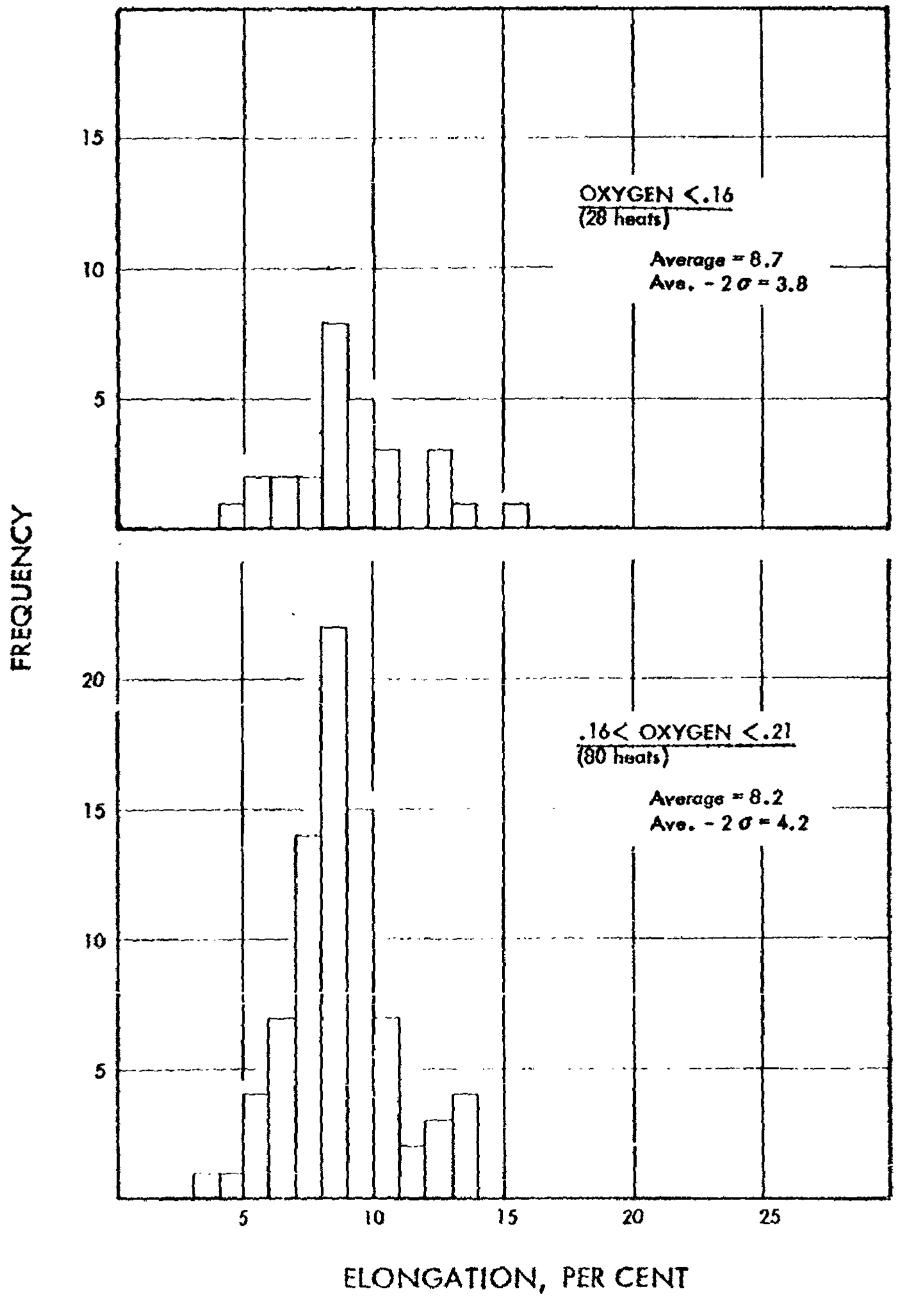


FIGURE C13

(FIGURE 12 CONTINUED)

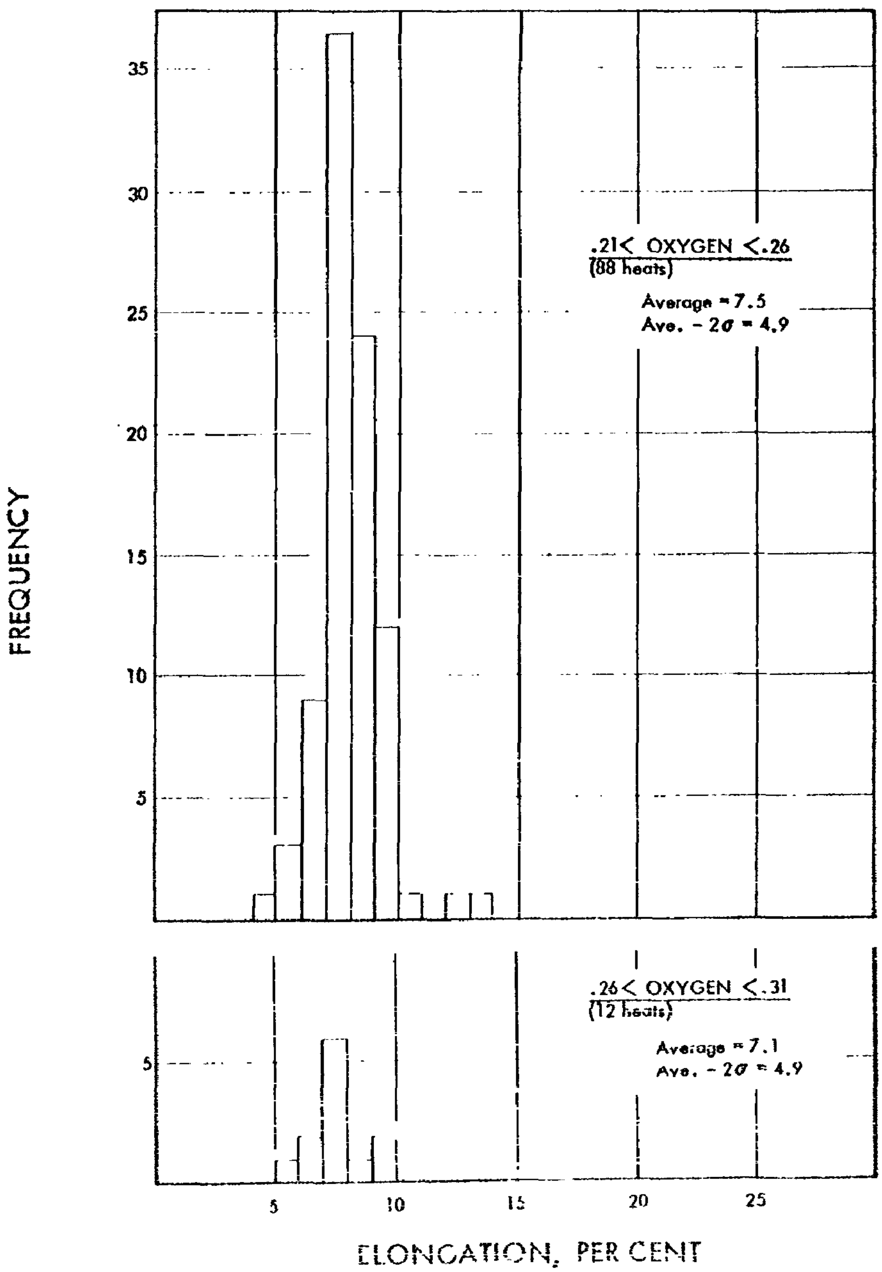
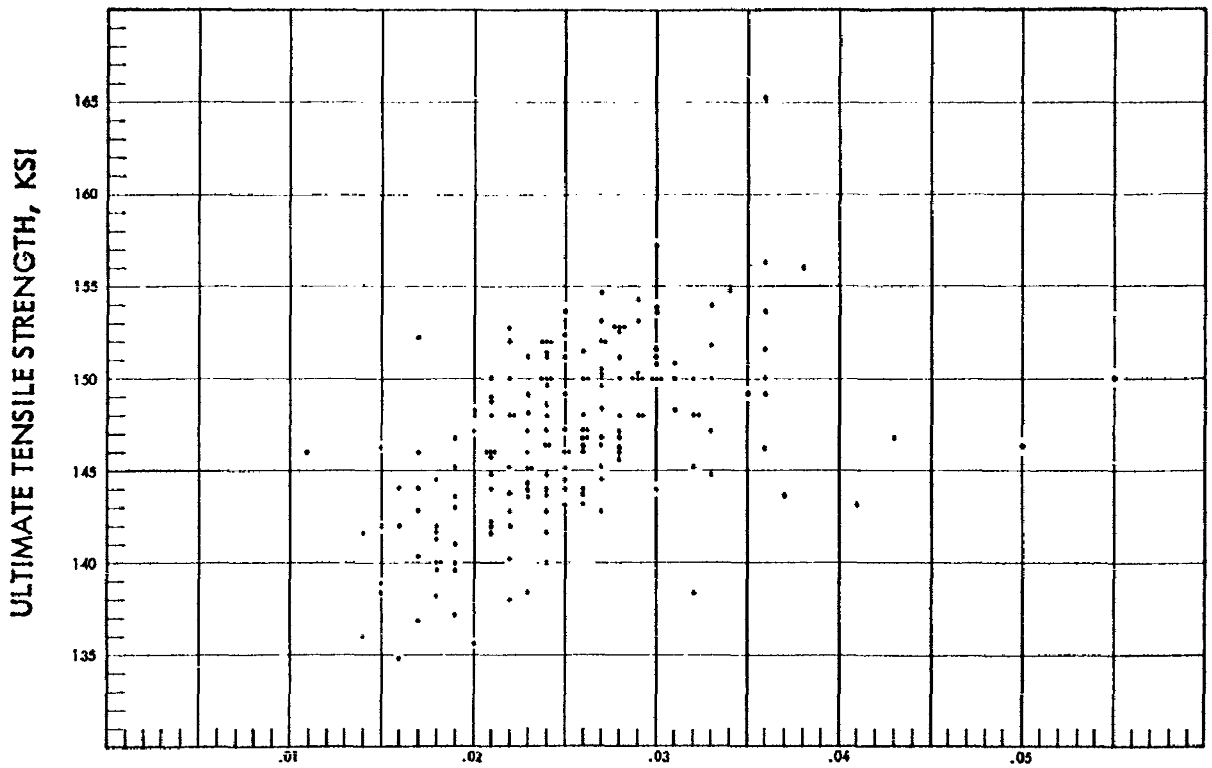


FIGURE C14

SCATTER DIAGRAM - NITROGEN VS. ULTIMATE STRENGTH



NITROGEN, PER CENT

FIGURE C15

SCATTER DIAGRAM - NITROGEN VS. REDUCTION OF AREA

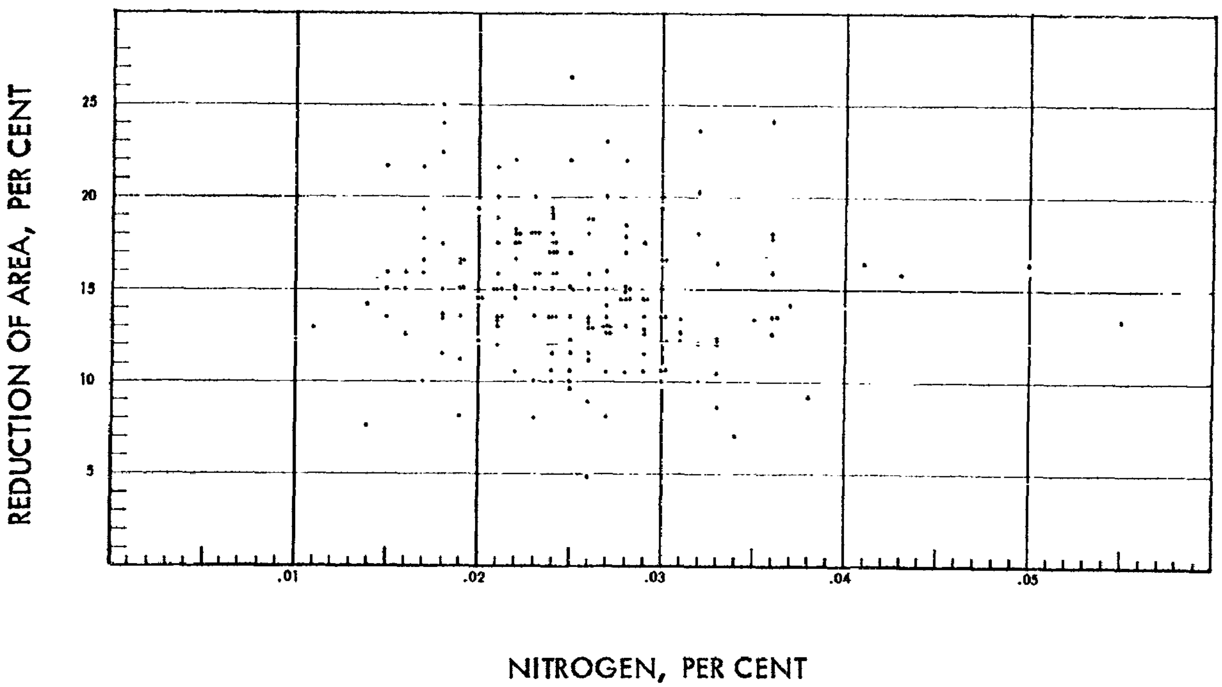


FIGURE C16

SCATTER DIAGRAM - NITROGEN VS. OXYGEN

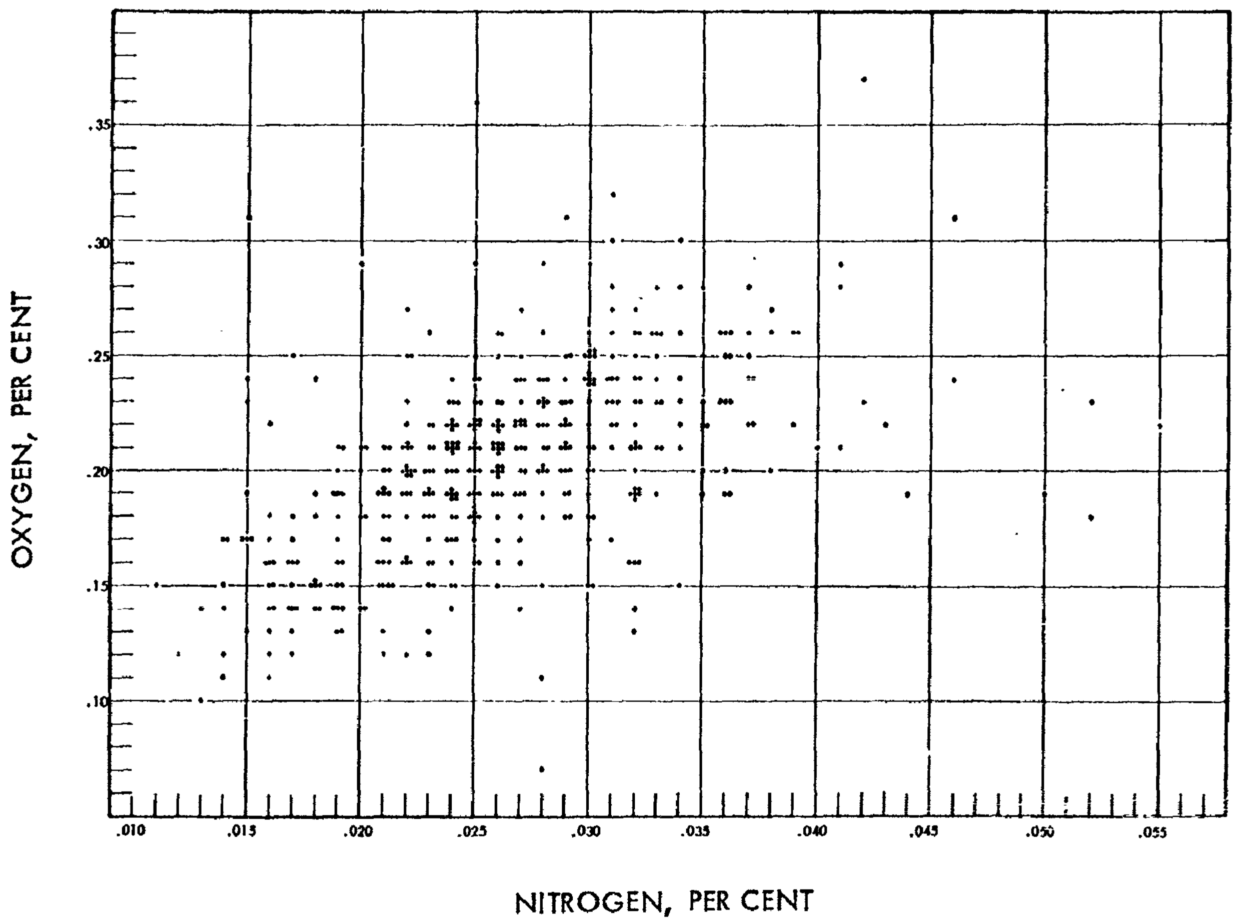
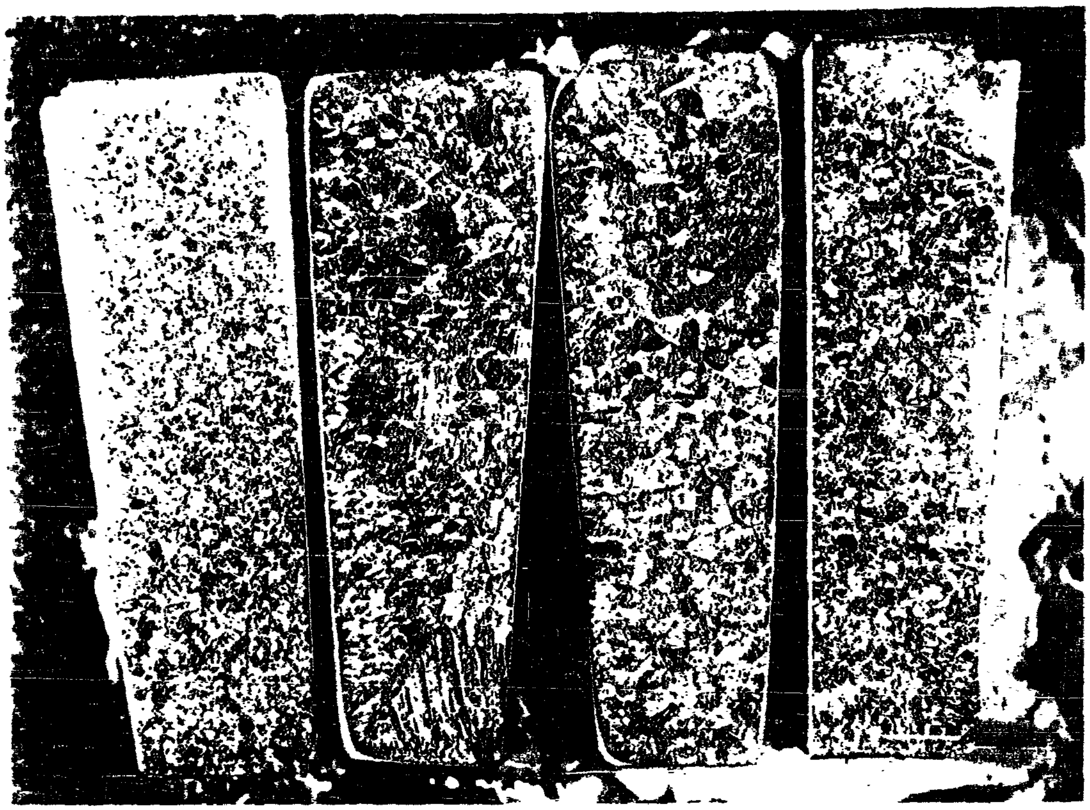


FIGURE C17

EFFECT OF COOLING RATE ON MACROSTRUCTURE



Copper Mold	Rammed Graphite Mold	Shell Mold	Machined Graphite Mold

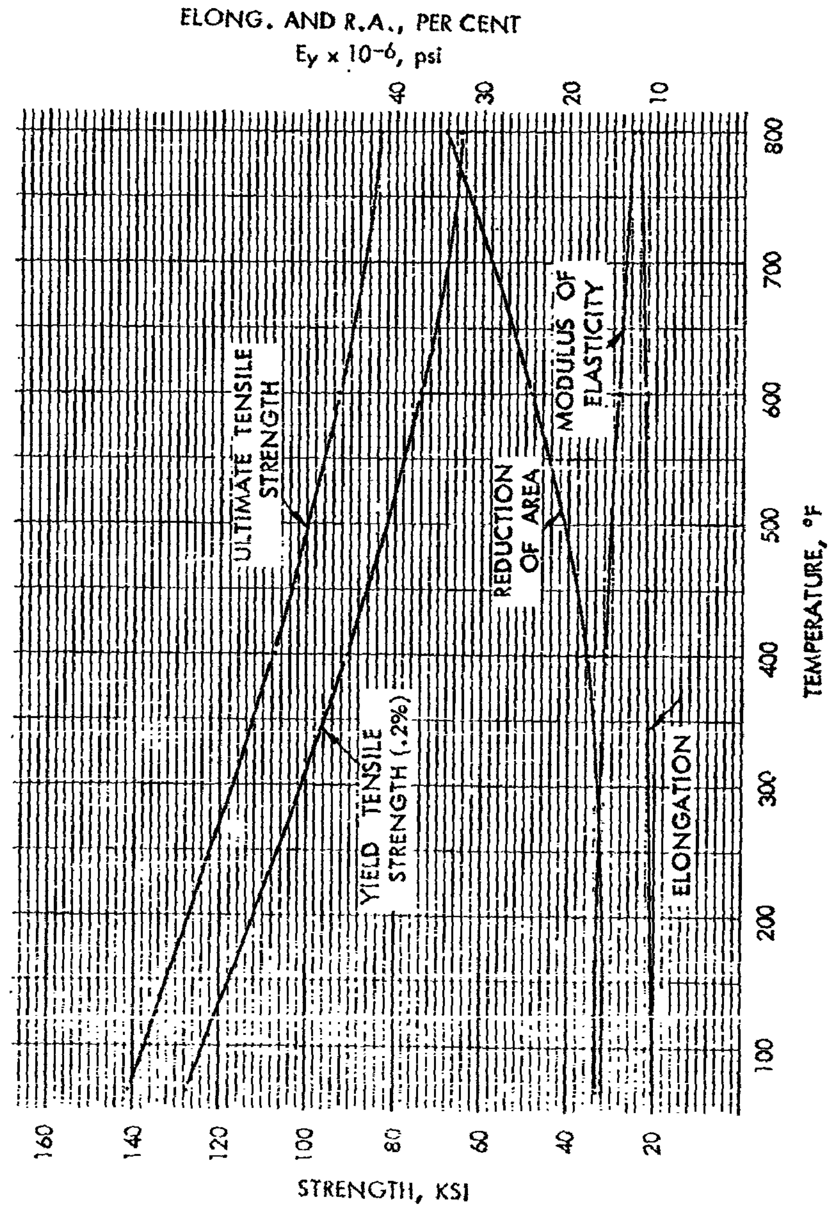
Samples: Test coupons of C-4 alloy cast in different mold materials.

Mag. 1 X

Structure: Note refinement of grain resulting from fast cooling in copper mold and directional solidification developed in slower cooling of rammed graphite material.

FIGURE C18

ELEVATED TEMPERATURE PROPERTIES OF AS-CAST Ti-6Al-4V



SECTION D

CASTING OF SHAPES

Selection of Components

Five parts were selected for use as developmental shapes in this program. The parts represent a variety of casting problems and are considered typical of structural members which would be desirable as castings.

The following parts were selected:

(1) Developmental Bracket

A sketch and a reduced size drawing of the Developmental Bracket are shown as Figures D1 and D2. This part is not an actual production component, but was designed specifically for development work on castings and forgings. As a shape, it is difficult to forge or cast because of the adjacent heavy and thin sections, the high thin flanges, and the thin confined web. The part is somewhat typical of airframe structural detail and is small and economical to produce, machine into a finished part, and test. The Developmental Bracket was used for much of the basic development work in this contract. As a titanium casting, the machined shape weighs approximately 2.2 pounds.

(2) Flap Track Support Link

A sketch and a drawing of this part are shown as Figures D18 and D19. This is a redesigned KC-135 Tanker-Transport structural brace, presently forged from AISI 4140 or 8740 steel and heat treated to the 180 - 200 ksi ultimate tensile strength range. Four of this configuration are used per airplane. The machined component weighs 2.9 pounds as a titanium casting.

(3) Sway Brace Case

This is a B-52 Bomber component, essentially a spring casing, presently used as an AISI type 410 steel rough centrifugal casting heat treated to 150 - 170 ksi ultimate tensile strength. The machined titanium part weighs 7.75 pounds. There are eight used per airplane. Conversion to a titanium casting would save 46 pounds per airplane. A sketch and a drawing of this part are shown as Figures D32 and D33.

(4) Elevator Torsion Fitting

A sketch and a drawing of this component are shown as Figures D36 and D37. The part is a redesigned structural component that converts rotation of an input shaft to change of attack angle of thehori-zontal stabilizer on the Bomarc missile. The fitting is designed for rigidity and is presently an AISI type 410 steel casting heat treated to 180 - 210 ksi ultimate tensile strength. One left and one right hand versions of this component are used per missile and weight 4.48 pounds each as machined titanium castings.

(5) Inboard Horizontal Stabilizer Rib

A sketch of this component is shown as Figure D4[illegible]. The corresponding production component controls angle of attack and attaches the horizontal stabilizer to the fuselage of the North American Aviation A3J-1 Airplane. The production part was initially designed and produced as a titanium alloy forging heat treated to 150 ksi ultimate strength but was later changed to a steel forging to increase rigidity. The titanium forging weighed 160 pounds and was machined to 37 pounds. This component was selected as a large casting which approached the size limitation of the available casting equipment. The part was not satis-factorily developed as a casting.

Casting of The Developmental Bracket

A sketch and drawing of the Developmental Bracket are shown as Figures D1 and D2.

The Bracket was first statically cast in both machined graphite and rammed graphite molds using the Ti-6Al-4V alloy. These first castings were produced without the optional holes in the web, and contained dispersed shrinkage in the web. This design, when produced in a machined graphite mold with a machined graphite core to form the web and inside surfaces of the flanges, also had extensive cracks in the web area because the high strength of the machined graphite restrained contraction of the metal during cooling after solidification. The casting was again produced in the machined mold using a rammed graphite core with no cracking.

Following further tests to verify the dispersed shrinkage distribution in the web area, the patterns were modified to include the optional holes through the web and castings were then produced in both machined and rammed graphite molds. The addition of the holes greatly improved the feeding characteristics of the web and relieved the problem of web cracking when machined graphite cores were used.

Experience with this design made it apparent that the conditions which produced web soundness were borderline, since several of the castings produced had some shrinkage in the web area. A typical risering and gating technique for static casting the Bracket is shown in Figure D3. Risers were located at each of the lugs, which represent three isolated thermal centers. Gating to the mold was through the risers so that risers would fill last and thus provide a greater temperature gradient from casting to riser.

Casting made in machined graphite molds generally exhibited a surface roughness visually comparable to a 150 RMS finish. In general, the surfaces of castings produced in rammed graphite molds were rougher than those in the machined mold, in the order of 120 to 300 RMS.

FIGURE D1

DEVELOPMENTAL BRACKET

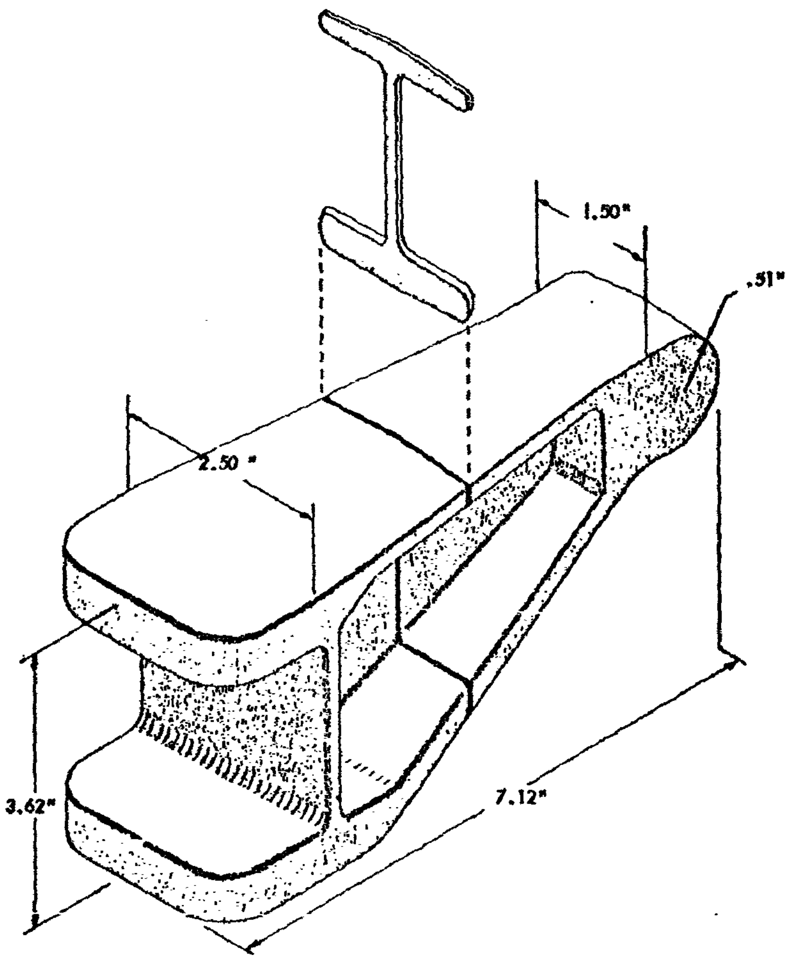
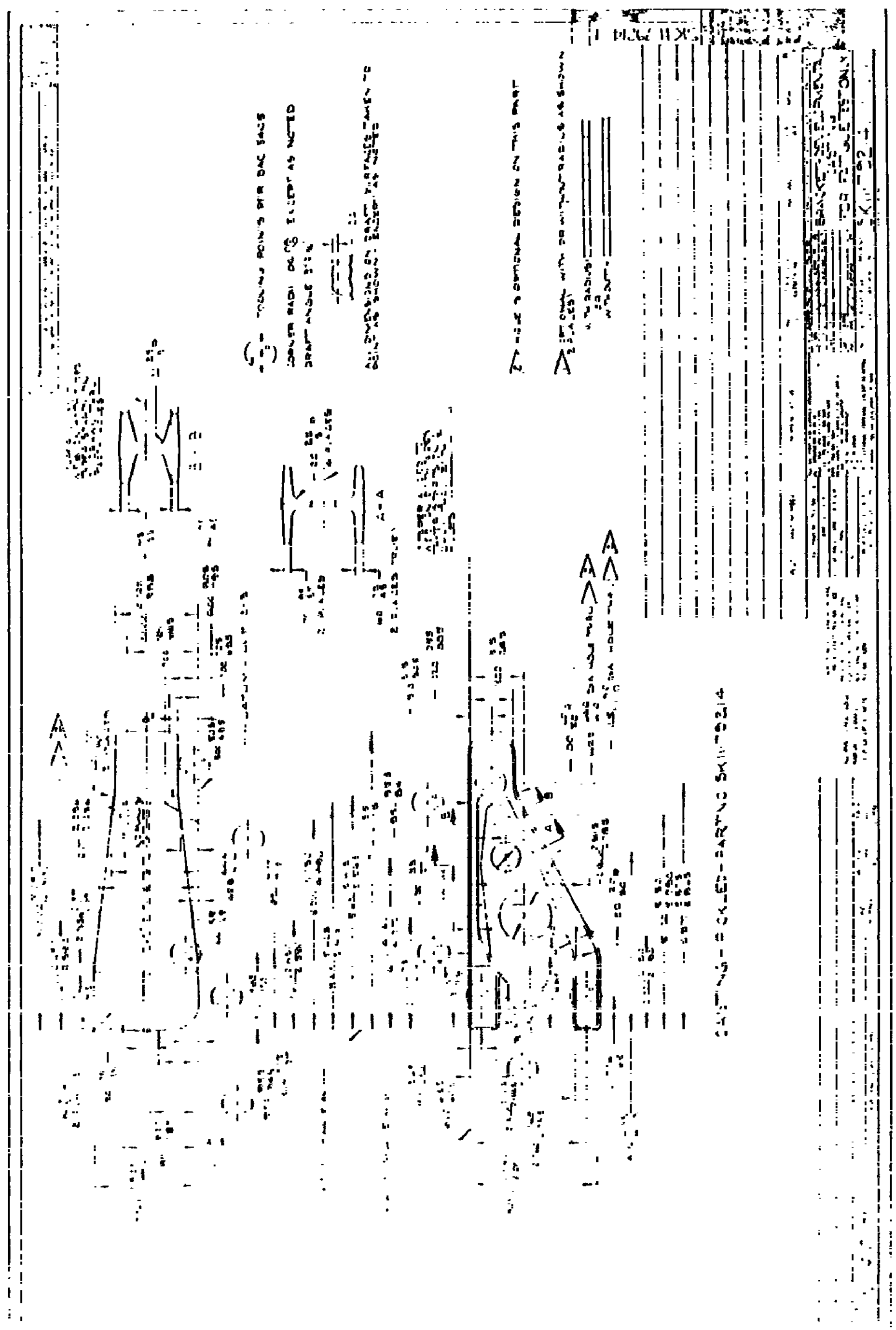


FIGURE D2

DEVELOPMENT BRACKET



Next, the shrinkage condition in the flanges was experimentally improved by adding a three degree taper to the exterior of the flanges, from the midpoint of the flange toward the riser connection. This reduced the shrinkage to very minor areas near the flange-to-web intersection. Incorporation of a one degree taper from the center of the web toward the flanges further improved the soundness to the point where shrinkage was no longer a problem in the web and flanges. The corebox was then modified to provide the flange taper on the inside of the flange to incorporate the web taper. It became increasingly obvious as shrinkage was eliminated that gas porosity was a major problem.

The initial trials of centrifuge casting the Developmental Bracket utilized machined graphite molds with machined or shell graphite cores to provide the web and inner flange surfaces. Centrifuge casting at 850 RPM (160 G's) resulted in nearly sound castings with slight shrinkage porosity in the heavy section at the small end of the part.

An additional casting was then made using a shell core with a larger ingate to feed the small end. This casting was also centrifuge cast at 850 RPM in a 16-inch diameter mold and had satisfactory soundness in the problem area. Surface quality of the casting was poor, because of penetration of metal into the core in the web and flange areas. The core material was easily removed from the casting by sand blast, but a rough surface remained on the casting. The roughness is attributed to lack of density at those surfaces of the core which are vertical in the corebox and did not receive adequate packing during shell molding.

A photograph of three casting made with the above mold arrangements is shown in Figure D4.

The Developmental Bracket was next cast by centrifuging in multiple cavity molds. The arrangement illustrated by Figure D5 was poured in a horizontal axis centrifuge casting furnace. The photograph shows the front of the mold as poured. The mold was rotated counterclockwise at approximately 900 RPM. This arrangement was used to provide "bottom pouring" into the mold cavity to prevent outward impingement of metal directly into the mold cavity. The metal enters the gates and is accelerated outward to the ends of the gates, fills them, and then enters the mold with little turbulence. The castings produced were sound except for a shrinkage cavity in the large lug which is not connected to the ingate, caused by the necessity for this flange to be fed through the relatively thin sections between the two heavy lugs.

The castings shown in Figure D6 were cast in the vertical axis furnace and were gated and risered at each heavy lug. These castings were x-ray sound but had slight surface laps or shuts along the lower flange, caused by metal entering from the top gate and flowing to meet the metal from the bottom gates.

The casting setup shown in Figure D7 was a variation used in an attempt to prevent surface laps. However this setup produced heavy surface laps because of too rapid filling of the mold cavity. The angle of the surface lap indicated a necessity for repositioning the mold in addition to a new gating arrangement. The results from this casting experiment indicated that in centrifugal casting, it is necessary that each end of the mold cavity be at an equal radius from the central sprue to permit even filling of the mold cavity.

The casting setup shown in Figure D8 was to determine the effect of higher casting forces on the outside mold and a new gating arrangement on the inside molds. The as-cast surface from the outside mold was improved slightly, and that from the inside mold was greatly improved. It is apparent that a reverse gating system is necessary to introduce a low-turbulence flow of metal into the mold cavity.

The setup shown in Figure D9 did not improve the casting surface to any great extent. The single gating arrangement did not reduce the turbulence for proper filling of the mold cavity.

The setup shown in Figure D10 illustrates improvements made in gating systems and mold position as a result of previous experimental heats. The mold position was changed such that a line through the mold cavity would be perpendicular to a line from the center sprue. This position permits low-turbulence filling of the mold cavity. The gate pipe feeding the ingates to the mold cavity has been reduced in size after the first gate opening to create a slight pressure head at the first ingate. This method of gating was to provide equal flow of metal into each of the ingates. However, the small ingates (1" O.D.) did not permit the metal to enter at the proper rate and some surface laps appeared as shown in the sketch in Figure D10.

The photograph in Figure D11 illustrates a setup similar to that shown in Figure D10 with a gating change that increased the ingate into the mold to 1 1/4" O.D. This increase in gating size further improved the surface finish obtained.

The casting setup shown in Figure D12 is the same as shown in Figure D11. The variation in casting was to increase the centrifugal forces by rotating at 215 RPM (25 G's force at the cavity). The surface finish of the castings produced was not improved over previous castings cast at 140 RPM (12 G's). The noticeable difference was that the surface laps were only on the straight flange and the angular flange. There was no change in metal penetration of the shell core or the rammed graphite mold. It was concluded that the relatively high rotating speed was not advantageous as there was no improvement in surface finish. The effects of centrifugally casting at high speeds will become important where molds are stacked inwards towards the center of the sprue, enabling rotation at high enough speeds to obtain x-ray sound castings at the inner locations without detriment to the molds rotating at high speeds nearer the periphery of the plate.

The photographs shown in Figure D13 illustrate the casting setup used to test a higher production experimental pour. The top photograph illustrates the arrangement of four molds on the central sprue and the bottom photograph shows the gating system, developed in the previous experimental casting setups.

Of the entire quantity of castings produced in these trials, only two experimental heats failed to yield x-ray sound castings. One of the two heats was rejectable because of gas porosity. It was centrifugally cast at only 5 G's force which is evidently too slow to completely remove gas porosity. The second heat was rejectable because of shrinkage porosity and was made with the molds reversed such that the risers had insufficient effect in feeding shrinkage prone areas.

Next, the Bracket was experimentally cast using a variety of mold setups aimed at the development of an improved gating system and of multiple-mold centrifugal production setups. Radiographically sound castings were consistently produced.

Figure D14 illustrates a setup of two castings produced with a two-ingate mold-filling system. The molds are attached to the periphery of the runner bars with vertical ingates feeding the risers. The runner bar is reduced in size after the first ingate, to create a pressure head and increase the metal flow through the first ingate, thus providing a more uniform filling of the mold cavity. This change in the gating system for the Bracket was made to prevent surface laps in the castings caused by turbulent mold filling. Examination of the castings showed them to be free of such laps.

Figure D15 shows a four-casting arrangement and an eight-casting arrangement used in developing multiple-mold production setups. Visual examination showed these castings also to be free of surface laps.

In this production-setup work, the approach taken was to use a casting method which has been proven successful for small pours (as illustrated in Figure D13), and adapt the method for increased numbers of molds until a maximum is reached as dictated by equipment size. Figure D16 illustrates the pouring setup used for casting a 16-mold production arrangement. This was found to be the maximum number of castings that can be made under the existing casting conditions. The setup consists of eight stacks of two molds each. The molds are attached to a runner bar and gate mold of rammed graphite. The lower photograph in Figure D16 shows the setup after pouring was completed. Very little metal was lost through splashing and spilling from the sprue.

Figure D17 is a photograph of castings produced in the setup shown in Figure D16. Visual examination showed these castings to be free of surface laps.

X-rays of the 16 castings made in the first maximum production pour revealed a void in 15 of them. These voids were all located in the same portion of the casting. The cause of the void has been traced to the

FIGURE D 3

TYPICAL RISERING AND GATING TECHNIQUE

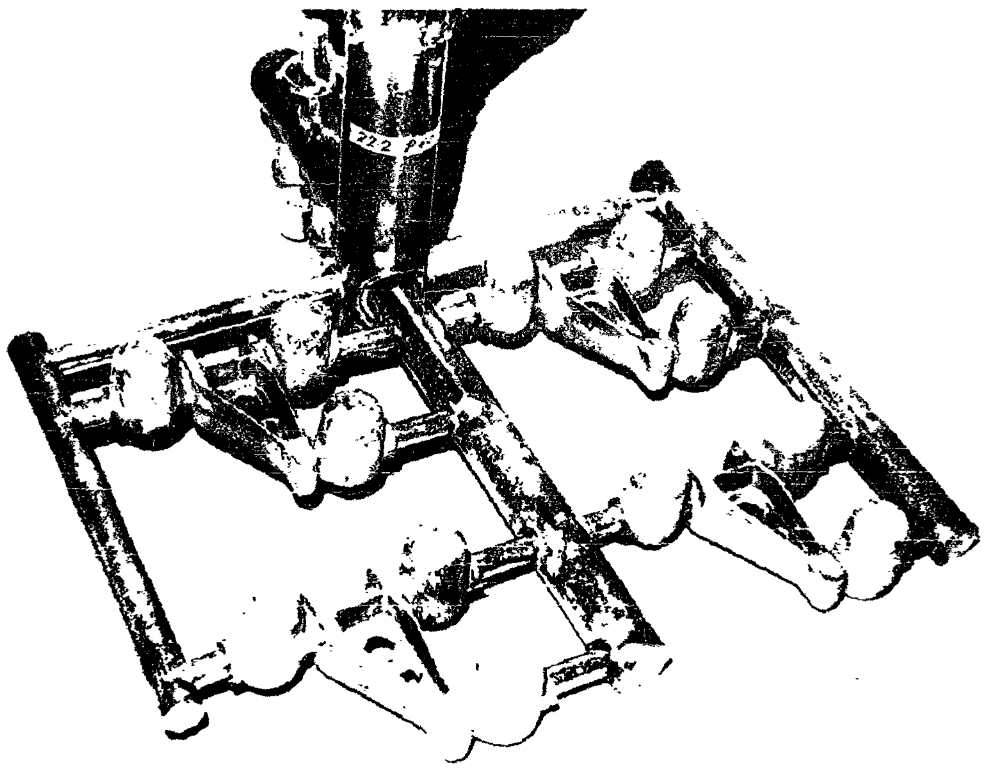


FIGURE D4

EXAMPLES OF SURFACE CONDITIONS
OBTAINED IN BRACKET CASTING TRIALS

Left - Centrifuged, Machined Graphite Mold and Core
Center - Centrifuged, Machined Graphite Mold, Shell Core
Right - Static Cast, Rammed Graphite Mold and Core

FIGURE D5

CENTRIFUGALLY CAST DEVELOPMENTAL BRACKET

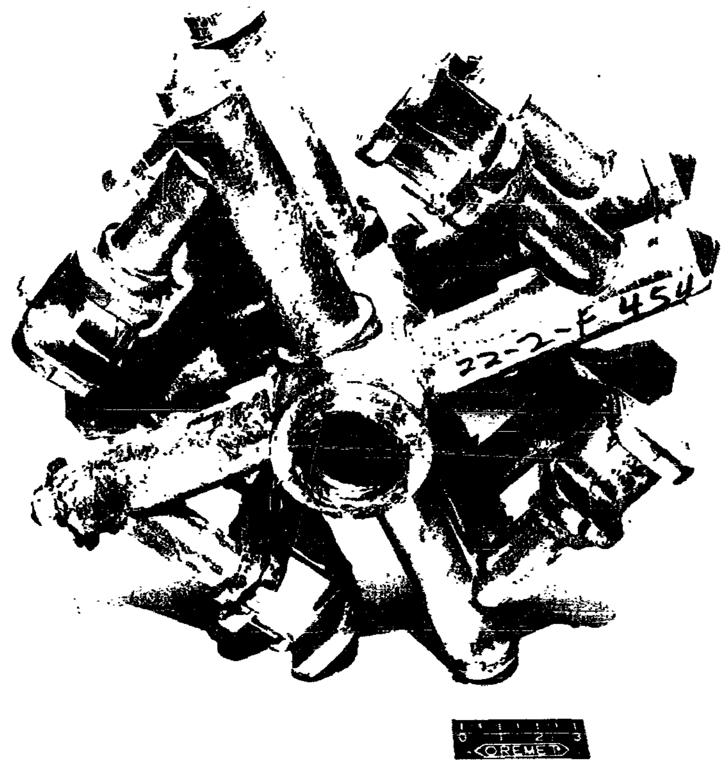
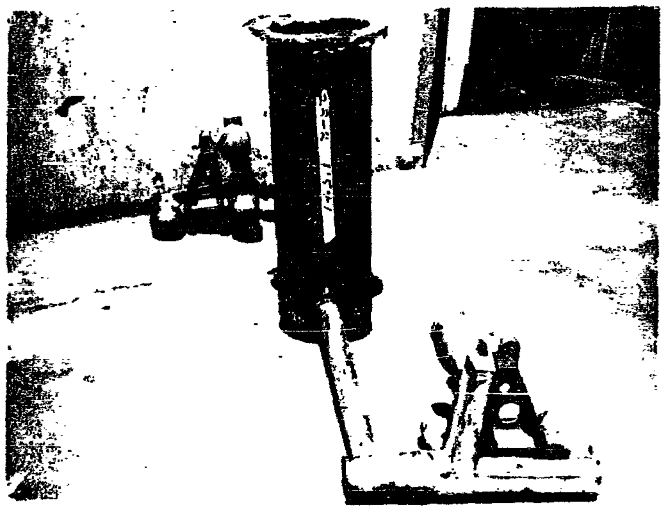


FIGURE D6



BRACKETS CENTRIFUGALLY CAST
AT 125 RPM (10G)

Rammed Graphite Mold, Shell Core

Below: Castings were X-ray Sound
Surface Showed Slight Laps

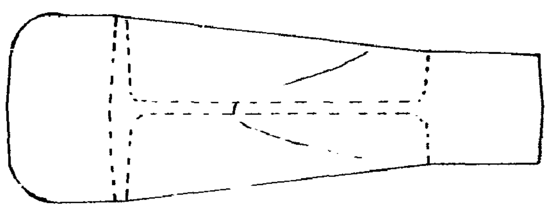
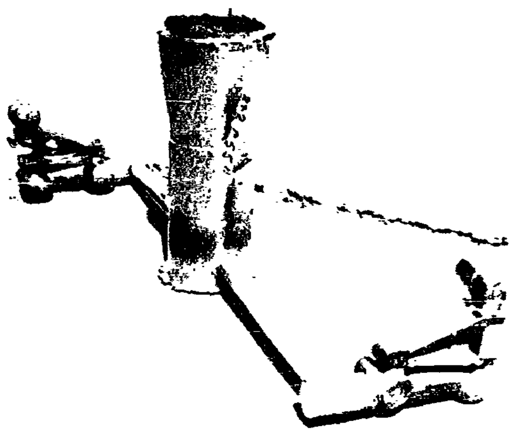


FIGURE D7



BRACKETS CENTRIFUGALLY CAST AT 125 RPM (10G)

Rammed Graphite Mold, Shell Core

Below: Castings were X-ray Sound
Surface Showed Heavy Laps

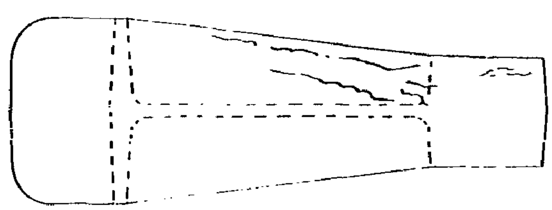
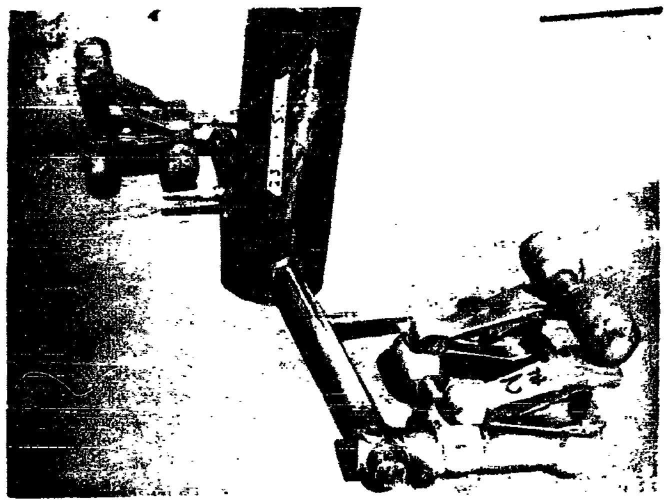


FIGURE D8



BRACKETS CENTRIFUGALLY CAST
AT 140 RPM (OUTER 126, INNER 106)

Rammed Graphite Mold, Shell Core

Below: Inner Castings Had Light Laps, Outer Had Medium Laps. Both were X-ray Sound

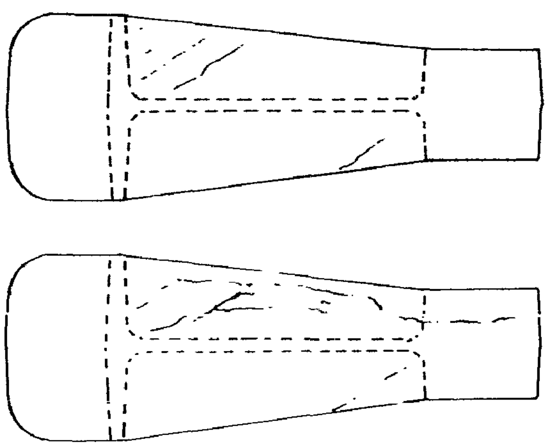
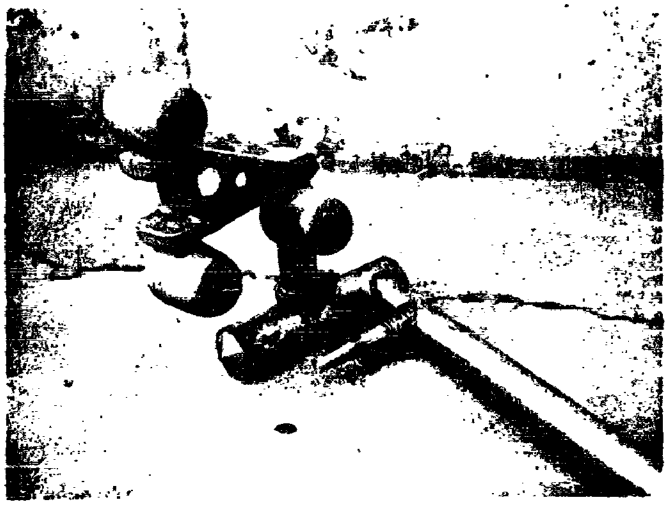


FIGURE D9



BRACKETS CENTRIFUGALLY CAST
AT 137 RPM (12G)

Rammed Graphite Mold, Shell Core

Below: Casting was X-ray Sound
Surface Had Medium Laps

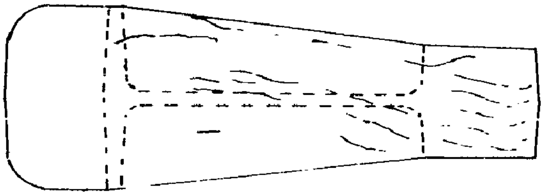
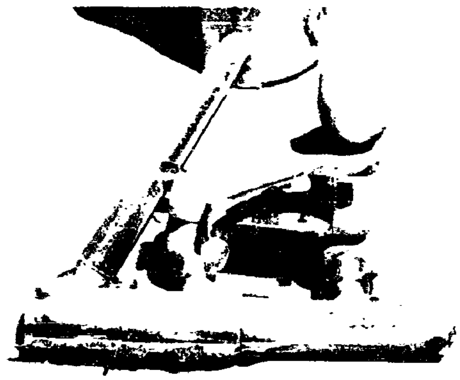


FIGURE D10



BRACKETS CENTRIFUGALLY CAST
AT 130 RPM (10G)

Rammed Graphite Mold, Shell Core

Below: Casting was X-ray Sound
Surface Had Slight Laps

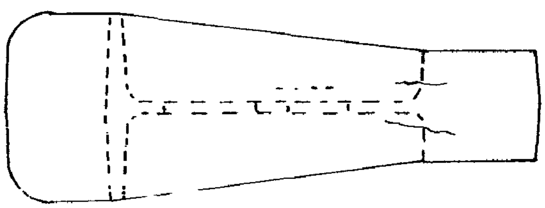
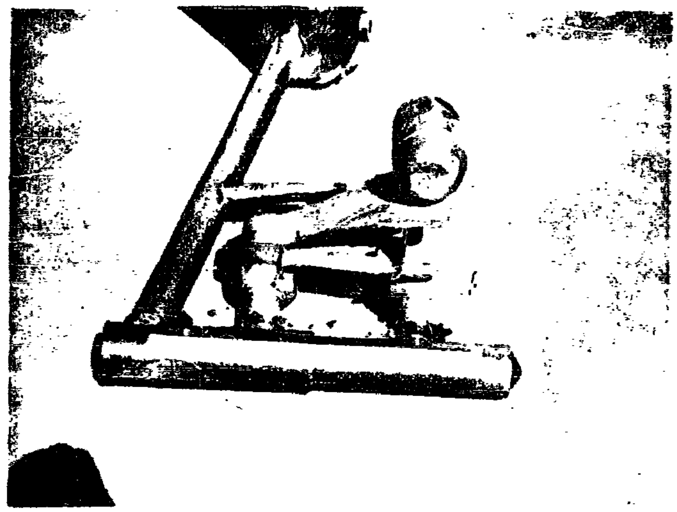


FIGURE D11



BRACKETS CENTRIFUGALLY CAST
AT 130 RPM (10G)

Rammed Graphite Mold, Shell Core

Below: Casting was X-ray Sound
Surface Had Slight Laps

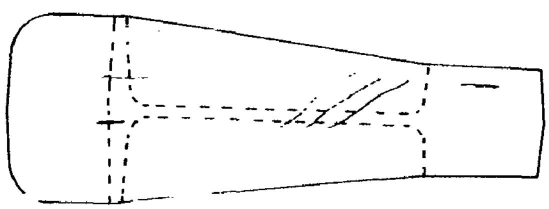
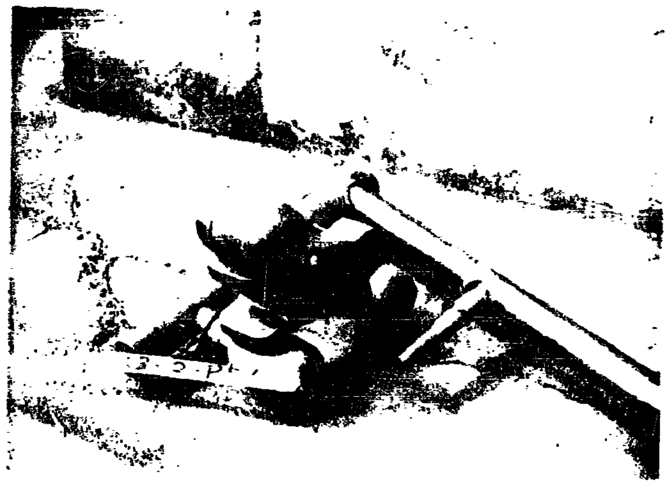


FIGURE D12



BRACKETS CENTRIFUGALLY CAST
AT 215 RPM (25G)

Rammed Graphite Mold, Shell Core

Below: Casting was X-ray Sound
Surface Had Medium Laps

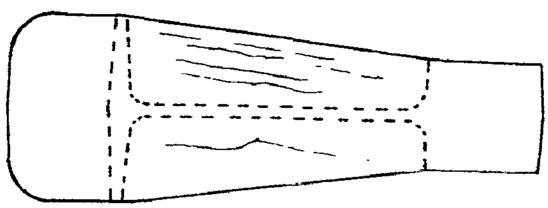
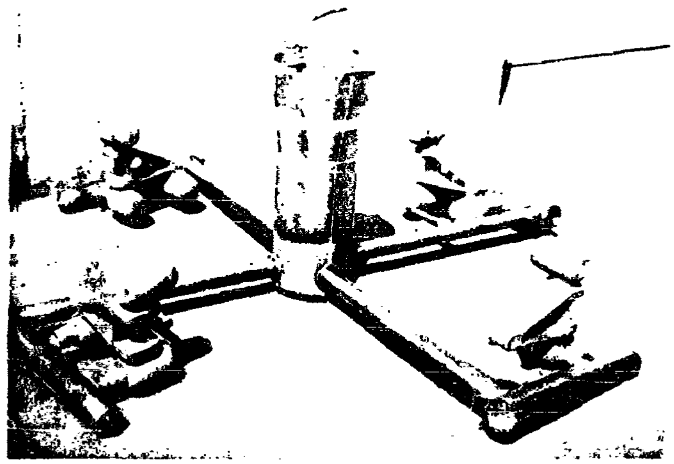


FIGURE D13



BRACKETS CENTRIFUGALLY CAST AT 135 RPM (12G)

Rammed Graphite Molds, Shell Core

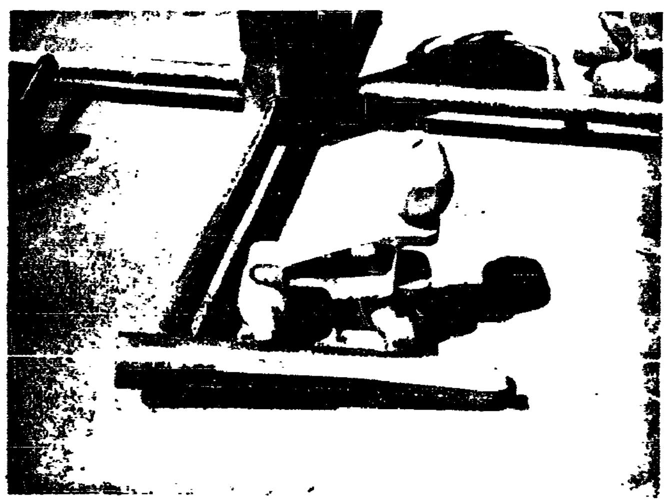
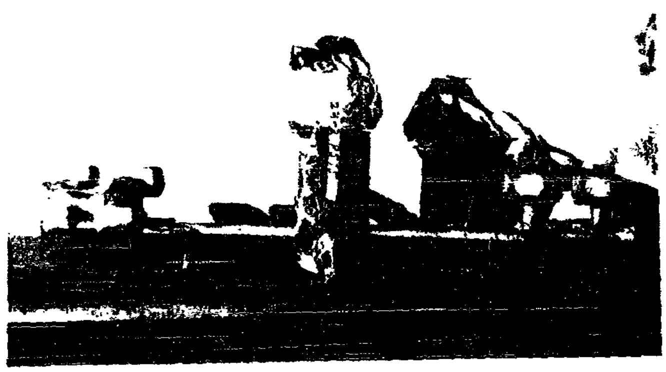


FIGURE D14

CENTRIFUGALLY CAST DEVELOPMENTAL BRACKETS

Two-Casting Arrangement



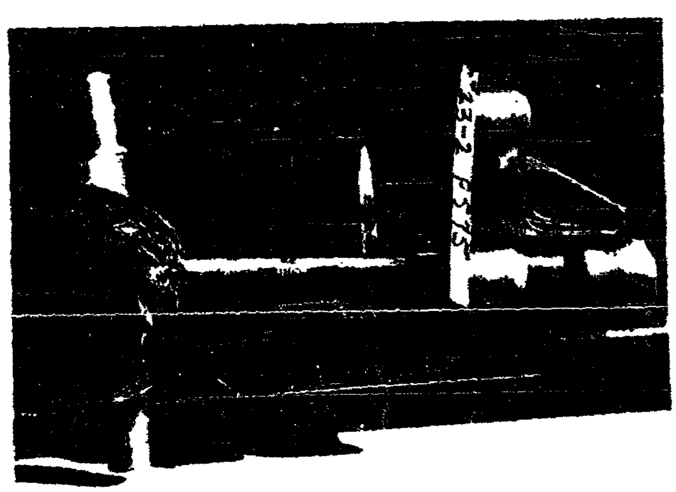
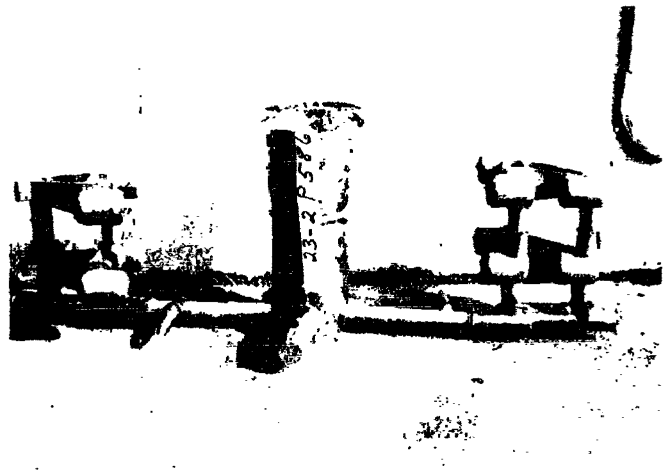
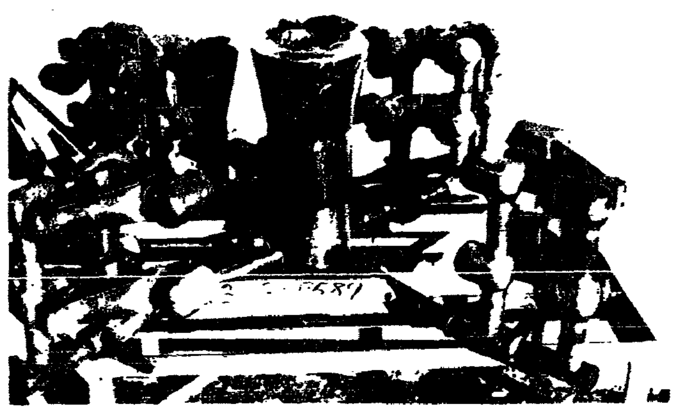


FIGURE D15

CENTRIFUGALLY CAST DEVELOPMENTAL BRACKETS



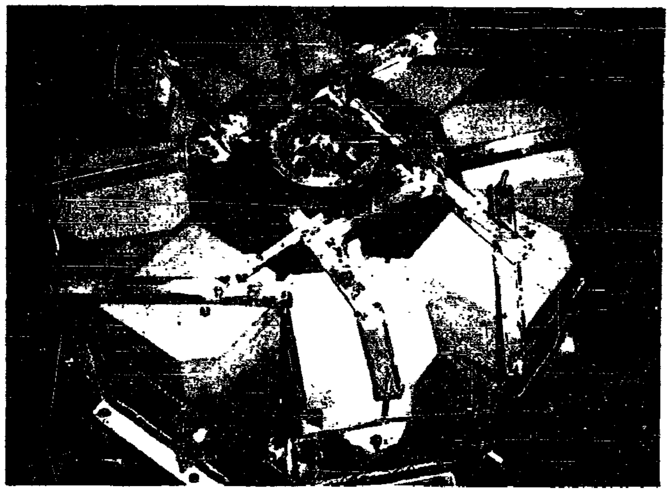
Four-Casting Arrangement



Eight-Casting Arrangement

FIGURE D16

SIXTEEN-MOLD CENTRIFUGAL SET UP
FOR DEVELOPMENTAL BRACKET



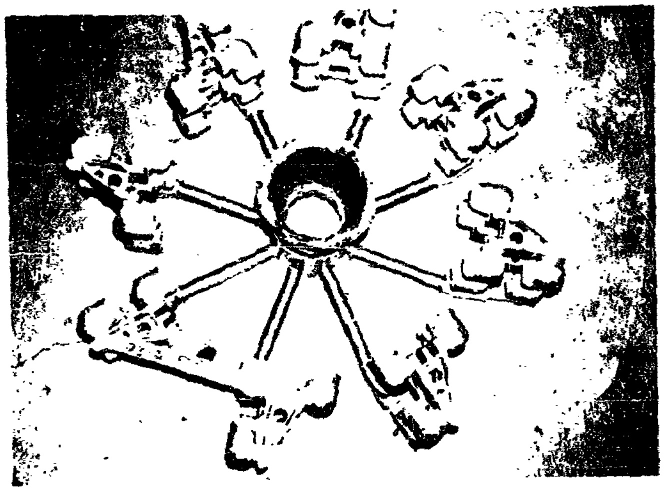
Before Pour

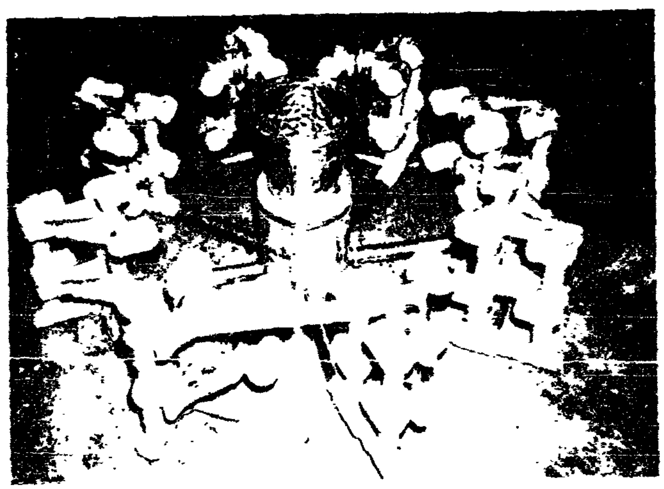
After Pour

FIGURE D17

CENTRIFUGALLY CAST DEVELOPMENTAL BRACKETS

Sixteen-Casting Arrangement





method of feeding the upper riser. An analysis of the gating system showed that a large volume of metal was being fed through a thin web to the riser, from where it was subsequently fed back to the casting. This situation caused improper thermal gradients to be set up across the riser and casting.

The gating system for this part was then revised to allow metal to flow to the mold cavity through each of the three risers as shown in Figure D6. The surfaces of castings made with this system were found tobe free of visible laps, and x-rays showed them to be sound. This mold arrangement was used to produce the pilot production lot of 50 castings.

To obtain the production lot of 50 parts, it was necessary to cast five heats, a total of 80 castings. The rejection rate was approximately 33 per cent, of which half the rejections were because of surface defects and the remainder because of internal (radiographic) defects. The foundry yield (acceptable casting weight/weight of poured metal) was in the order of 14 per cent.

Of the castings shipped, none were entirely within the dimensional tolerances established as targets early in the program or within the tolerances later established as representative of this process, mostly because of pattern errors which were not corrected before beginning the production phase. All of the shipped castings were x-ray acceptable. The ranges of deviation from average of several specific dimensions on the 50 production phase parts was determined and is discussed in the section of this report dealing with development of specifications. Representative tolerances were statistically developed from these data.

Casting of The Flap Track Link

A sketch and drawing of this component are shown in Figures D18 and D19. Initial design of this casting included a cored hole through the cylindrical portion, but this requirement was removed in favor of machining the bore when it did not core satisfactorily.

FIGURE D18

FLAP TRACK SUPPORT LINK

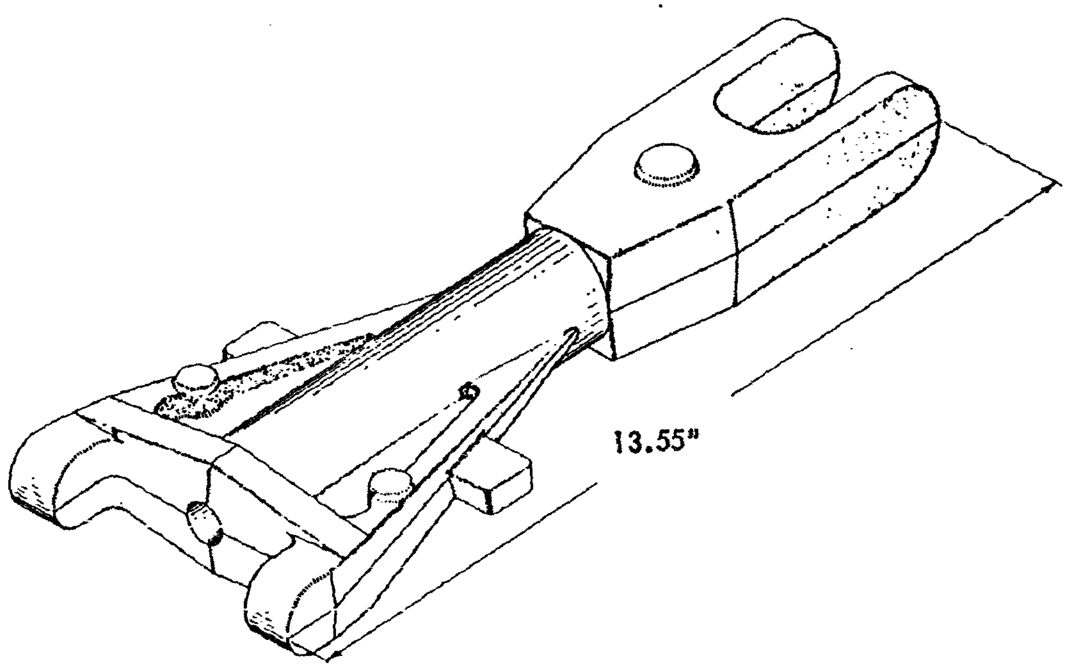


FIGURE D19

FLAP TRACK SUPPORT LINK

The initial castings were made in rammed graphite molds with rammed and with machined graphite cores. The first results obtained were considered generally good. The tool hold-down lugs (along the flanges reinforcing the tubular section) represent isolated thermal centers that caused shrinkage voids. Other isolated shrinkage areas are located at the junction of the tubular portion and the transverse flange at the wide end of the part. A photograph of the first casting made is shown as Figure D20. The gating and risering setup is shown as Figure D21.

Next, a shell core was used in an attempt to cast the Flap Track Link to soundness. It had been established that the use of the shell core promoted soundness by reducing the chilling effect and extending feeding distance. The web areas at the large end of the link presented a borderline shrinkage problem with soundness being obtained part of the time. Some of the castings exhibited shrinkage at riser junctions, because of the difficulty of attaching properly sized risers to the casting without obscuring casting detail. Large heavy risers were added at the top of the casting at the heavy sections in an attempt to better feed the casting. The riser was necked down to tain casting detail and unfortunately the necked down portion of the riser closed off feed metal before the casting solidified.

The two tooling lugs extending from the sides of the casting were, at this time, problem areas in shrink porosity. Chilling of the tool lugs and use of shell cores promoted directional solidification to the point where the shrink void was located just inside of the casting at the riser junction. The location of the single shrink void in the middle of the tool lug is acceptable since these lugs are removed after the part has been machined, but since the location of the shrink void was partially in the casting when shell cores were used, an attempt was made to remove the shrink by supplementary gating from the riser located in close proximity to the tool lug.

Experimental castings were next made without coring. This method permitted the shrinkage to concentrate along the centerline areas where it is removed by machining the center of the tubular section. Castings of the link were made while varying the position of the mold. Most of the variations in positioning resulted in very poor surface finish due to cold laps being formed by metal impinging on the sides of the mold cavity.

Figure D22A illustrates the shrinkage in the Flap Track Link cast in a rammed graphite mold with rammed core at the small end and a machined graphite core through the center bore. Six thermal areas are represented by the six localized shrink areas shown at the relatively isolated heavy sections. Slight dispersed shrinkage occurred in the thin triangular web area. The casting was side gated through four risers located as shown on the sketch.

The sketch of the Link in Figure D22B represents a variation to determine the effect of copper chills placed at the tool hold down lugs to remove the shrinkage areas present. The copper chills moved the shrinkage area into the casting and reduced the size of the voids slightly. The six localized shrinkage areas remained.

Figure D22C represents a Link cast in a machined graphite mold with 2-1/2-inch diameter risers attached. The only noticeable difference in casting in the machined graphite mold was the change in location of the shrinkage at the tip of the thin triangular web area into the body of the casting.

Figure D23A arrangement was cast without a core in the center section to determine the possibility of isolating shrinkage at the center of the casting. This Flap Track Link was cast in a rammed graphite mold preheated in a vacuum heating oven to 320°F. The major shrinkage areas occurred along the center line of the casting. The previous shrinkages at the tip of the triangular web shaped area and near the core at the wide end of the casting were removed. The two shrinkage areas at the tool hold-down lugs remained with some change in location toward the center of the casting. General dispersed shrinkage again occurred in the web area of the casting.

The Flap Track Link illustrated in Figure D23B had an extra riser attached [illegible] heavy section [illegible] the narrow end of the Link. The [illegible] necked down slightly at the point of junction with the casting to [illegible] "[illegible] Core" effect to permit easier removal. [illegible] all the shrinkage in that portion [illegible] back into the riser. [illegible] casting at that [illegible] in this experi[illegible] the [illegible] gradients conducive to removal of the shrink areas at the tip of the web area. Isolated shrink remained near the core at the wide end of the Link. The shrinkage areas in the tool hold down lugs also remained.

The illustration in Figure D23C is of a second experimental casting without the core through the center. Shrinkage was isolated along the center line with the exception of the tool hold down lugs and the web. Figure D24A is the same casting x-rayed after drilling through the center of the casting to remove shrinkage.

Figure D24B represents a modification of the Flap Track Link by varying the method of gating. In attempting to remove the shrinkage area in the tool lug, a slot from the riser to the tool lug was milled into a rammed mold to provide a feed channel and gate. The shrinkage area in one tool lug was absent and in the other lug it developed as an elongated center shrink in the head along the thin web section. One isolated shrinkage area still remained at the wide end of the flange. The shrinkage had been reduced to one side of the casting, possibly indicating incorrect flow of metal into the mold cavity and the setting up of higher thermal gradients on one side of the casting.

Figure D24C is an illustration of a core modification in an attempt to remove shrinkage by a larger taper towards each end of the casting where risers are located. A two piece core of shell graphite and machined graphite was used. The shrinkage was generally isolated to the tip of the triangular shaped web areas.

Figure D25A illustrates a variation in the core by machining a straight machined graphite core and using it in conjunction with a shell graphite core at the small end of the Link. The straight center core causes the shrinkage to be isolated at the tip of the thin triangular web section. The same 7/8-inch diameter center core with a slight modification as in Figure D25B eliminated shrinkage in the casting. The variation in Figure D25B reduced the concentration of metal by coring a portion of the critical area and establishing a favorable directional solidification condition. A general gas condition has prevented definite soundness conclusions to be reached.

The photograph shown in Figure D26 is of a static casting setup with gating and risering attached. Using the static casting method, the Flap Track Link can be produced with shrinkage only in areas which are subsequently machined out. The major problem in static casting, however, is the presence of dispersed gas porosity. The problem is an uncontrollable factor influencing the soundness quality of all of the statically cast parts. The sketch in Figure D26 illustrates areas where shrinkage is typical. Further experimental static casting was discontinued in favor of centrifuge casting to solve the gas porosity problem.

Next, experimental pours of this part were made in a vertical-axis centrifugal furnace. Figure D27 illustrates the setup of the part and the attached gating and risering. The mold was made using the same pattern and risering as is used for static casting. The gating arrangement was revised and repositioned to accommodate the centrifuge arrangement. A detrimental centerline shrinkage area occurs at the narrow end of the casting as shown in Figure D27. The method used to gate the casting was not satisfactory and medium surface laps occur along the surface of the part. A modification to introduce a smooth low-turbulence flow was necessary to remove the surface lap defect and produce a smooth cast surface.

Figure D28 illustrates a different experimental setup poured in the vertical-axis centrifugal furnace. The gating, risering, and mold position were modified in an attempt to arrive at a workable pouring setup. The sketch illustrates the location of resulting centerline shrinkage. The major shrinkage area occurred in an area where normal machining would not remove the defect. The risers located at the narrow end of the Link were intended to feed the area where shrinkage occurred and to feed the two flanges at that end. The thin section adjacent to the risers prevented adequate feeding of the heavier section where major shrinkage occurred. This gating system provided a low-turbulence method of pouring the casting and produced an excellent surface finish. The Link was free from porosity.

A small riser was next added to the Link at the centerline of the wide end to control shrinkage at that location. A comparison of Figures D29 and D30 will show the location of this riser and its effect on shrinkage in the area. The position of the parts shown in Figures D29 and D30 during casting was such that the casting was self risering with the exception of the wide end, which was located nearest the center sprue. The shrinkage void at the riser, shown in Figure D30 could be removed entirely by enlargement of the riser.

Further modifications in the risering and gating system for this part are shown in Figure D31. In the system shown in the lower photograph of Figure D31, the large risers at the narrow end of the Flap Track Link were modified. This modification did not provide a sufficient volume of metal to feed the narrow end, allowing shrinkage to occur. To eliminate this shrinkage, small risers were added at the narrow end of the Flap Track Link. The risers at the narrow end of the part in the top photograph of Figure D31 are unnecessarily large and contribute little to the soundness of the casting.

The method of gating the Flap Track Link at the outer extremity of the casting, as shown in Figure D31, is necessary to achieve a bottom pour with low turbulence as metal enters the mold cavity. Gate sizes are varied to cause an even flow of metal into both of the ingates.

Next, a preliminary dimensional analysis of the Flap Track Link was made. The general trend was for the parts to be oversize, indicating that the combined mold and metal shrinkage averages slightly less than 3/8 inch per foot.

The pattern equipment was modified prior to casting pilot production heats. Risers were added to the narrow end of the Link and a riser was added to the center of the wide end to reduce the large shrinkage void occurring at that point. A 1/8-inch-radius fillet was added to the edges of the pattern to provide a mold with rounded edges, thus preventing a mold crushing problem and possible graphite inclusions.

The production run set of Links was to be made in five heats of twelve castings per heat. Mishaps and rejections caused an increase to six heats. A total of 50 parts was produced. Of the 72 castings made, 50 were accepted. Seventy-five per cent of the rejections were because of mold shift during casting and incomplete filling, the remainder were rejected because of grinding errors. The overall rejection rate was 35%.

The castings were centrifugally cast twelve molds per heat. The molds were rotated at 130 RPM to obtain 10 G's on the center of the part.

X-ray quality of the accepted castings was good. Dimensional accuracy was fair but not within the specified tolerance. Tolerances are further discussed in the section on specifications.

FIGURE D20

FLAP TRACK SUPPORT CAST IN RAMMED GRAPHITE MOLD

FIGURE D21

TYPICAL GATING AND RISERING
SETUP FOR FLAP TRACK SUPPORT LINK

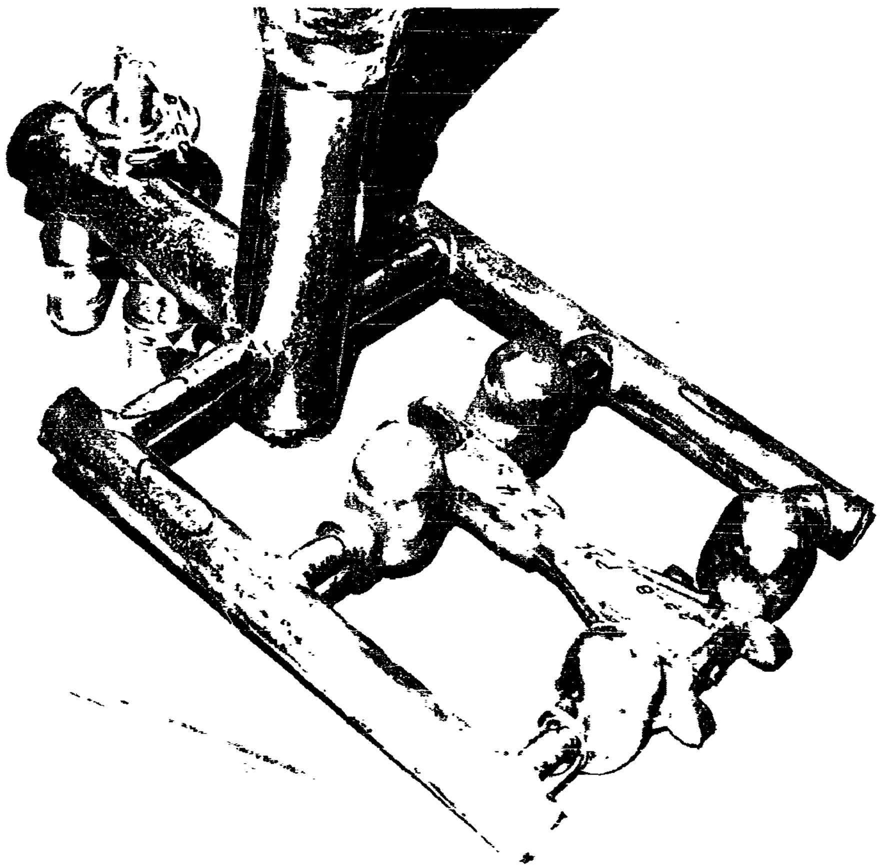


FIGURE D22

Porosity In Flap Track Link

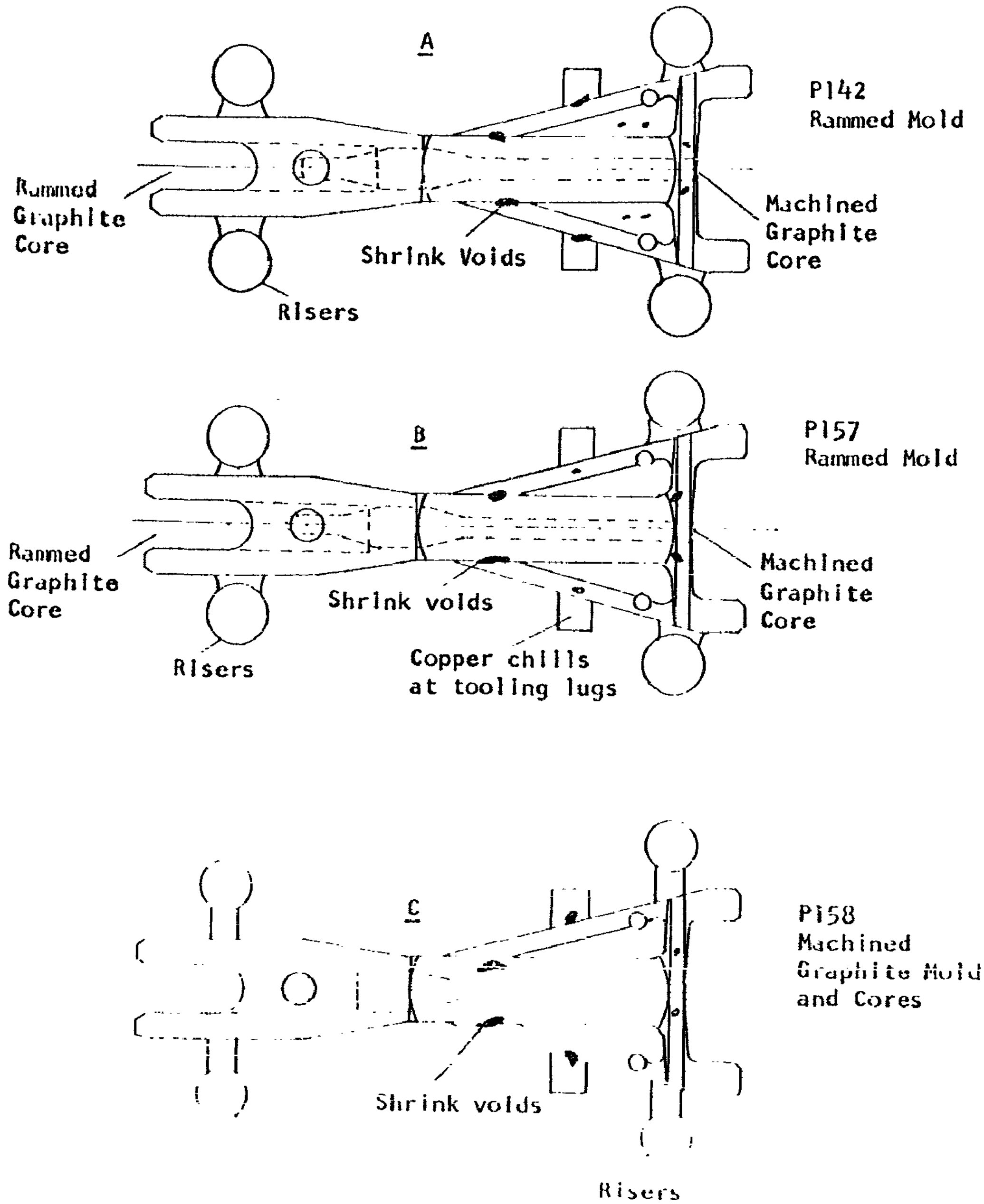


FIGURE D23

Porosity In Flap Track Link

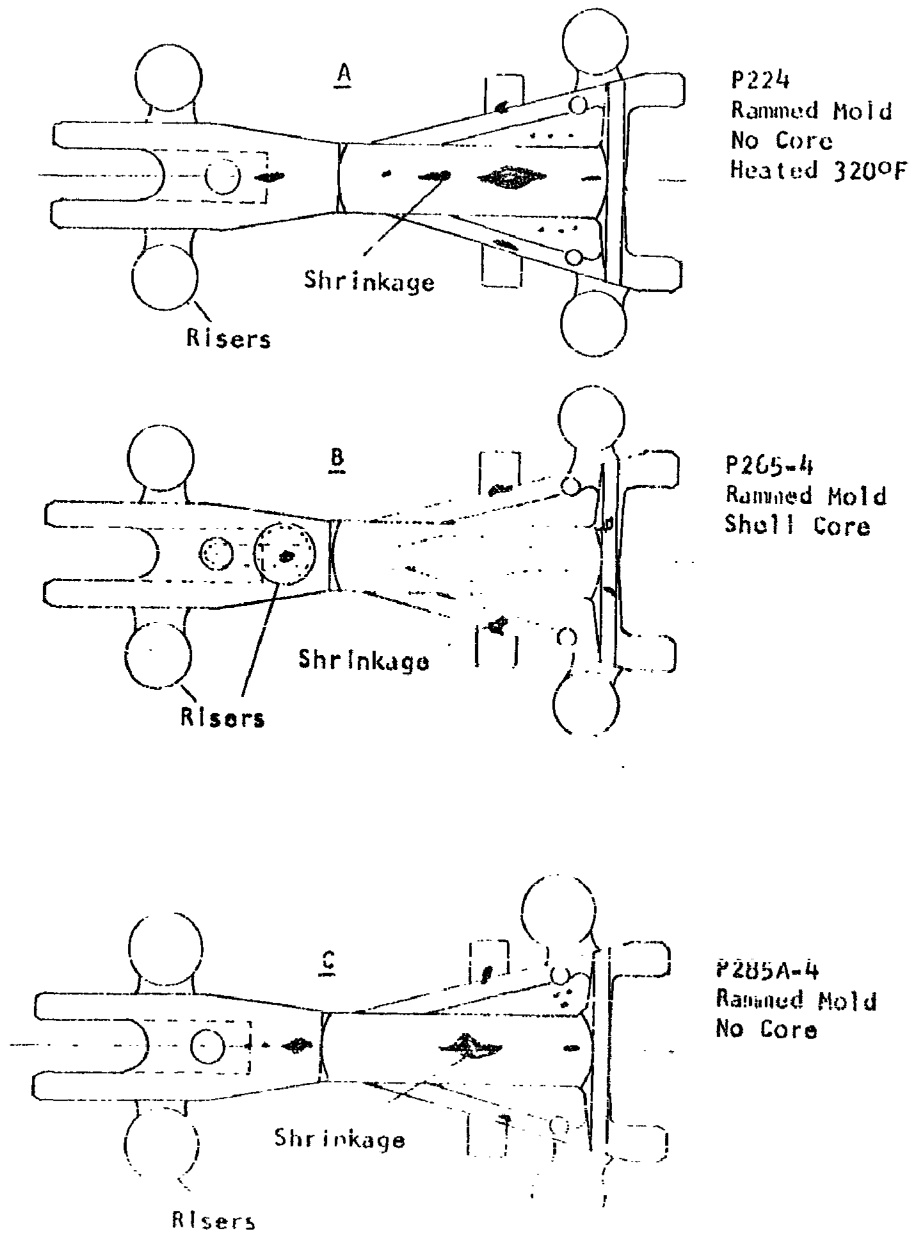


FIGURE D24

Porosity In Flap Track Link

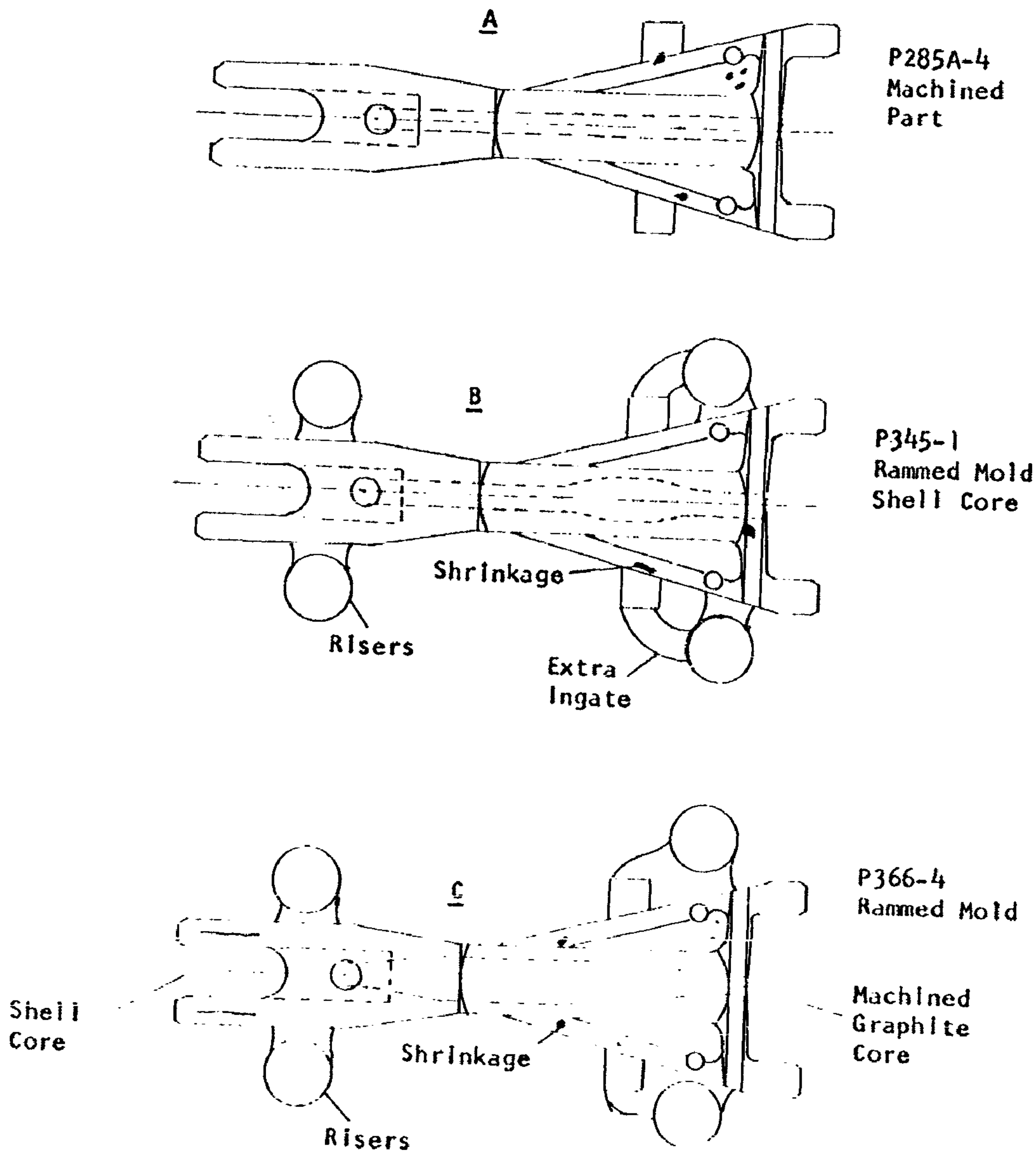
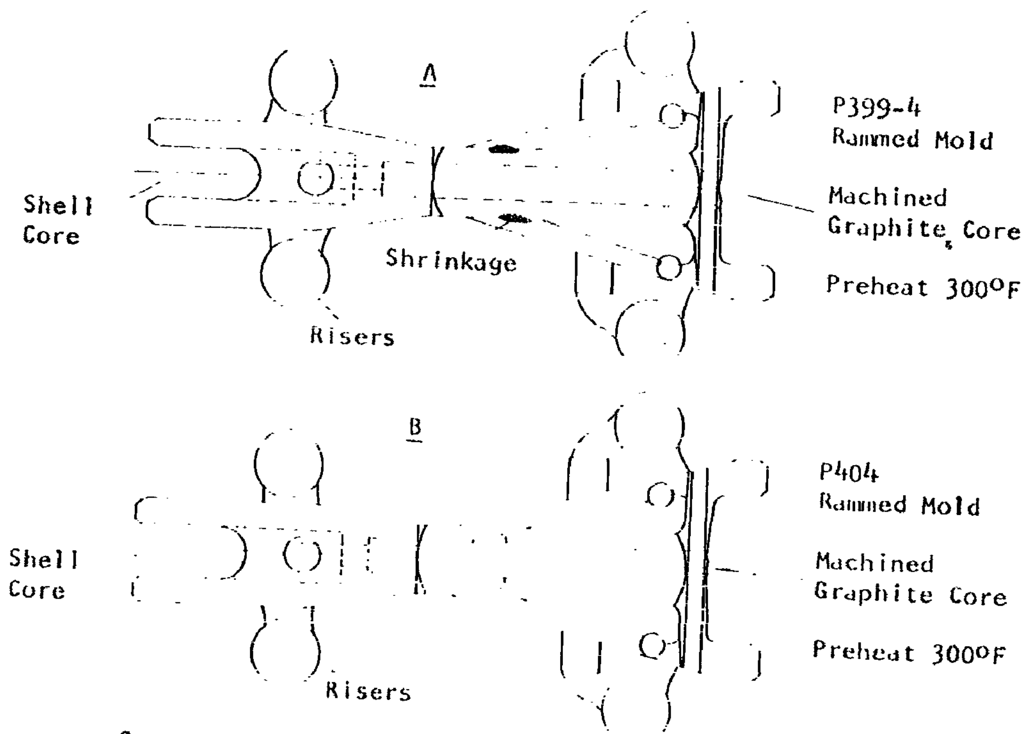


FIGURE D25

Porosity In Flap Track Link



General dispersed gas condition

FIGURE D26

FLAP TRACK LINK, STATICALLY CAST

Rammed Graphite Mold, No Core

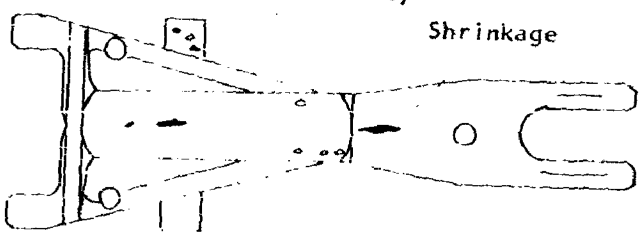
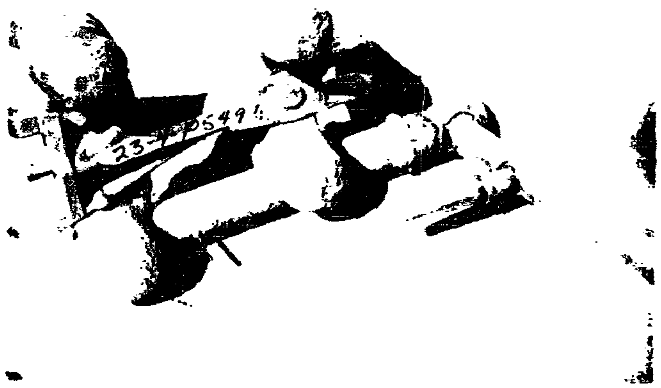


FIGURE D27



FLAP TRACK LINK CENTRIFUGALLY
CAST AT 150 RPM (10G)

Rammed Graphite Mold, No Core

Results Below

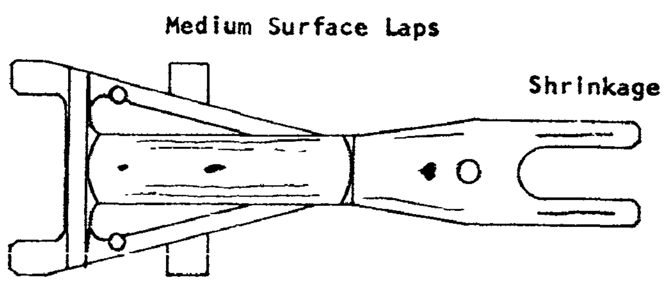
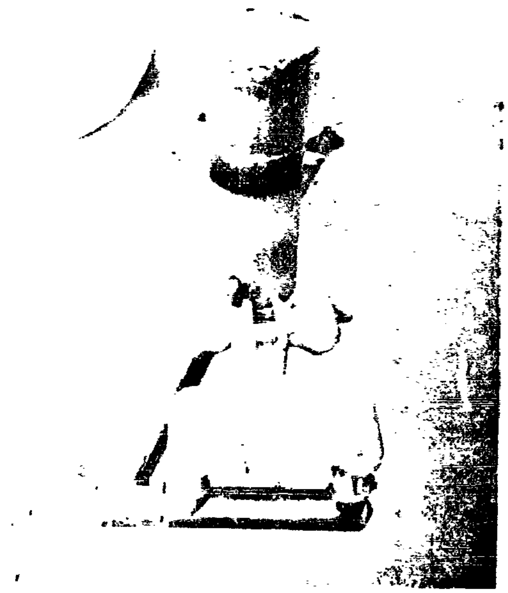


FIGURE D28



FLAP TRACK LINK CENTRIFUGALLY CAST AT 110 RPM (10G)

Rammed Graphite Mold, No Core

Results below

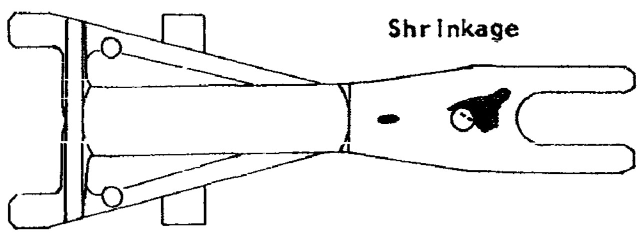


FIGURE D29

X-RAY OF FLAP TRACK LINK SHOWING
SHRINKAGE IN CYLINDRICAL SECTION

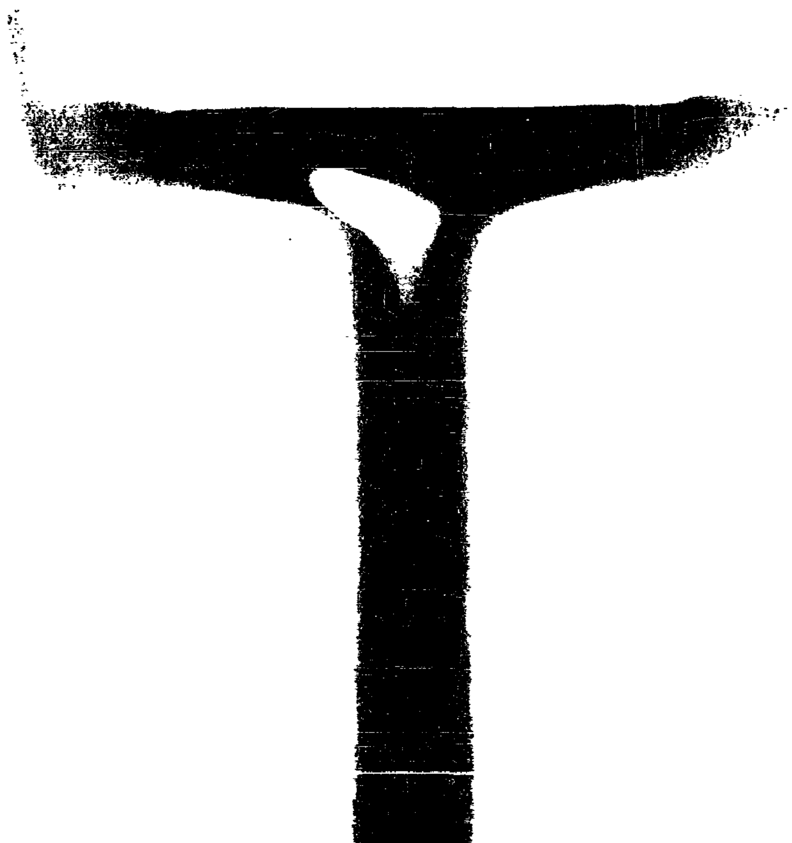
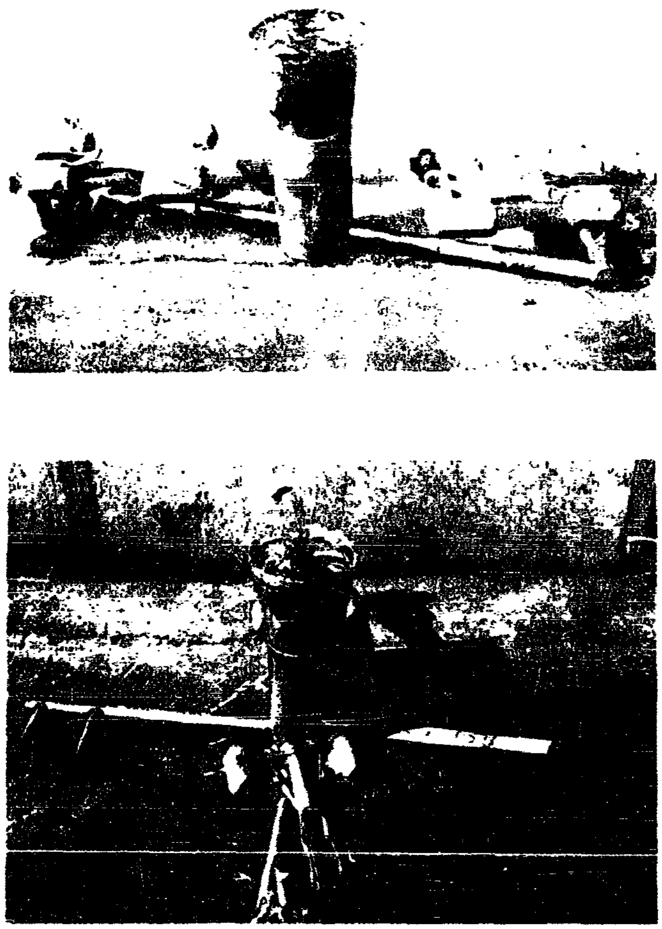


FIGURE D30

X-RAY OF FLAP TRACK LINK SHOWING
SHRINKAGE ADJACENT TO INADEQUATE RISER

FIGURE D31

CENTRIFUGALLY CAST FLAP TRACK LINKS



Casting of The Sway Brace Case

The Sway Brace Case was first cast from Ti-6Al-4V alloy in static molds of rammed graphite with rammed graphite cores. The casting was poured in the horizontal position, gating through four risers. A riser was located at each corner of the casting and connected to the casting through the lugs on one side and directly to the heavy section on the other side. Basic problems exist with this design for casting in titanium. It should be noted that minimum wall thickness throughout the cylindrical section of the part is 1/4-inch and that no difficulty was experienced in producing a smooth casting without misruns. However, as would be expected from the feeding studies, the uniformly thin center section had dispersed shrinkage porosity. As the section increased in thickness toward the ends of the casting and the riser locations, the shrinkage disappeared and the casting was sound with exception of the thermal centers adjacent to the lugs. Connection of the risers to the casting was difficult at these lug positions since an adequate connection would destroy definition of the lug outlines. Shrinkage occurred in the characteristic manner at the thermal centers behind the lugs, appearing as a single concentrated void existing at each location as shown in Figure D34B. It should be noted that the two tapered ears and the closed end of the casting were completely sound since their design produces exceptionally good directional solidification conditions.

Figure D34A shows the effect of pouring position on casting soundness. The casting was poured with the open end down. It was evident that gas was rising to the surface of the mold and being collected under the surface of the metal in all castings poured in this position. Shell cores were used for these trials. Risers were attached to the lugs extending from the parting line plane. The mold cavity was gated through each of the four riser locations. Shrinkage in the thin tube section was dispersed indicating poor feeding of the wall area. Heavy shrinkage was located at the lugs extending from the open end of the casting.

Figure D34B illustrates a casting that was poured with the open end at the top of the mold. The casting was gated through two of the four side risers with an additional four risers attached to the top of

FIGURE D32

SWAY BRACE CASE CASTING

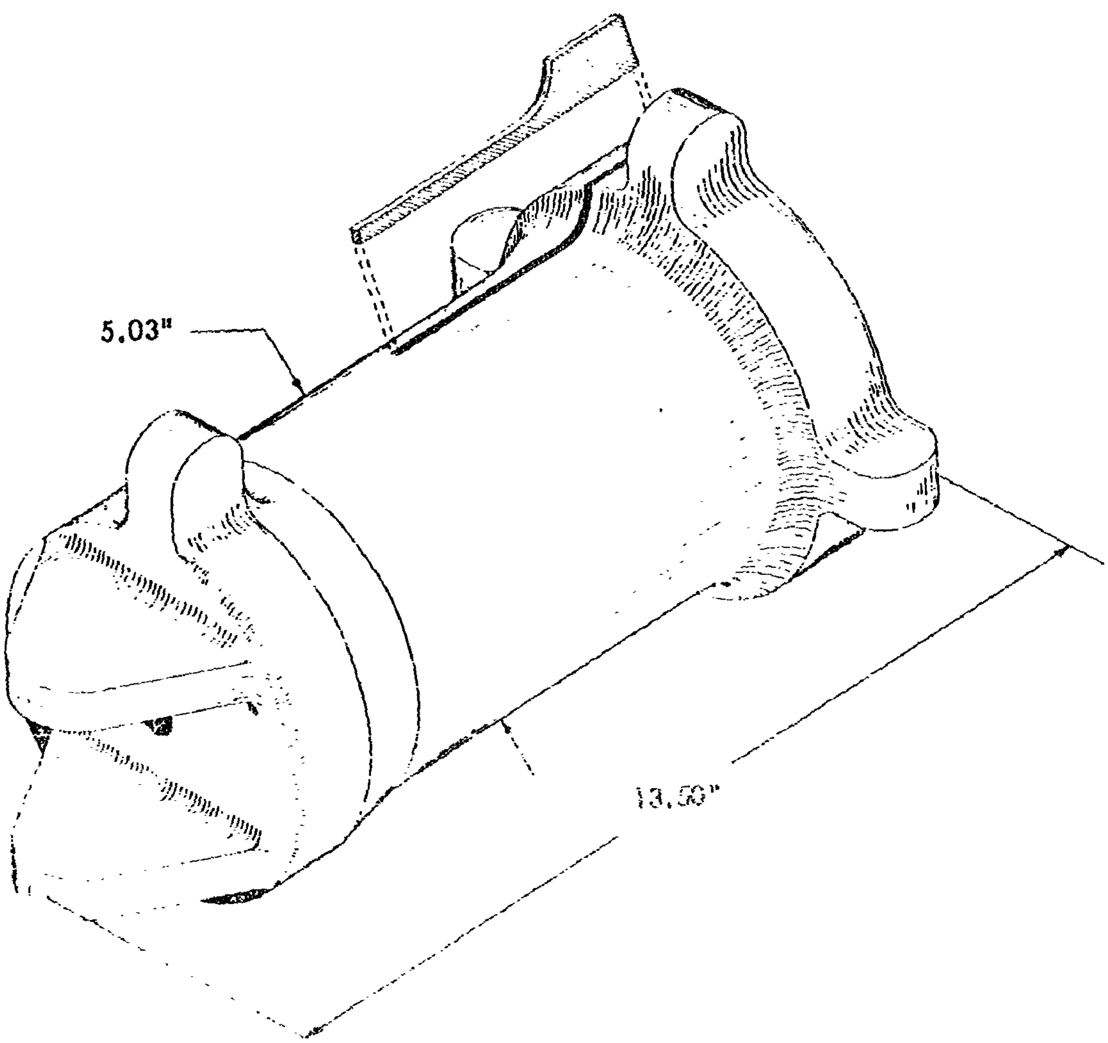
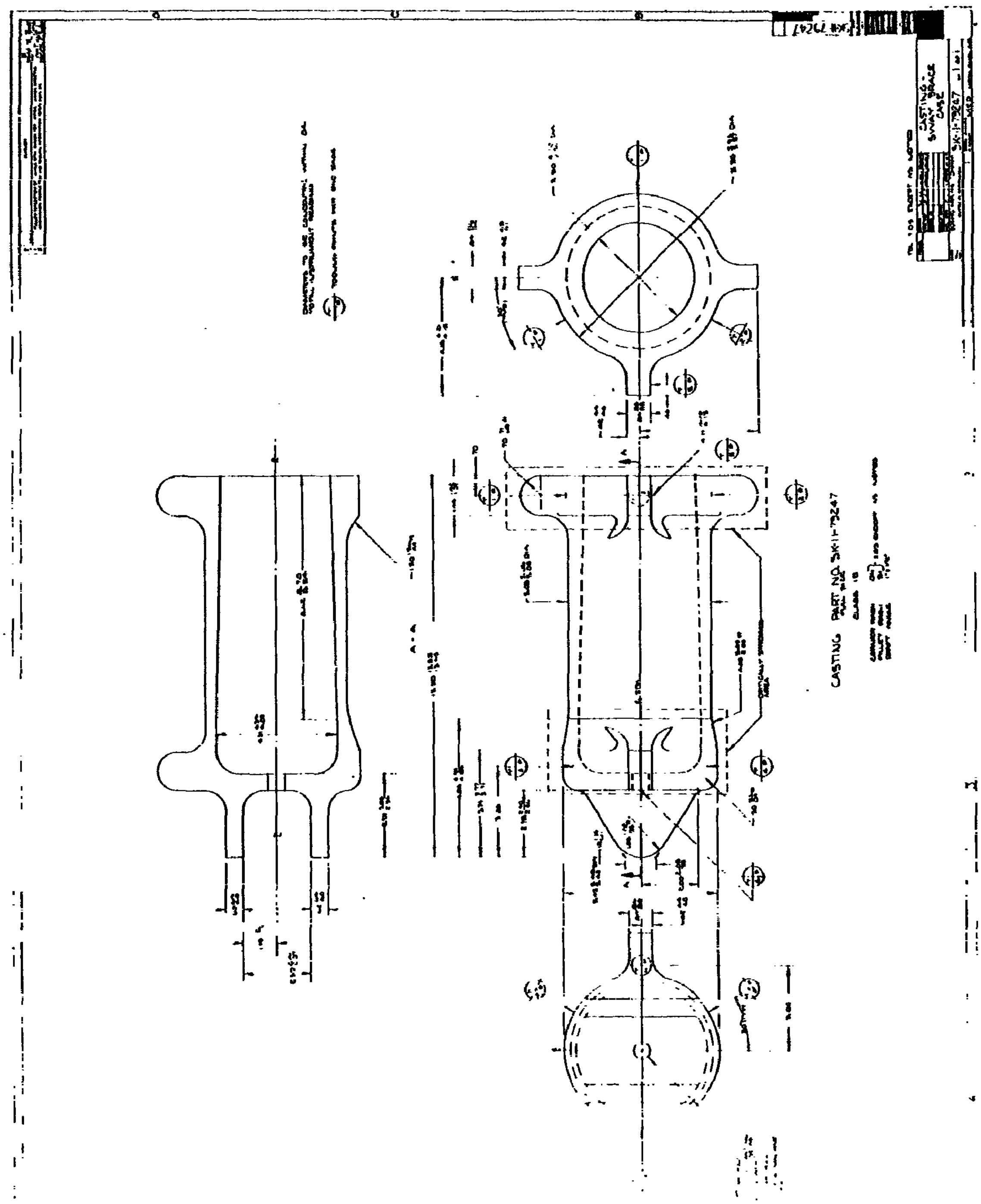


FIGURE D33

SWAY BRACE CASE CASTING



the casting. Dispersed shrinkage was still present in the tubular section. The four top risers were attached to the top of the casting in an attempt to feed the lugs extending from this area. The riser connections were not sufficient to permit the metal to feed the top of the casting.

The initial pattern revisions were decided upon the basis of the experimental casting shown in Figure D34C. In this casting a heavy shell core was tapered from one end toward the open end of the Sway Brace Case to provide a thicker wall section near the top end of the casting. The core modification increased the feeding of the top section to the tube section. Shrinkage was still evident in the heavy top end, since no provisions were made in this modification for additional feeding of the heavy section at the top of the casting.

Figure D34D illustrates the modified casting with redesign and location of risers. The top riser is a wedge shaped ring covering the entire area at the top of the casting, to provide more efficient feeding of this area. The shell core was modified to include a 5° taper, starting at approximately 2 inches from the bottom of the core. This amount of taper was believed to be more than needed to establish proper directional solidification and soundness of the tubular section. The top section of the casting did not feed properly to obtain soundness because of the greater volume of metal located at the top of the open end of the casting.

The tubular section of the casting poured in this manner did not show any shrinkage. There was some surface roughness from both the rammed graphite mold and the machined graphite core. The core was machined hollow to 1/4-inch thickness at the open end to reduce the chilling effect and clean-out problems. There were a few cold shuts in the interior of the casting due to the rapid skin chilling effect of the machined graphite core. The shell core was not satisfactory for casting the Sway Brace Case because of the large amount of metal concentration. The shell core does not have sufficient heat capacity to prevent rapid heating to high temperature and consequent wetting of the core by the metal [illegible], [illegible] severe penetration. A casting setup for a centrifuged pour [illegible] Figure D35 in which [illegible] made relatively thick (1/2-inch) to give it sufficient thermal capacity to prevent penetration by the molten metal. Breakage of the core at the support hole occurred after the casting had solidified, without damage to the casting. Movement of the shell core, if any, was very slight.

The photograph in Figure D35 is of a casting setup in which a rammed graphite core was used. The use of a rammed graphite core with a machined graphite insert at the support end of the core gave consistently good results. The major disadvantage in the rammed graphite core is that it was difficult to remove from the casting. It was necessary to chip almost the entire core free from the casting. An advantage of the rammed core over shell core was the better dimensional accuracy in the finished castings.

The Sway Brace Casting was bottom gated through two side risers attached to the closed end of the part. These two risers provided feed metal for the two end lugs and the heavy portion of the casting to which they were attached. This gating arrangement provided uniform metal flow to the top riser, which was attached to the entire open end of the part, forming a ring riser. The inner portion of the Sway Brace Case was tapered from the open end to the closed end to provide a sound wall section. With incorporation of this taper, the wall section was consistently cast with very little shrinkage or gas defects. The ring riser at the top of the part supplied metal for the wall section and the heavy portion at the open end of the part. The part as centrifugally cast was consistently sound. The production run of 16 Sway Brace Cases was completed by pouring four heats of four parts each.

The parts were cast with 12 G's force on the mold cavity by centrifuging at 140 RPM. This speed was found to be necessary to obtain proper feeding from the ring riser attached to the top of the casting. The ring riser was relatively close to the spin axis of the mold setup and did not feed properly at reduced speeds.

The rejection rate for Sway Brace Cases was 25%. The cause of rejection was insufficient metal to fill the mold cavity. Casting yield was 28 per cent. There was no difficulty encountered in the pilot production casting of this part. The incorporation of taper in the bore of the part provided adequate thermal gradients to properly feed the walls of the cylinder and heavy riserings in close proximity to thermal centers prevented shrinkage in the heavy sections.

FIGURE D34

Porosity in Sway Brace Case

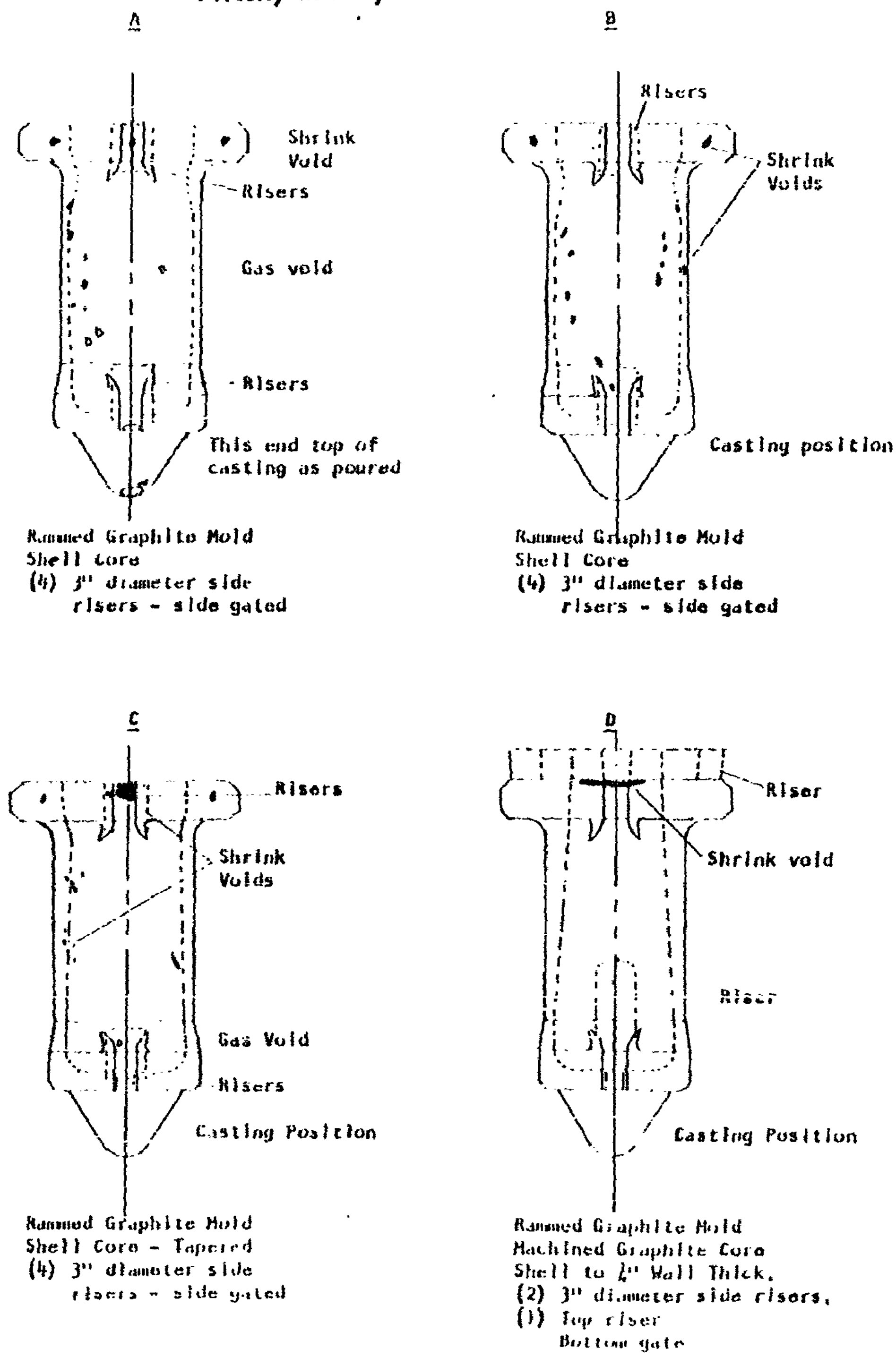
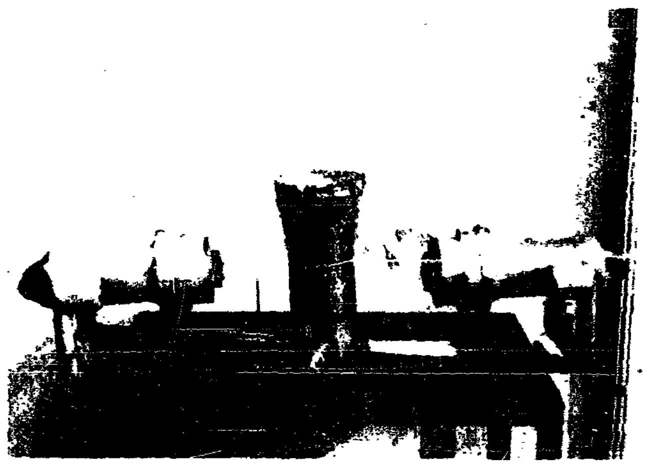


FIGURE D35

CENTRIFUGALLY CAST SWAY BRACE CASE

Rotated at 140 RPM (12 G)



Casting of the Elevator Torsion Fitting

The Elevator Torsion Fitting was first cast in machined graphite with a machined graphite core, in machined graphite with a rammed graphite core, and in rammed graphite. Machined cores produced the same cracking difficulty in the thin flat areas at each end of the casting as was experienced with the Bracket. This condition was readily corrected with the use of a rammed graphite core in the machined mold. As was expected from the result of the feeding studies, the casting evidenced shrinkage porosity in the wide thin webs at each end as shown in Figure D 38, and in the four heavy sections around the center of the part. Approximately two degrees of taper were added to the webs, thickening the casting toward the heavy center which decreased the total shrinkage but did not remove all shrinkage in that area.

The four heavy sections around the center of the Elevator Torsion Fitting presented difficulty in risering with sufficiently large riser connections, because the wall thickness of standard graphite tubing held the risers at least 1 - 1/4-inches apart, and the slight jog at the edge of the casting prevented a full-width riser connection without loss of casting detail. Characteristic shrinkage in these heavy sections is shown in Figure D 39.

Through further casting attempts, it was determined that the web section with taper to approximately 1/4-inch of the center did not have sufficient taper to promote direction solidification. In attempting to obtain sound web sections, risers were located along the edges of the channel to feed the web area. This was not successful. The thin sections required feeding to remove dispersed shrinkage, but were not thick enough that risering at the edges of the channels would provide the directional solidification required to remove the shrinkage.

The next trials in statically casting the Torsion Fitting were based on increasing the taper of the thin web section and increasing and modifying gating and risering.

FIGURE D36

ELEVATOR TORSION FITTING

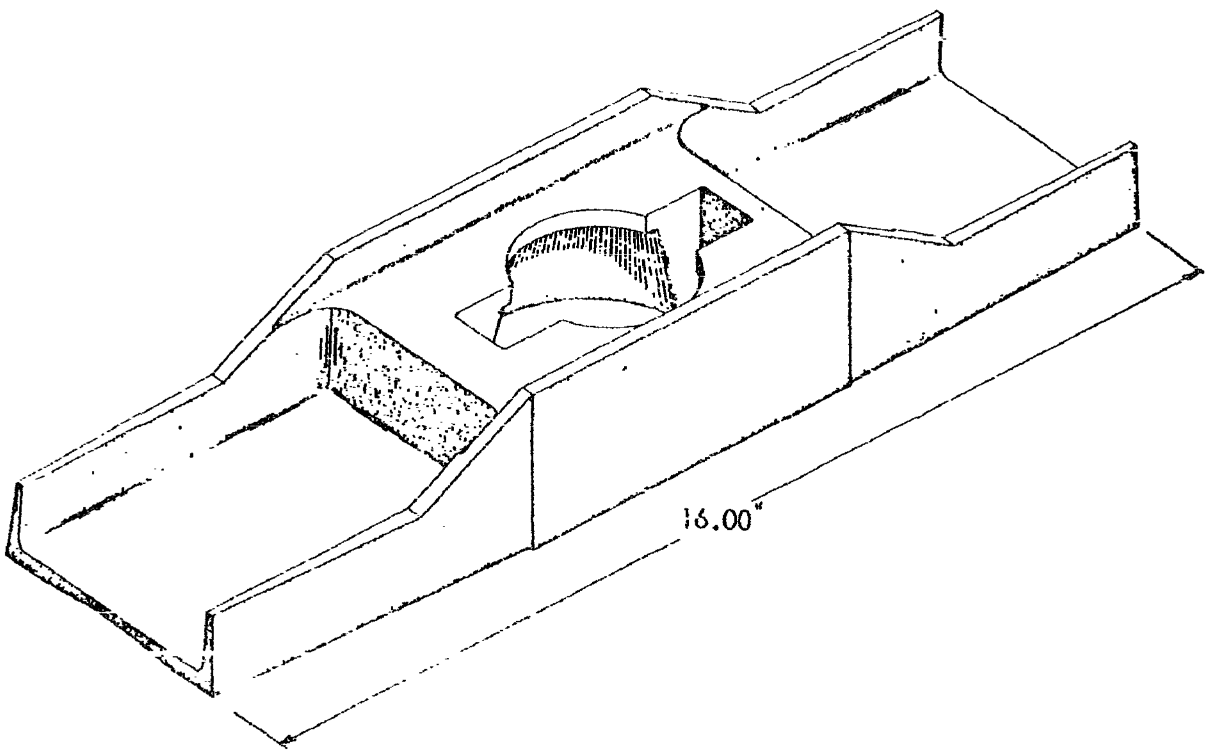
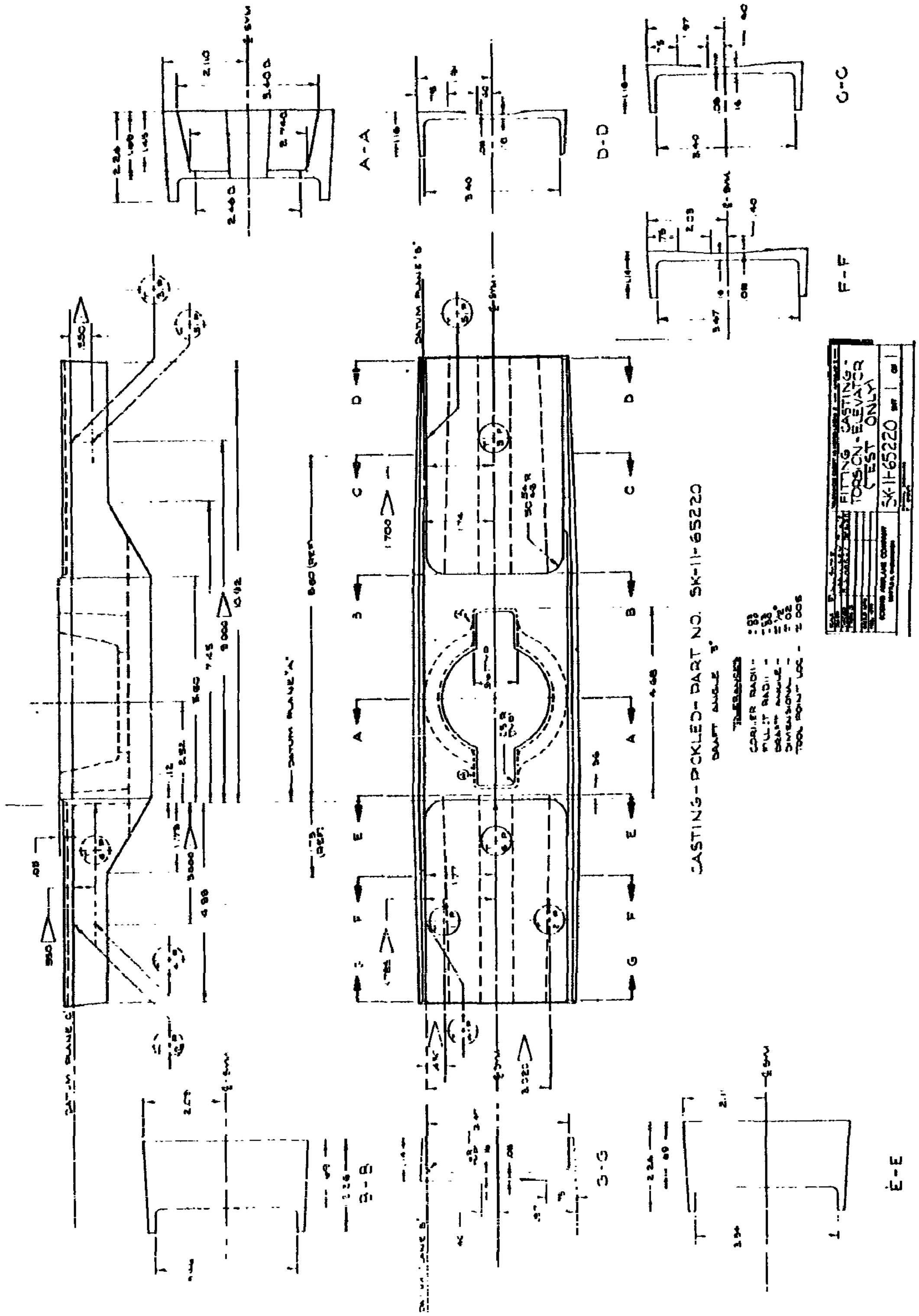


FIGURE D37



The taper added to the thin web areas was varied from 12° to 14° by tapering from the center of the webs toward the edges where a rectangular riser was attached to each side for the entire length of the web area. The 12° taper in the web area did not free the area of shrinkage. Slight dispersed shrinkage was still evident in the center of the web. The 14° taper did not show any definite shrinkage areas, but gas porosity was extensive and conclusive results were not obtained.

Figure D 40 A is the initial type of set up used in attempting to obtain a sound part by static casting. The mold was made of rammed graphite with rammed graphite cores. Risers were attached to the mold externally and fed into the casting through gates. The entire cavity was fed by runners and gates that entered through the riser locations, establishing thermal gradients toward the risers. Dispersed shrinkage occurred in the web areas in all of the static castings made with this arrangement regardless of riser size and location. Localized shrink areas occurred at the center of the heavy sections near the hole where isolated thermal areas were formed. The riser location was critical with regard to feeding this central area.

Figure D 40 B represents a casting modification with riser attached to the top of the casting and connected through a necked-type core system to facilitate removal. The actual riser connection to the casting was formed by contouring the opening to fit the shape of the areas to be fed. The modification did not provide a sound casting. The mold cavity was side gated in four places at the heavy areas. The inclusions of 12° taper from the center of the web areas reduced the degree of shrinkage but did not eliminate it.

Figure D 40 C and D 40 D castings were poured to determine if an advantage could be gained by pouring the casting upside down from its normal position. Figure D 40 C, poured in the usual position, illustrates [illegible] web areas with one [illegible]. Figure D 40 D, [illegible] section and dispersed shrinkage [illegible] to the two [illegible] [illegible]

The photograph in Figure D41 illustrates a static casting setup with side risers along the tapered web area. The web area had been revised to include a 14° taper from the center of the web to the edges in an attempt to obtain a sound casting. The addition of 14° of taper to the web section did not provide adequate thermal gradients to obtain soundness. Adding taper from the center of the web section to the edge did not successfully remove shrinkage in any of the trials conducted. The heavy rectangular riser shown located at the central portion of the casting, feeding the heavy section, did not result in a sound heavy section.

The photograph in Figure D42 is of an experimental pour made to determine the effectiveness of adding taper from the extreme ends of the web towards the center section. The taper added to the web section was parabolic, starting at 7° at the extreme ends of the casting. The tapers required to feed the section of the casting were determined from the feeding distance studies; i.e. for the first inch from the end a 7° taper is required to cast a one-inch length of 1/8-inch section thickness sound or to obtain a soundness ratio of eight. The second taper was 6° to the two-inch length and thereafter 2° to the five-inch length.

The X-ray of the casting did not reveal any dispersed shrinkage, although some gas porosity was apparent. This type of taper was more effective in increasing the feeding distance than a straight taper. Upon straight tapering 6° from the end of the casting to the heavy center section, dispersed shrinkage occurred at the outer edges of the thin web section. The parabolic taper not only increased sound feeding distance but reduced the total volume of metal required to pour the casting. As experimental casting trials progressed, experience showed a necessity for large tapers on large thin sections and less taper as section thickness increases. Several factors involved in the cooling of the metal contributed to this. The rapid chilling effect of the graphite mold causes thin sections to freeze very rapidly, and as section thickness increases heat transfer is less rapid. The problem is similar to all casting processes but is exaggerated in the case of titanium because of high melting temperatures and high thermal conductance of the mold materials.

The casting was made centrifugally in rammed graphite molds. Figure D 43A is a sketch of the first centrifuge cast part. Some dispersed shrinkage was prominent in one of the web areas while the opposite end had slight amounts of shrinkage close to the heavy center section. Isothermal areas under the ingates presented two shrinkage areas at the same end of the heavy section that contained the greatest degree of shrinkage in the web area. The part was gated at the four heavy sections at the center of the casting. The four gates were attached perpendicularly to the casting and centered sprue. The castings were in a horizontal position attached centrally about a sprue. Castings poured in this arrangement did not give satisfactory results in surface quality because of excessive turbulence as the metal enters the mold.

The sketch in Figure D 43B represents a casting centrifuged using the pour technique shown in Figure D 44. The molds were side gated and cast in the horizontal axis centrifugal casting furnace. The benefits of gating in this manner were reduced turbulence and continued pressure on the mold cavity as solidification took place. The thin web section was relatively free of general dispersed shrinkage, although gas porosity was evident in this section.

Figure D 43C is an example of a casting containing large amounts of gas porosity. This casting was made by tapering the web section to obtain a 14° taper from the center of the web toward the outside edge and the rectangular riser located to feed the web area. The gas porosity may have been intensified by machining the rammed mold and exposing the subsurface of the rammed graphite mold. The center section was free from shrinkage. The casting was side gated through the risers located at the heavy center section of the casting.

Figure D 43D illustrates the casting modified to incorporate 6° of taper from the end of the casting at the web area toward the center section. Risers were located on the top of the casting and overlapped the sides with bottom gating employed to feed the casting. Shrinkage was greatly reduced, but was still present both in the web area and at the heavy center section.

Absence of gas porosity in centrifugally cast parts was noted when molds were centrifuged at high speeds. Localized shrinkage at the heavy thermal areas in the center of the casting illustrated that sufficient metal supply was not available to feed those areas as solidification progressed.

The sketch in Figure D 45 shows the characteristic dispersed shrinkage found in the part when cast with inadequate padding and centrifuged at high speeds. The casting shown was centrifuged at 140 rpm (12 G's). It has been established through experimental heats that a higher G force will not remove this shrinkage. The ultimate removal of shrinkage such as this depends almost entirely on improved padding and risering.

The sketch in Figure D 46 shows the location of shrinkage when a 1 - 1/2-inch diameter riser has been added at the center of the web. The addition of this riser improved the soundness of the part by moving the shrinkage area to within 1/2-inch of the ends of the part. The illustration in Figure D 47 shows the location of shrinkage with a 2-inch diameter riser used. The shrinkage still remains near the ends of the web.

Risering of the center of the web section does not appear to be an effective method of obtaining a sound section. A thin web does not lend itself to feeding from a centrally located riser, as has also been shown in previous feeding distance studies on tapered plates. The present casting attempts also demonstrate that the feeding distance of a centrally located riser is not influenced greatly by centrifugal casting techniques.

Figure D 48 illustrates a further modification of the risering system. A riser of large connecting area is at the end of the web at the location of previous dispersed shrinkage. Occasional shrinkage occurred such as shown in the sketch.

Two heats were required to make the pilot production run of ten castings. Six molds were poured in each heat.

The gating and risering system was similar to that shown in Figure D 48. The molds were centrifuged to obtain 12 G's on the mold cavity, requiring centrifuge speed of 140 rpm to obtain proper casting conditions.

The rejection rate for the castings was 17%. The two casting rejections were caused by breakage of mold setup braces and consequent dislocation of molds during pouring. The yield of casting weight to poured weight was 20%.

The Torsion Fitting was the most difficult part to cast to the internal soundness levels required. The thin web section is very difficult to feed properly to establish thermal gradients required for casting sound parts. In some instances a random dispersed shrinkage was located at the extreme ends of the fittings. The 12 G force on the mold cavity has succeeded in eliminating the shrinkage occurring in most instances.

FIGURE D38

DISPERSED SHRINKAGE IN WEB SECTION -- MACHINED GRAPHITE MOLD

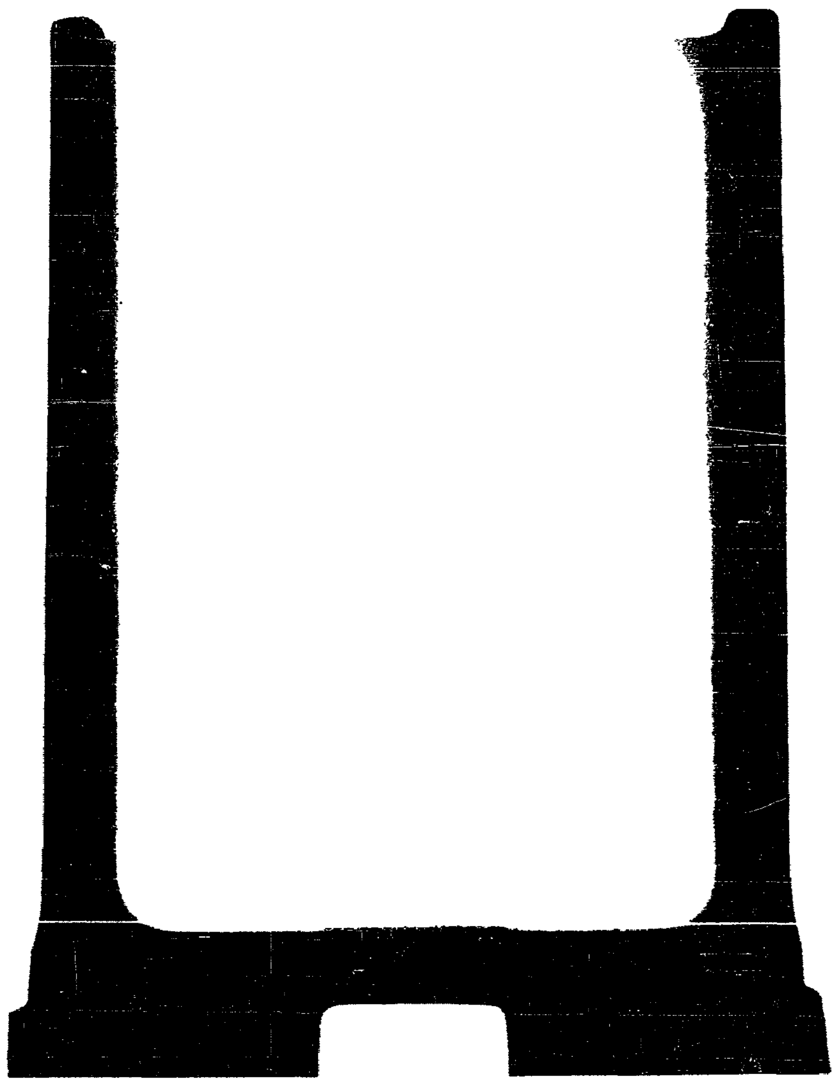


FIGURE D39

SHRINKAGE IN HEAVY SECTION

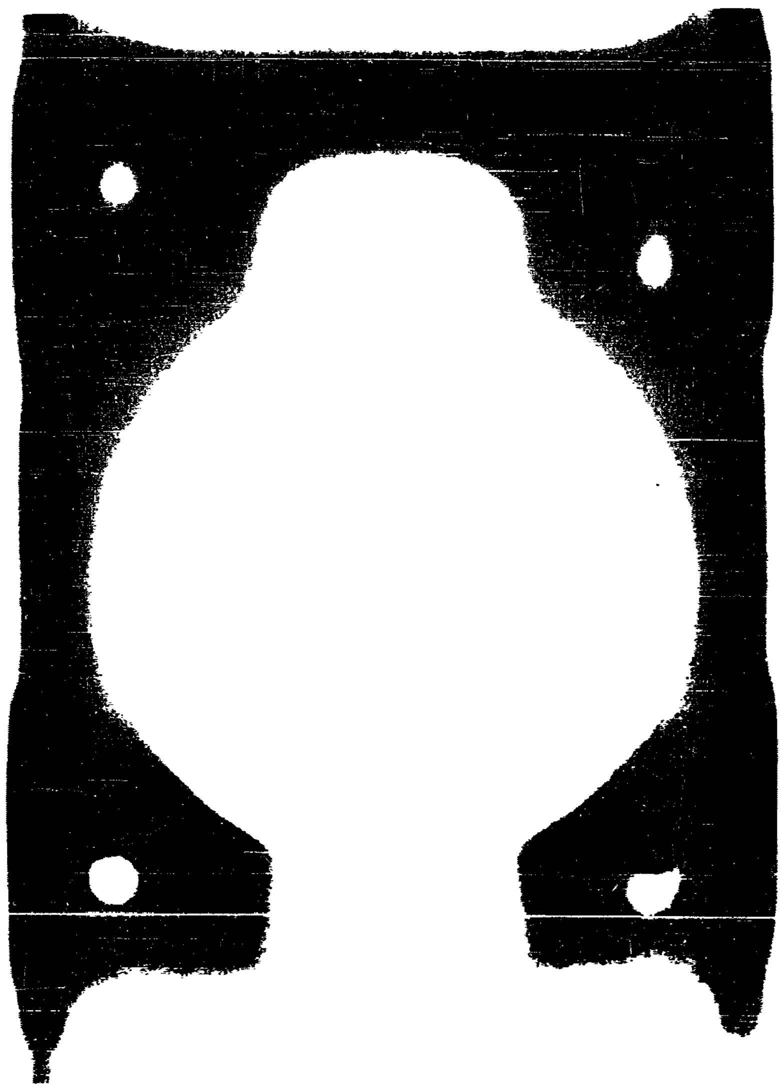


FIGURE D40

Porosity in Torsion Fitting

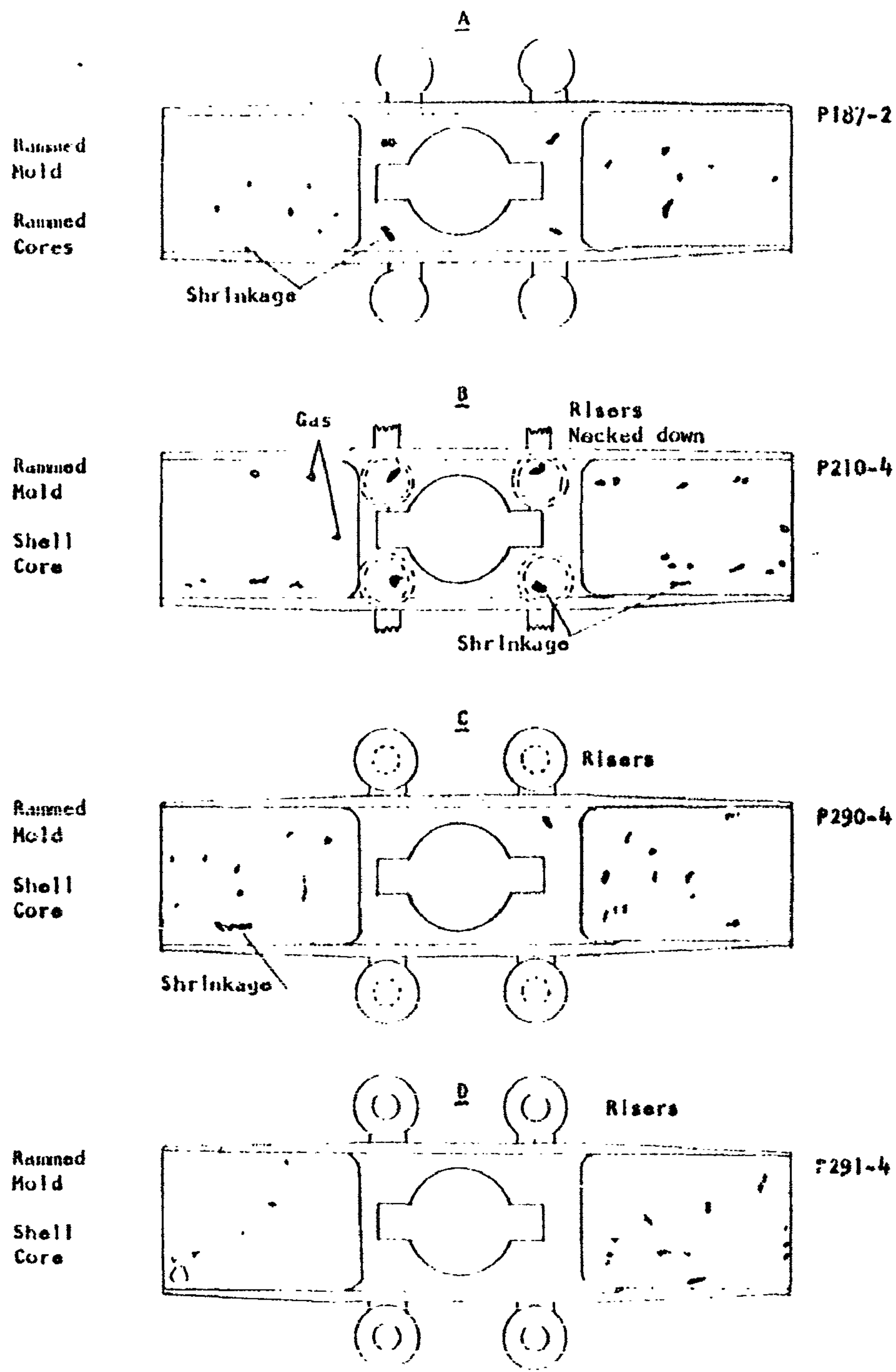


FIGURE D41

STATICALLY CAST TORSION FITTING

Rammed Graphite Mold, Shell Core

Result below

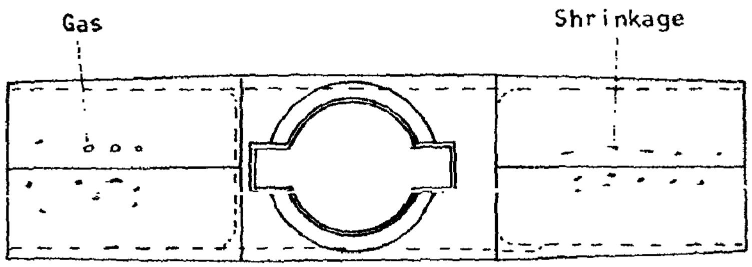
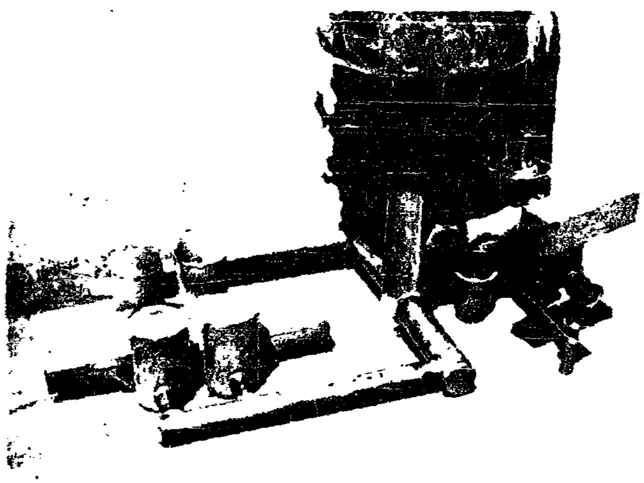


FIGURE D42



STATICALLY CAST TORSION FITTING

Rammed Graphite Mold, Shell Core

Result below

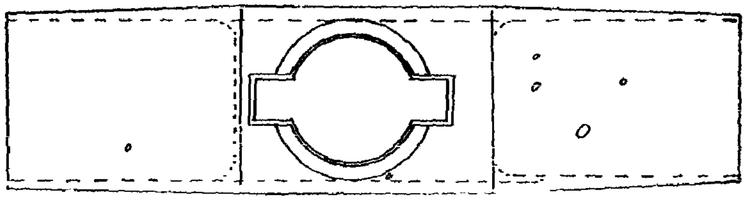


FIGURE D43

Porosity In Torsion Fitting

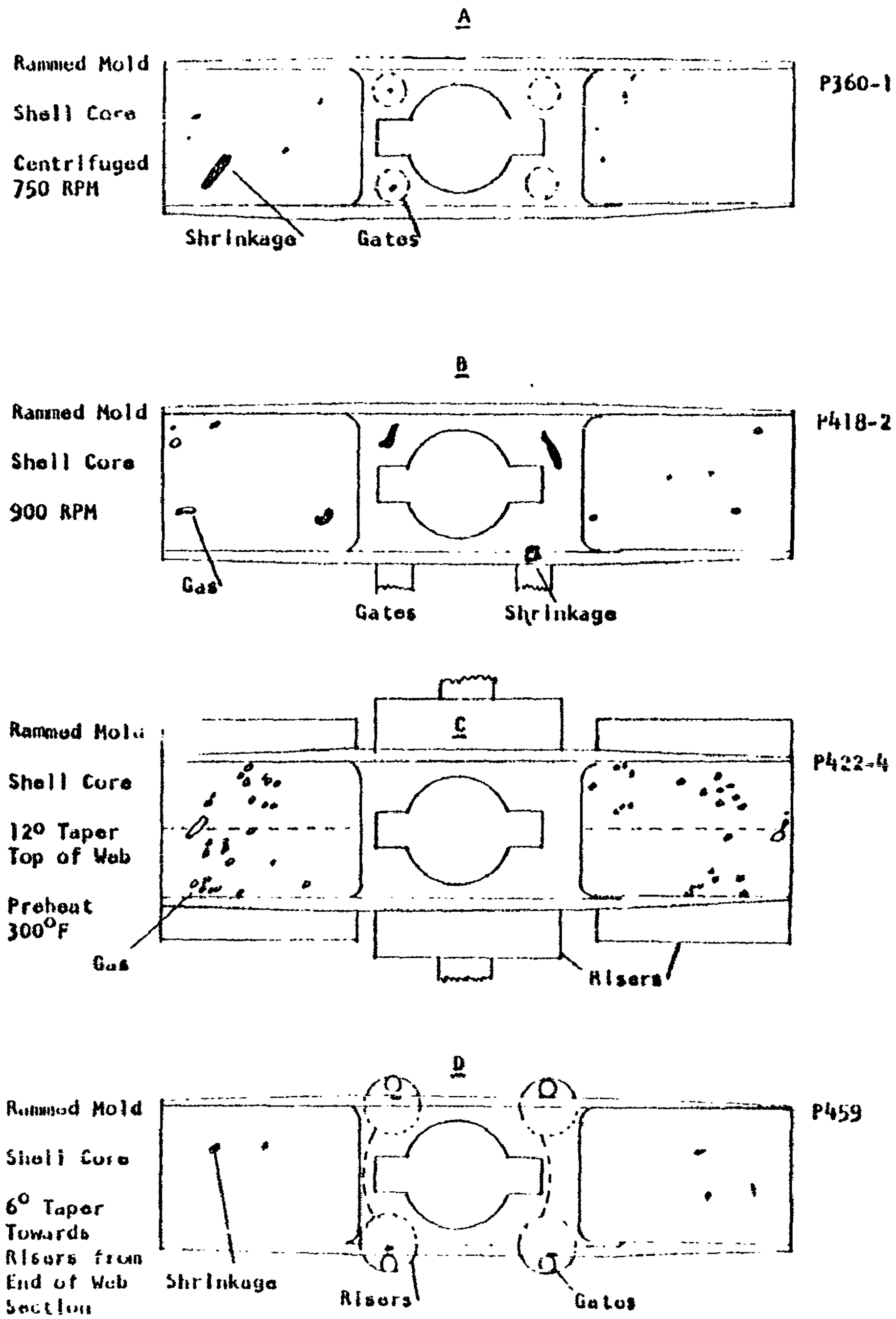


FIGURE D44

TORSION SUPPORT FITTING CENTRIFUGALLY CAST
IN RAMMED GRAPHITE MOLD

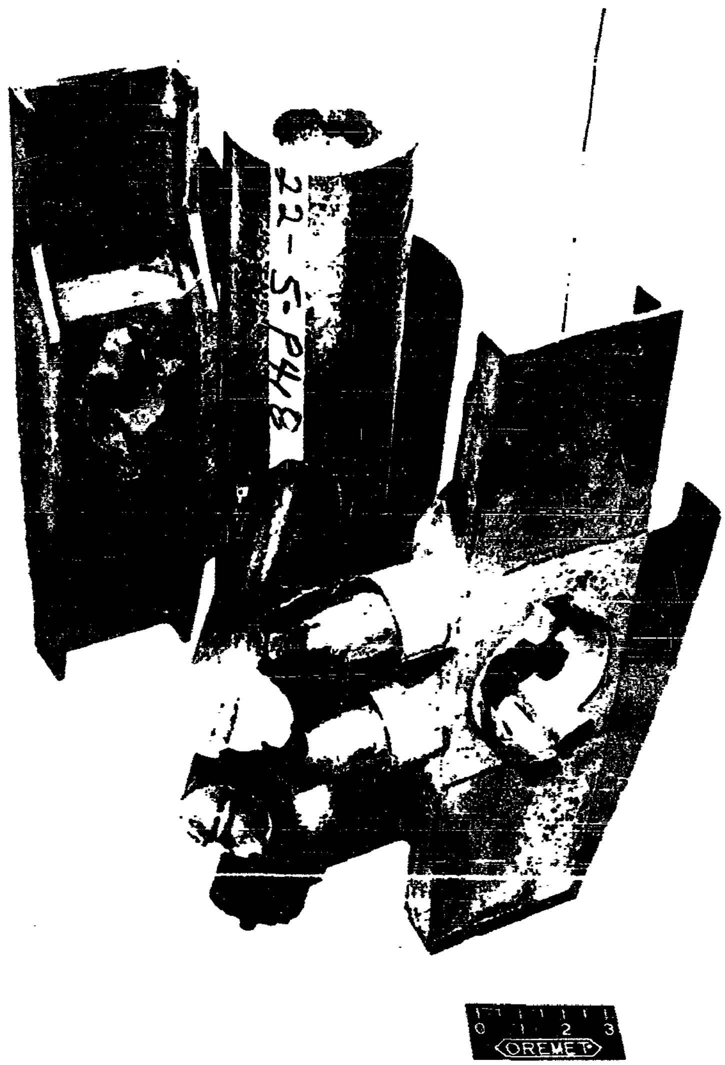
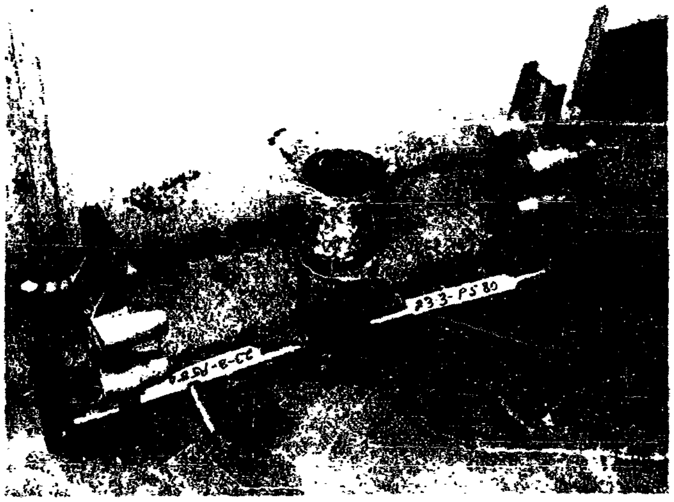


FIGURE D45

CENTRIFUGALLY CAST TORSION FITTING

Rotated at 140 RPM (12 G)



Shrinkage

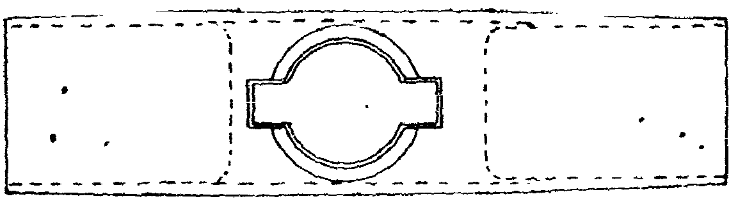
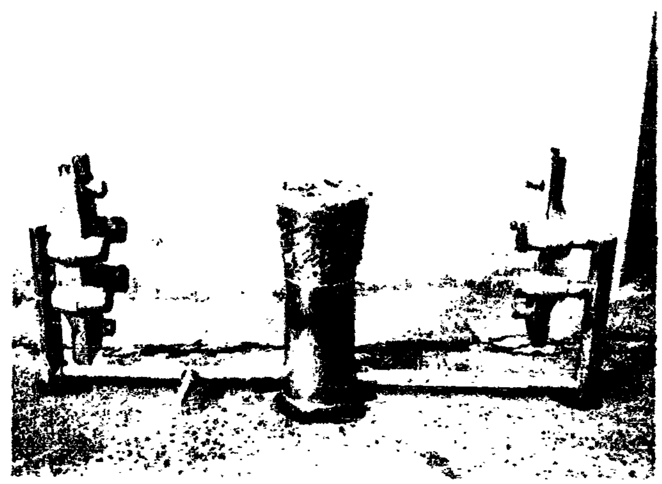


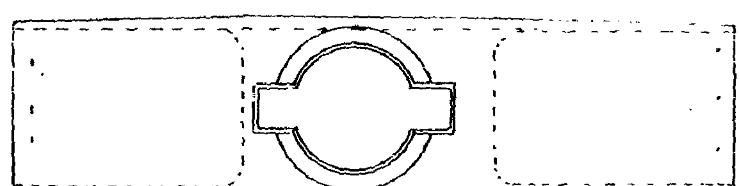
FIGURE D46

CENTRIFUGALLY CAST TORSION FITTING

Rotated at 160 RPM (15 G)



1 1/2-inch Diameter Riser Added to Centers of Webs

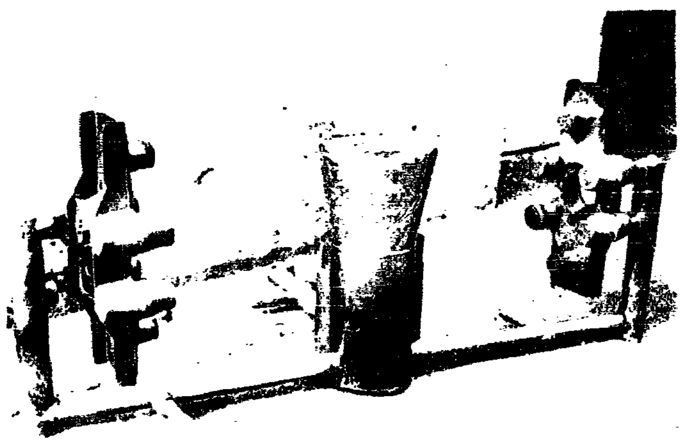


Shrinkage

FIGURE D47

CENTRIFUGALLY CAST TORSION FITTING

Rotated at 160 RPM (15 G)



2-inch Diameter Riser Added to Centers of Webs

Shrinkage

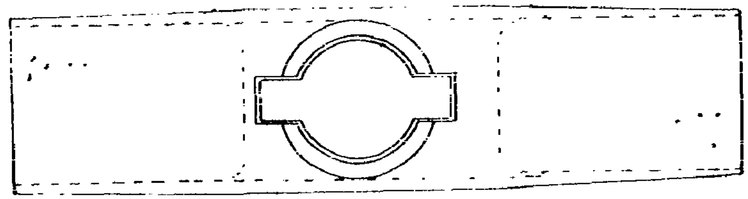
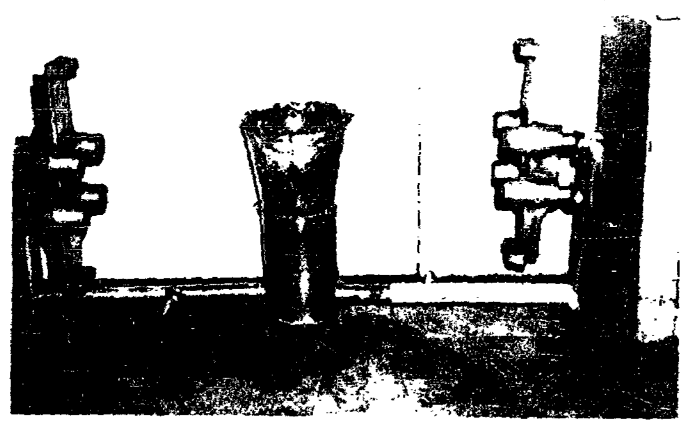
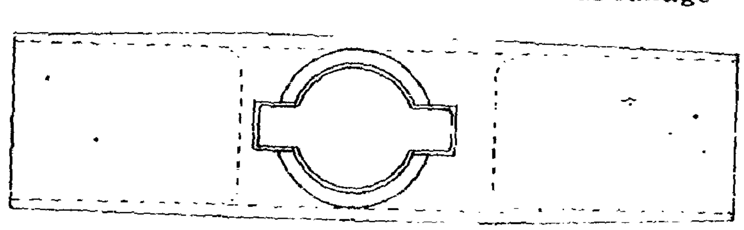


FIGURE D48

CENTRIFUGALLY CAST TORSION FITTING



Rectangular Riser Added to Ends of Webs



Casting of the Horizontal Stabilizer Fitting

The Horizontal Stabilizer Fitting was first cast statically. The mold required sixteen sections fitted together. Gating and risering was accomplished by drilling into the rammed graphite mold and by addition of graphite piping to provide the external connections.

This casting was not sound. Numerous gross shrinkage areas occurred as a result of insufficient risering. The web areas of the part contained widely dispersed shrinkage demonstrating that inadequate tapers had been incorporated in the original pattern equipment. In addition to the shrinkage problem, severe gas porosity was noted.

The photograph in Figure D50 shows the front of the casting with gates and risers attached. In this casting experiment two-thirds of the metal was theoretically to flow through the large front gate and through its interconnecting system, feeding the length of the fitting. The remaining one-third was to flow through the two smaller gates into the enclosed arm of the part, thereby preventing cold shuts and surface laps. The system succeeded in minimizing surface cold shuts, but not in entirely eliminating them. A slight misrun occurred in one of the thin webs in the bottom of the mold as shown in Figure D51 This misrun was due primarily to too much metal flow through the end ingates and not through the next inside ingate. It would be necessary to reduce the size of the runner or ingate feeding the end of the casting to provide a more desirable flow of metal.

Figure D51 illustrates the bottom of the casting and the cored out detail. Evidence of blowing is visible in the web areas of the cored sections. The cause of this irregularity was not determined.

The second attempt to cast the Horizontal Stabilizer Fitting was accomplished in the vertical axis centrifuge furnace. The part was extremely large for centrifuge casting in this furnace.

This casting also was not sound. It contained numerous shrinkage defects where risering was insufficient. There was a noticeable increase in soundness of the web areas of the angular 'U' section and the extremities of the Fitting. The center portion of the casting was absent, due to insufficient metal in the pour. The casting was gated along the trailing edges, to provide low turbulence metal flow into the mold cavity. The mold cavity was gated at several places from a main runner, and gating size changed to provide uniform filling through each of the gates. The 'U' shaped extension was also gated in three locations at the trailing edge to fill this area at approximately the same time as filling of the remainder of the mold cavity. It was expected that filling of the center portion would be difficult, and therefore a large gate was provided to feed metal to the center. Because of spilling and splashing there was insufficient metal to fill the mold cavity.

It was concluded that although sufficient development would be expected to solve the shrinkage porosity problem, the gas porosity problem could not be overcome without centrifuge casting the part. This component was too large for centrifuge casting in the furnace equipment available.

FIGURE D4

INBOARD BEARING SUPPORT RIB, HORIZONTAL STABILIZER
(as machined from forging)

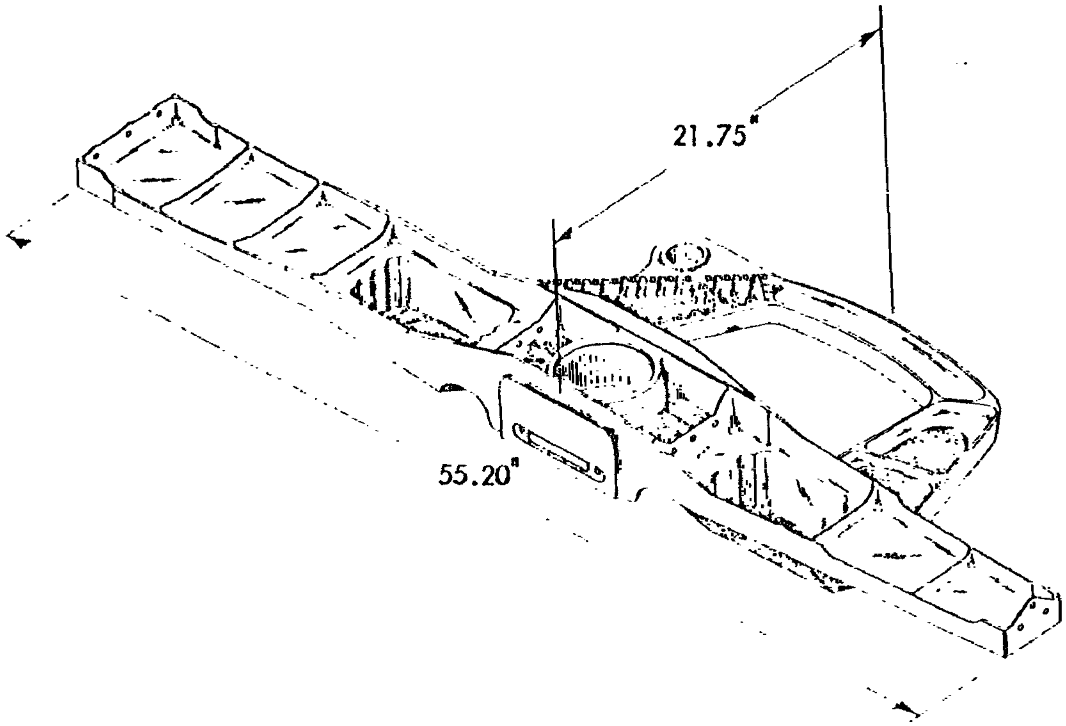


FIGURE D49A

TYPICAL SECTIONS - INBOARD BEARING SUPPORT RIB

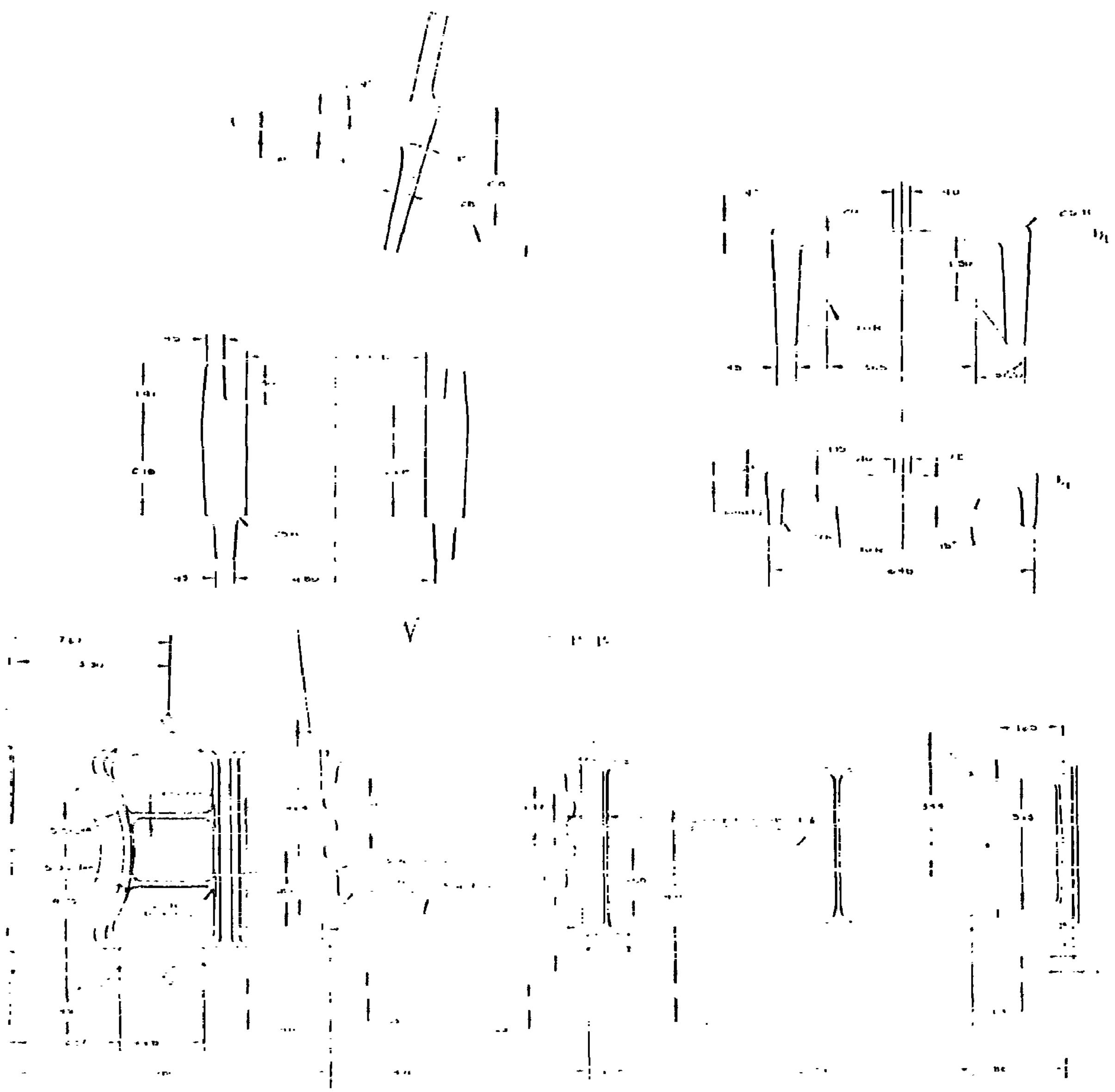


FIGURE D50

STATICALLY CAST HORIZONTAL STABILIZER FITTING

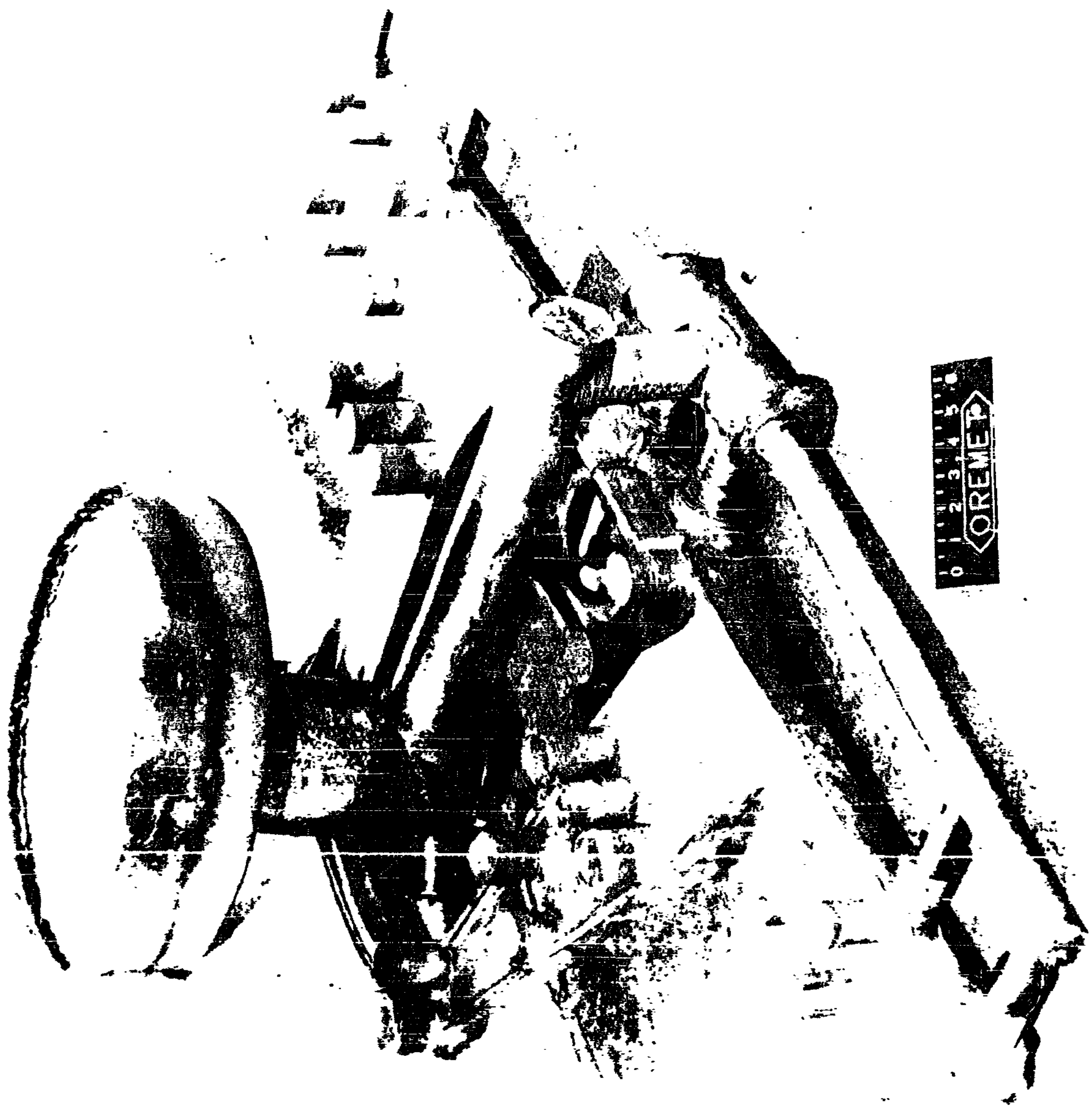
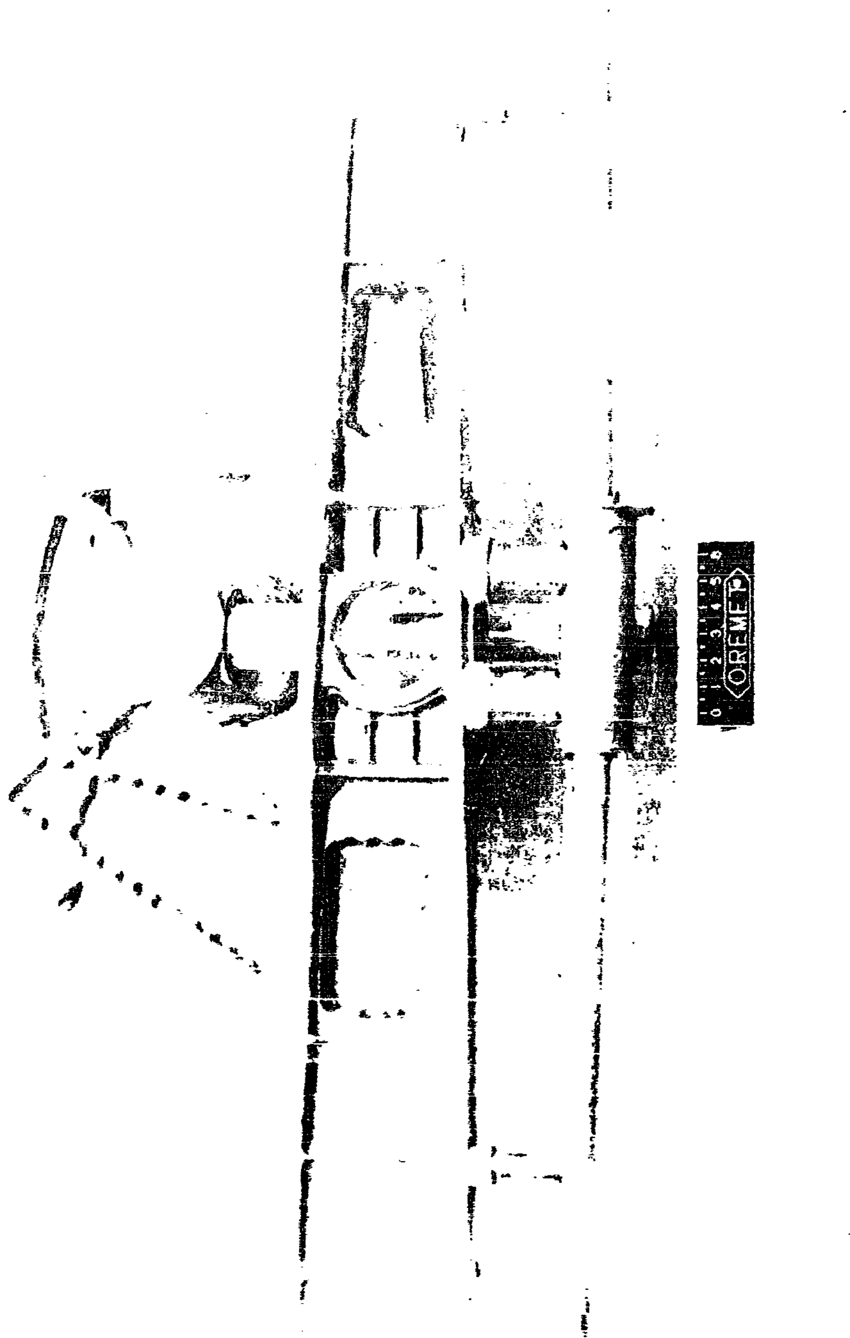


FIGURE D51

STATICALLY CAST HORIZONTAL STABILIZER FITTING



SECTION E

EVALUATION TESTING

The following mechanical tests were used to evaluate the general properties of cast titanium alloys and to compare the structural components with conventional materials and fabrication methods:

(1) Conventional Materials Tests

(a) Tensile, room and elevated temperature
(b) Compression
(c) Impact
(d) Shear
(e) Tension fatigue
(f) Notched tensile
(g) Bearing

(2) Component Tests

(a) Developmental Bracket - Static and fatigue simulat service tests, cast Ti-6Al-4V compared to cast type 410 steel.

(b) Flap Track Link - Static and fatigue simulated service tests, cast Ti-6Al-4V compared to forged AISI 4340 steel.

(c) Elevator Torsion Fitting - Torsion load vs deflection simulated service tests, cast Ti-6Al-4V compared to AISI 4340 hog-out.

(d) Sway Brace Case - Static simulated service tests, cast Ti-6Al-4V compared to cast type 410 steel.

(e) Inboard Bearing Support Rib - No testing do to failure to develop a satisfactory titanium casting.

Conventional Materials Tests

All tensile tests were conducted on conventional 1/4-inch gage diameter, 1-inch gage length tensile specimens similar to those specified in Federal Test Method Standard No. 151, type R3 specimen. The strain rate used was .005 ± .002 in./in./minute through 0.2 per cent strain. All tensile yield strengths reported are at 0.2 per cent offset. The results of tension tests are reported in the section of this report on alloy development.

The notched tension test specimens were as shown in Figure E1 and had a notch factor (K_t) of 3.3. Results of notched tests were used to compare properties of experimental alloys and are reported in the alloy development section.

The impact test specimens were conventional charpy test specimens. Results of impact tests are reported in the alloy development section.

The compression, shear, and bearing tests were on conventional specimens and were conducted to provide allowables data for design purposes. Results are in the section on development of specifications, standards, and design allowables.

Tension fatigue specimens were tested to establish requirements for chemical removal of surface contamination. The results of the tests are reported on page B60.

COMPONENT TESTS

Testing of The Developmental Bracket

The tests on components were to compare cast titanium structural shapes with the presently conventional aircraft materials and fabrication methods. All tests were at room temperature and were designed to simulate service conditions applicable to each part. All parts tested were compared with the present production part, except the developmental bracket which was not a production part. Two attempts were made to produce this part as a titanium forging, but the thin webs and high thin flanges made the part impractical to forge. Therefore, type 410 steel castings were obtained and tested for comparison with the titanium castings.

The Bracket was prepared for testing by milling both faces of the two heavy lugs and a slot in the small lug and then drilling and reaming the fastener holes. Castings were considered satisfactory for testing if X-ray defects were absent in all areas except the web and the two flanges which received almost no load. In those areas, slight shrinkage porosity was accepted. The castings were fatigue tested using the jig shown in Figure E2 and static tested in a conventional tensile test machine using a similar jig. The castings were loaded 26.6° from vertical (as shown in Figure E2) to provide a horizontal load equal to one half the vertical load.

All of the type 410 steel castings were X-ray sound and were heat treated by the vendor to 180,000 psi minimum ultimate tensile strength, 150,000 psi minimum yield strength, and 25 per cent minimum reduction of area. The Ti-6Al-4V castings were in the as-cast condition and had not been pickled.

Four cast Ti-6Al-4V brackets and one type 410 steel bracket were statically loaded to failure. The four cast Ti-6Al-4V brackets failed at the mounting hole in the upper large lug (Figure E3) at 24,400, 27,900, 25,000, and 21,800 pounds load. The type 410 steel bracket failed in the upper flange (Figure E3) at 34,100 pounds load. The average of the four cast Ti-6Al-4V values is 73 per cent of the ultimate load for the type 410 steel bracket. This value is very close to the ratios of ultimate tensile strengths of the two materials.

Ten cast Ti-6Al-4V Brackets and seven cast 410 steel brackets were fatigue tested for comparison of fatigue properties. Table J23 and Figure E4 show the results of these tests. The fatigue strength of the Ti-6Al-4V castings at any given number of cycles is 55 to 60 per cent of that of the 410 steel castings.

An additional series of fatigue tests was conducted on a modified version of the Bracket to determine the necessity of chemical removal of surface material from the as-cast surface. Since several of the brackets already tested failed adjacent to the machined mounting hole, in the upper lug, that lug was thickened by twenty per cent to make the casting fail in the flange, which had an as-cast surface. In addition the flange was tapered from its midpoint toward the lugs to encourage failure at the flange midpoint. Although the static strength of the modified design was an average of 37,000 pounds load for three tests (compared to 25,000 pounds for the unmodified design), the casting continued to fail frequently at the same machined hole. For this reason, a tension fatigue specimen having a gage diameter of 0.5 inch was designed and used for the chemical removal study. The results of this study are reported on pages B59 and B60, in Figure B30, and Table J16.

FIGURE E1

NOTCHED TENSILE TEST SPECIMEN
(K_t = 3.3)

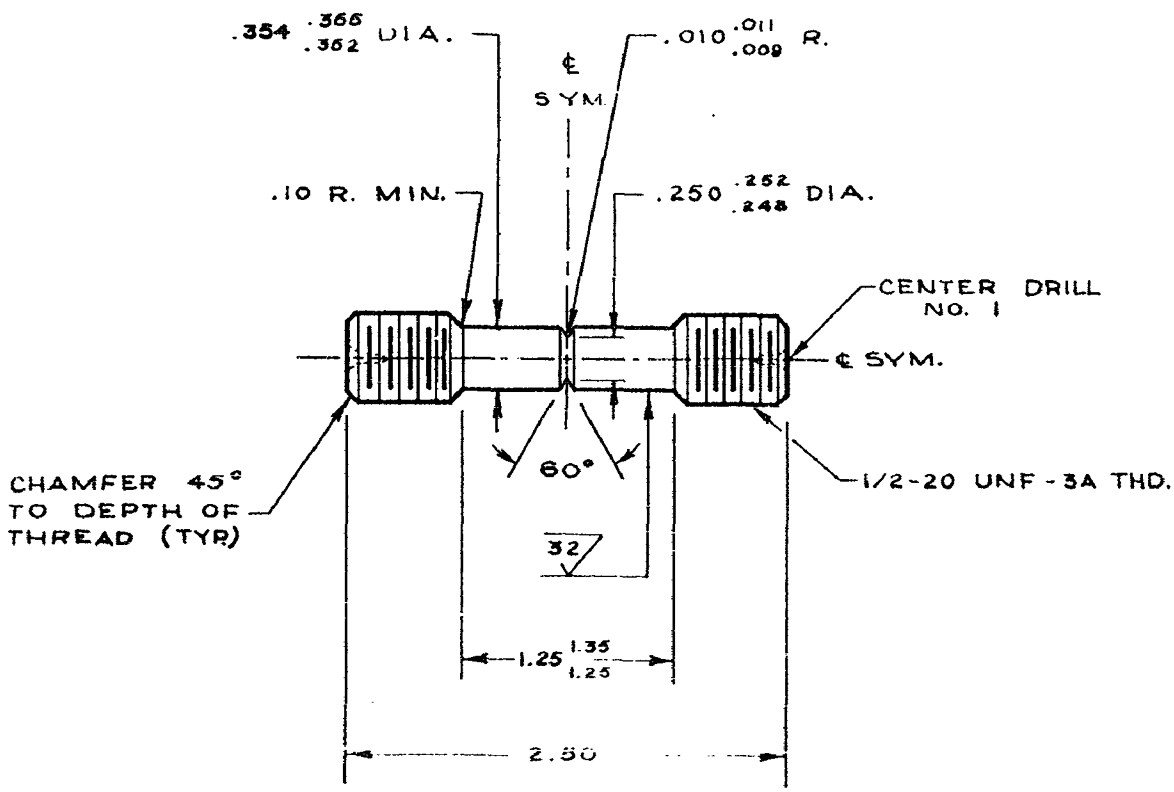


FIGURE E2

SETUP FOR FATIGUE TEST OF DEVELOPMENTAL BRACKET

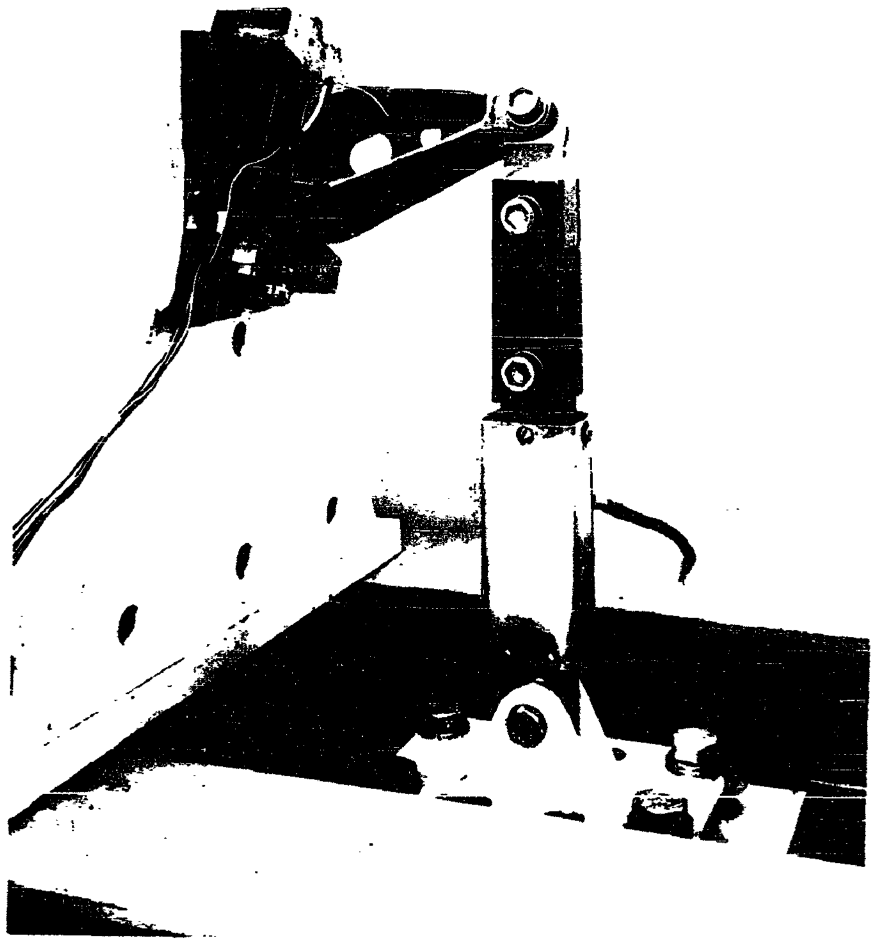
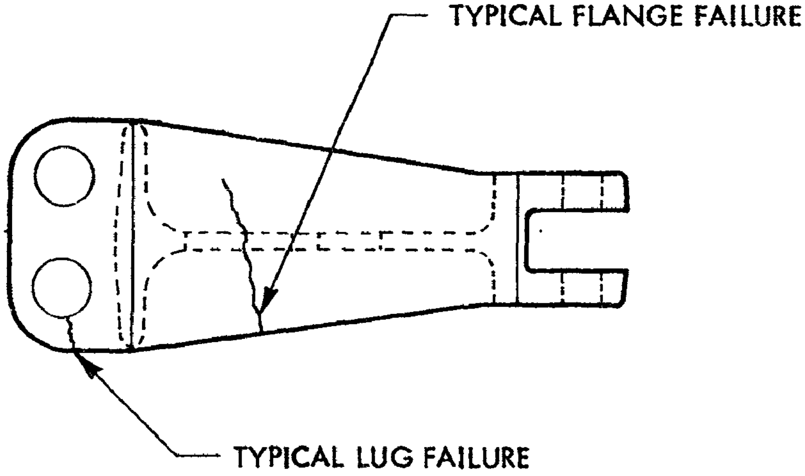


FIGURE E3


TYPICAL FLANGE FAILURE
TYPICAL LUG FAILURE

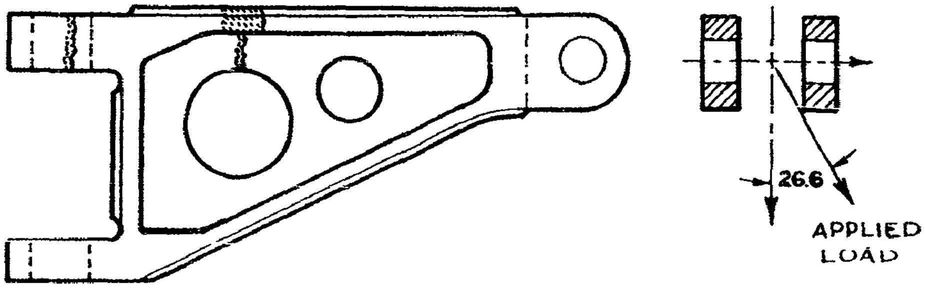
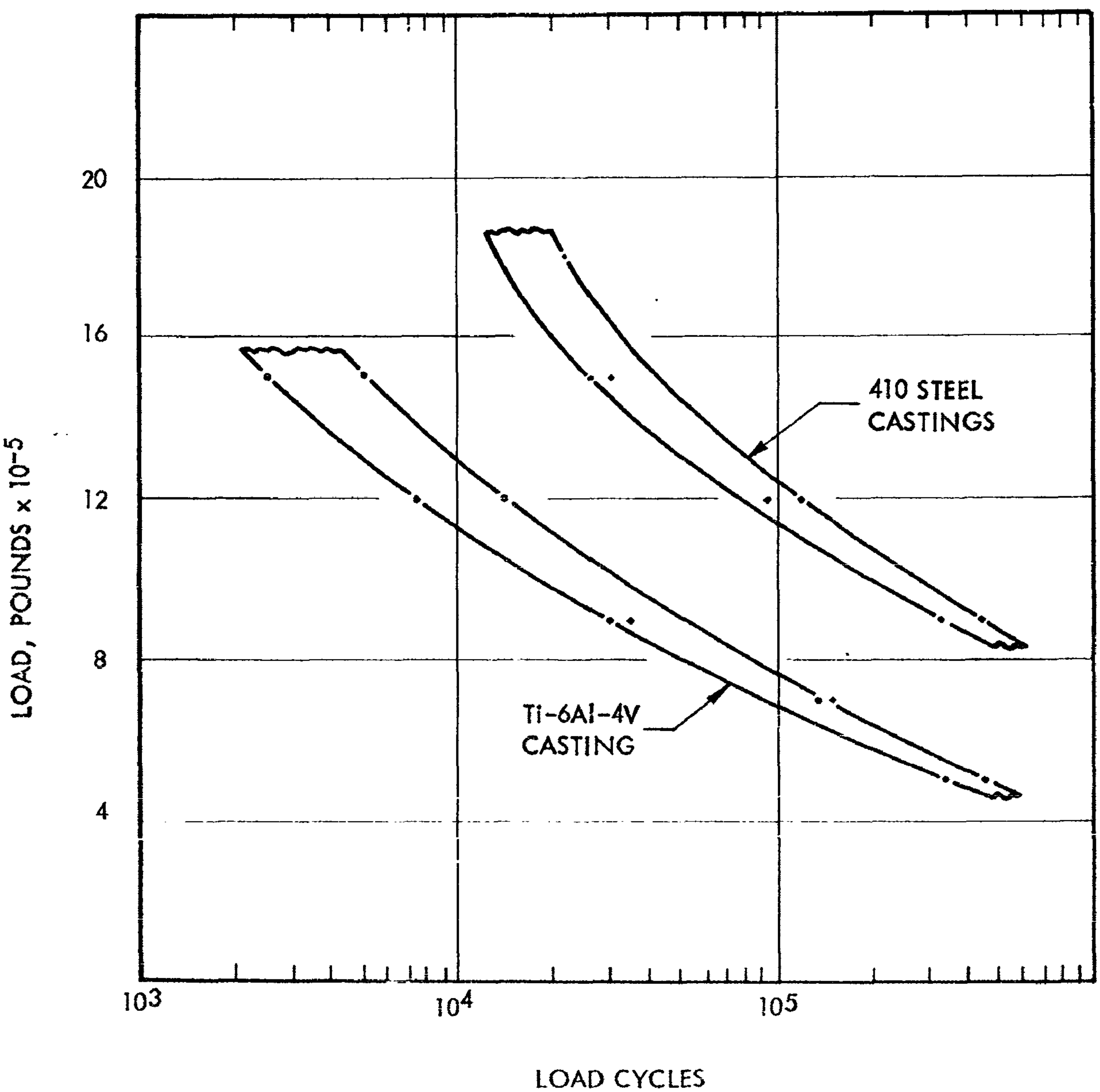

26.6
APPLIED
LOAD

FIGURE E4

RESULTS OF FATIGUE TESTS OF THE DEVELOPMENTAL BRACKET



Testing of The Flap Track Link

Two types of tests were used to evaluate the cast Ti-6Al-4V Flap Track Link. One production AISI 4340 steel part and one cast Ti-6Al-4V part were static compression loaded to failure as shown in Figure E5. Three steel parts and six cast Ti-6Al-4V parts were fatigue loaded to failure.

The AISI 4340 parts were obtained directly from production stock in the finished condition. They had been heat treated to the 180,000 to 200,000 psi ultimate strength range. The Ti-6Al-4V castings were in the as-cast condition and had been pickled to remove .015 inches material thickness per surface. The static tests failed the steel component at 127,600 pounds load and the cast Ti-6Al-4V component failed at 104,700 pounds load. The mechanism of failure was uniform bending of the shank for the steel part and localized crippling of the tubular portion of the cast Ti-6Al-4V part.

The fatigue tests were conducted in a fixture designed to load the part in combined bending and torsion, to simulate expected service conditions. The torsional load on the part is equal to 6.17 times the bending load. The results of the fatigue tests are as follows:

Material	Bending Load, Pounds	Cycles to Failure
Steel	5000	4,667
	3000	24,330
	2000	148,231
Cast Ti-6Al-4V	2000	11,602
	2000	6,067
	1500	66,408
	1500	57,557
	1000	216,833
	1000	1,000,000 (Not failed)

Figure E6 is a S-N curve of these test results.

FIGURE E5

FIXTURE FOR COMPRESSION TESTING OF FLAP TRACK LINK

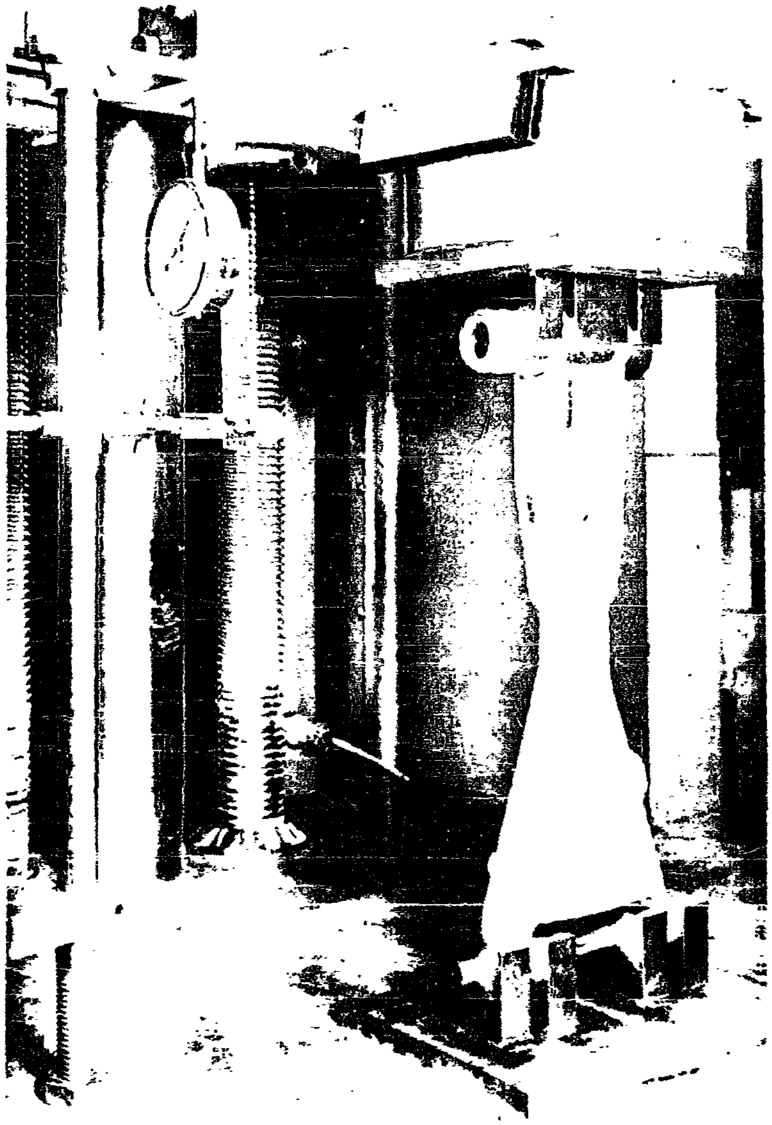
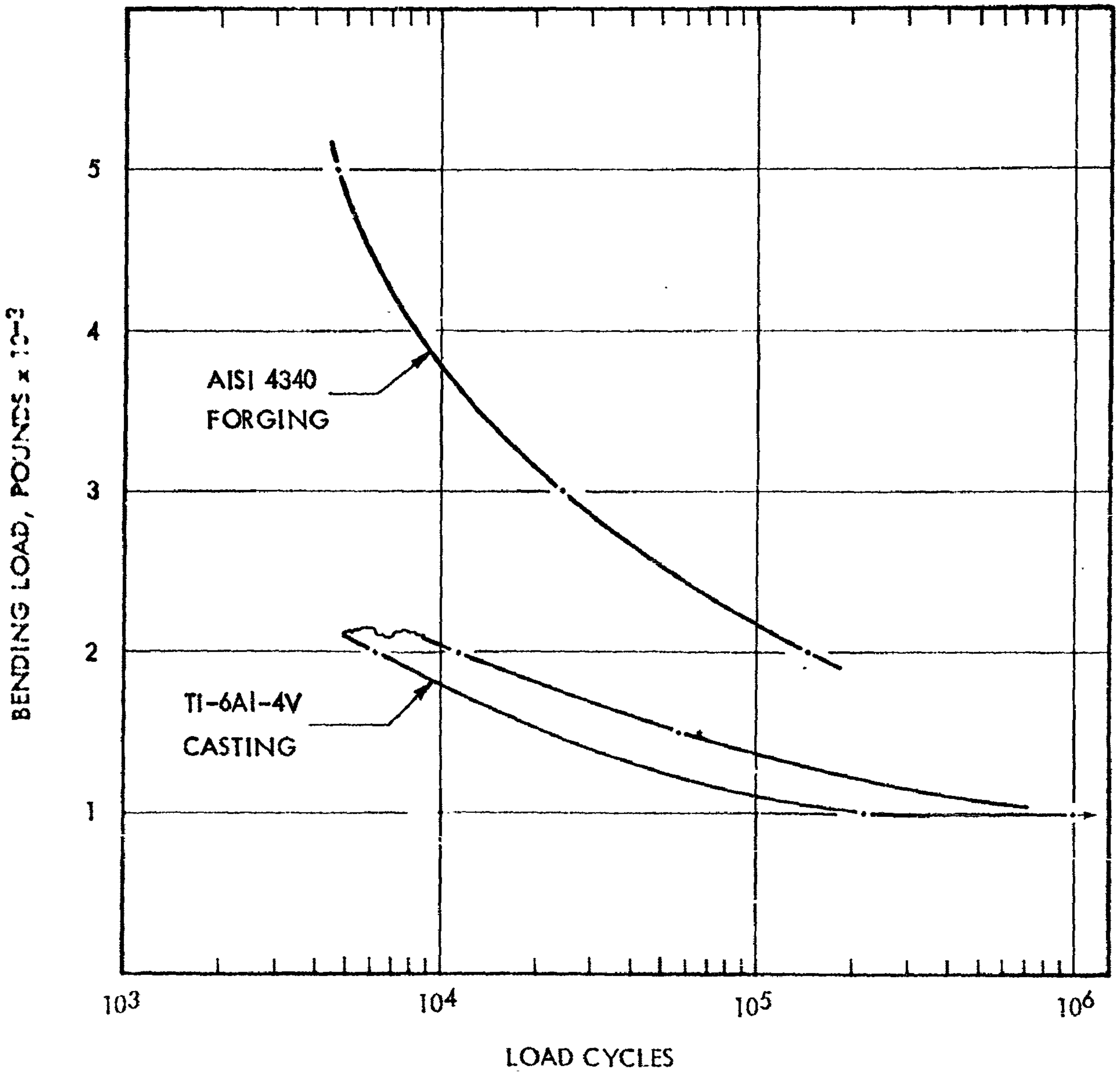


FIGURE E6

RESULTS OF FATIGUE TESTS OF THE FLAP TRACK LINK



Testing of The Sway Brace Case

Static tests were used to compare the properties of five cast Ti-6Al-4V components with two production cast type 410 steel components heat treated to the 150,000 psi ultimate tensile strength level. The Ti-6Al-4V castings were in the as-cast condition.

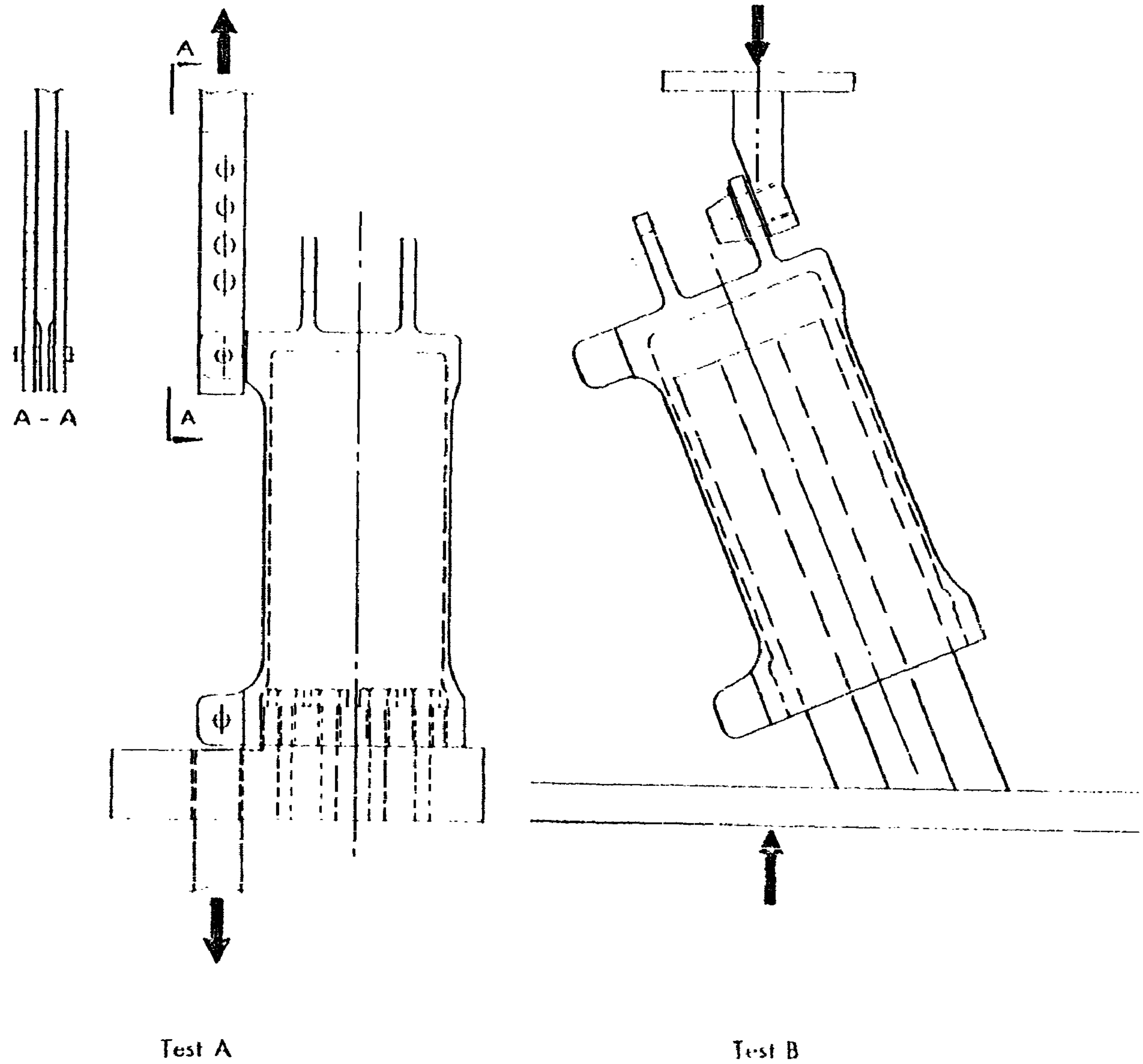
The test setup and loading conditions were as shown in Figure E7 and were designed to simulate actual service loads.

No casting failures were experienced in the tests which loaded the large lugs in compression (Test B in Figure E7). In all trials, the bolt which loaded the lug failed in shear.

The 410 steel cast Sway Brace Cases tested as shown in Test A (Figure E6) failed at 32,700 pounds and 35,300 pounds tension load. Both failures were in the upper lug and exhibited good ductility. The five Ti-6Al-4V castings failed at 22,900; 23,400; 25,000; 25,000; and 28,600 pounds tension loads at the same location. These failures exhibited fair ductility but not equivalent to the 410 steel test parts.

FIGURE E7

TEST FIXTURES FOR THE SWAY BRACE CASE



Testing of The Elevator Torsion Fitting

This component is a part of a missile control system and was designed for rigidity rather than strength or fatigue requirements. Consequently, the evaluation tests were comparisons of rigidity of the cast Ti-6Al-4V part and the production AISI 4340 steel part which was machined from bar stock. The Ti-6Al-4V parts were in the as-cast condition and the steel parts had been heat treated to the 180,000 - 200,000 psi ultimate strength level. (Since these parts were obtained, this production component has been redesigned as a type 410 steel casting.)

The Torsion Fittings were tested in a fixture adapted to a conventional torsion test machine. The torsion load was fed into the slotted center hole and the reaction load restrained at the channel ends. Deflection of the parts was measured by dial indicators supported by the load input bolts and cantilevered to the channel ends. A schematic load diagram is shown in Figure E8. Typical load-deflection curves obtained from these tests are shown as Figures E9 and E10.

FIGURE E8

LOAD SCHEMATIC FOR ELEVATOR TORSION FITTING

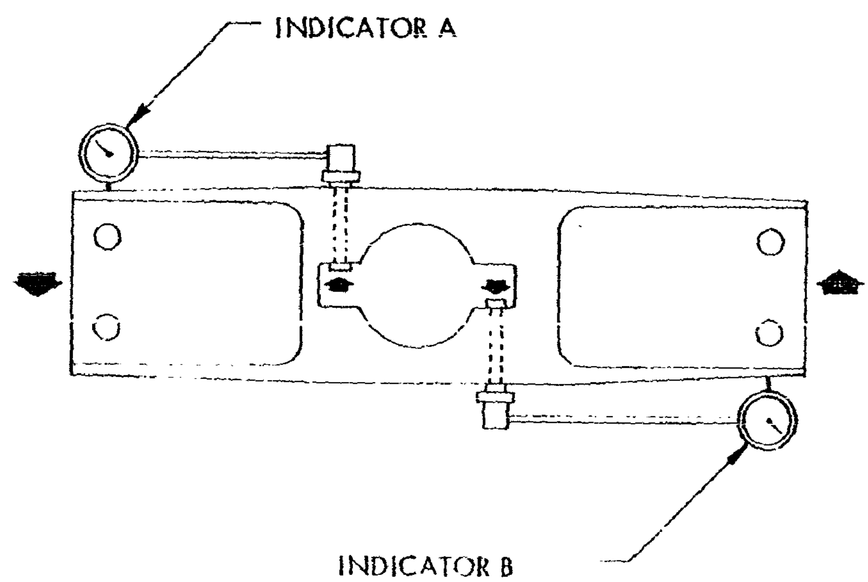


FIGURE E9

RESULTS OF DEFLECTION TEST OF CAST Ti-6Al-4V ELEVATOR TORSION FITTING

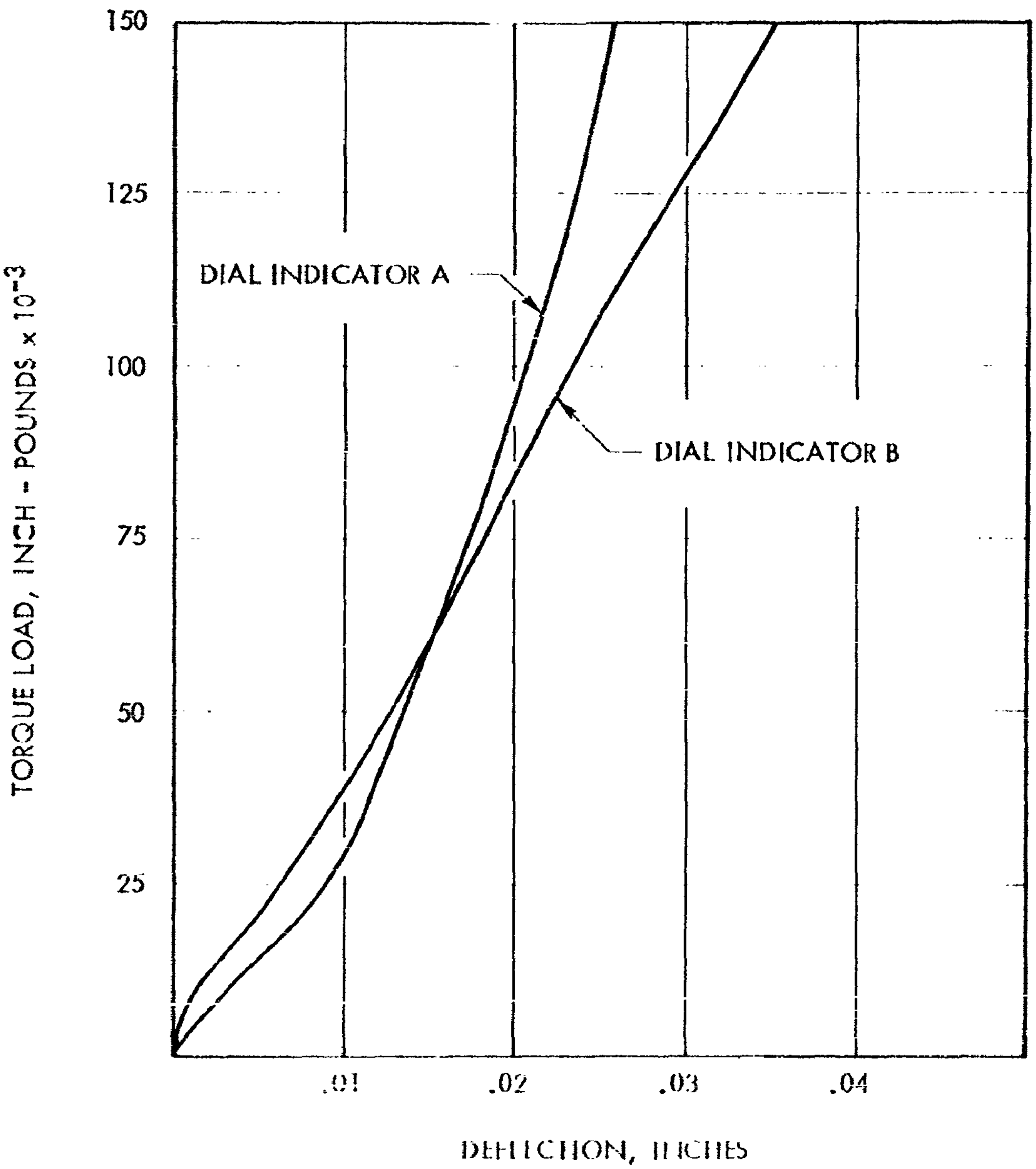
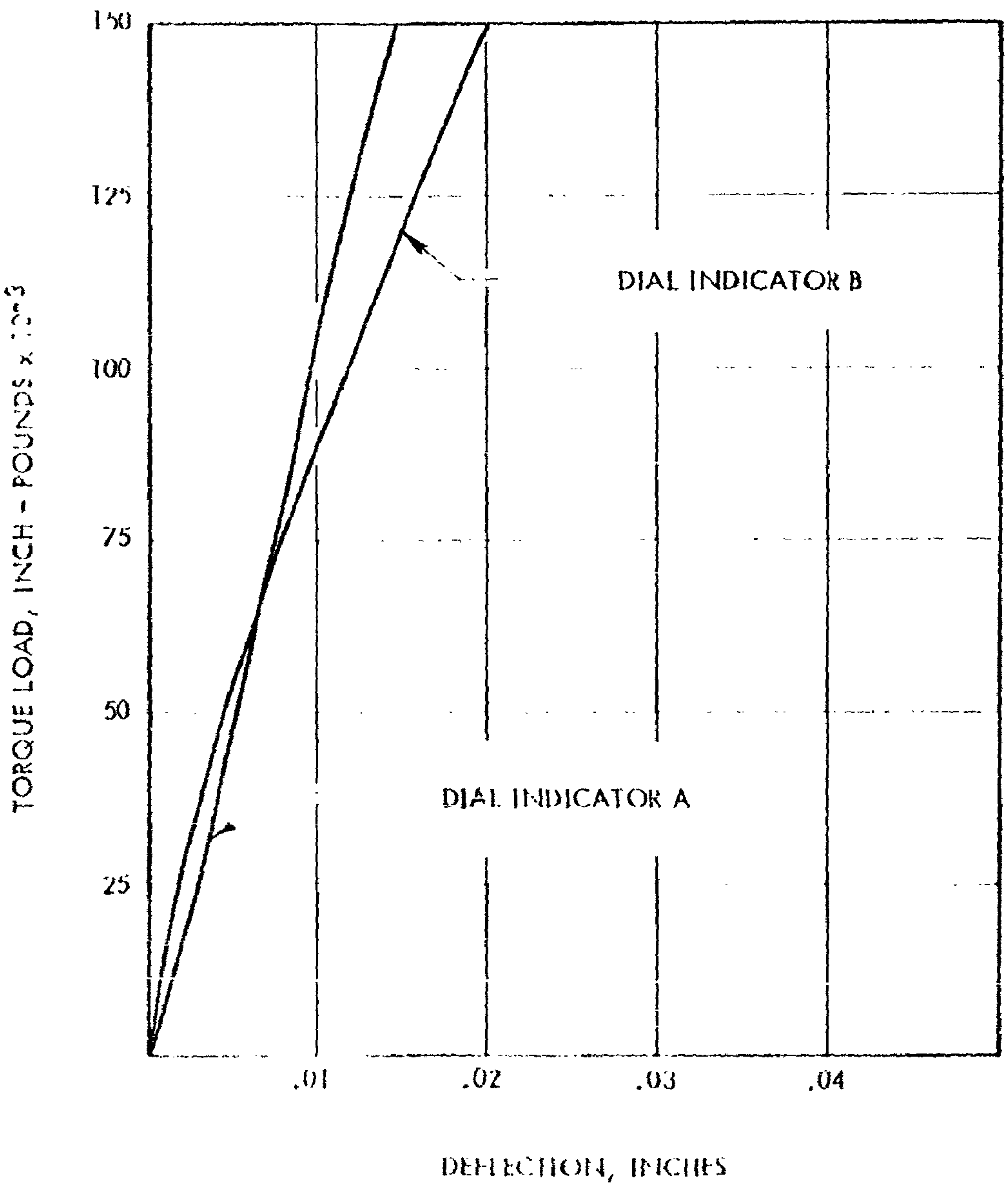


FIGURE E10

RESULTS OF DEFLECTION TEST OF A STEEL ELEVATOR TORSION FITTING



Testing of The Inboard Horizontal Stabilizer Rib

Since this part was not satisfactorily produced as a titanium alloy casting, no tests were conducted.

SECTION F

SPECIFICATION AND DESIGN CRITERIA

DEVELOPMENT OF CASTING SPECIFICATIONS

A tentative material specification for procurement of air-frame quality Ti-6Al-4V castings has been developed and is presented on page F3. This specification is based on the conclusions made from the development work conducted in this program and from experience gained in development and use of other casting specifications.

TENTATIVE SPECIFICATION - TITANIUM ALLOY CASTINGS (Ti-6Al-4V)

Tentative Boeing Material Specification BMS 7-111
Oregon Metallurgical Corporation Specification--OMC 164

1. ACKNOWLEDGMENTS:

1.1 A vendor shall mention this specification number in all pertinent quotations and when acknowledging purchase orders.

2. APPLICABLE SPECIFICATIONS:

2.1 The following specifications, of the issue in effect on date of invitation for bids, form a part of this specification to the extent herein described:

2.1.1 MIL-I-6865 Inspection, Radiographic

2.1.2 MIL-I-6866 Inspection, Penetrant

2.1.3 MIL-C-6021 Castings, Classification and Inspection

2.1.4 Federal Test Method Standard No. 151

2.1.5 Reference Radiographs for Titanium Castings (Boeing Document D2-2786-9)

3. APPLICATION:

3.1 This specification is primarily for high strength titanium alloy aircraft castings requiring room temperature ultimate tensile strength above 140,000 psi, light weight, and good corrosion resistance.

4. TYPES AND GRADES:

4.1 Unless otherwise specified, castings are to be in the as-cast condition. If annealed condition is specified, the annealing heat treatment shall be 1000°F for 4 hours followed by air cool.

4.2 Casting classification shall be as specified on the applicable casting drawing. Class definitions shall be as specified in MIL-C-6021.

5. CASTING METHOD:

5.1 Casting molds shall be rammed graphite mixed with suitable binders, unless otherwise specified

5.2 Melting shall be by the vacuum double-melt process when the titanium source is either raw sponge or raw sponge compacts. Use of titanium solids in preparation of electrode stock is permitted, provided all other requirements of this specification are met. All melting shall be by the vacuum consumable-electrode process.

6. COMPOSITION:

6.1 Castings shall be of the following composition:

	Weight Per Cent
Carbon	.10 max.
Hydrogen	.015 max.
Nitrogen	.07 max.
Oxygen	.25 max.
Iron	.30 max.
Aluminum	5.5 - 6.5
Vanadium	3.5 - 4.5
Other Elements	.4 max.
Titanium	Balance

6.2 Each heat shall be analyzed for each of the elements listed in paragraph 6.1 except titanium. Chemical analysis of each lot shall be certified by the vendor. Analysis for hydrogen shall be on samples removed after all vendor processing. All analyses shall be performed using equipment and procedures approved by the procuring agency. Hydrogen analysis sample shall be removed from a location designated on the casting drawing, or from a separate coupon from the same heat and processed at the same time as the casting lot. This coupon shall be no thicker than the thinnest section of the casting.

7. QUALITY:

7.1 Castings shall be uniform in quality and condition, well cleaned, and have a uniformly smooth surface compatible with the casting process. Castings shall be free of surface contamination (such as oxygen, nitrogen, or other foreign contaminants).

7.2 Unless otherwise specified, metallic grit or shot shall not be used for final cleaning.

7.3 Castings shall not be repaired by plugging, welding, peening, or other methods without written permission of the procuring agency.

7.4 The areas of castings subject to soundness requirements shall be as specified, and the number and extent of defects in such areas shall not be greater than indicated by the standard furnished or approved by the procuring agency. Combinations of cracks, shrinkage cavities, cold shuts, misruns, or other defects not individually cause for rejection, but which are so aligned as to cause stress concentration are cause for rejection.

7.5 When soundness is specified in accordance with paragraph 7.4, it shall be determined in accordance with visual, penetrant, and radiographic inspection methods established by MIL-C-6021, MIL-I-6865, and MIL-I-6866.

8. TENSILE PROPERTIES:

8.1 All test specimens shall be cast in a graphite mold in the same heat and in the same manner as the castings which they represent.

8.2 Two cast test bars per heat shall be furnished to the purchaser. Bars shall be of sufficient size to be machined into type R3 specimen in accordance with Method 211.1 of Federal Test Method Standard No. 151.

8.3 Vendors shall conduct at least two tensile tests per heat.

8.4 Tensile tests are to be performed in accordance with Federal Test Method Standard No. 151 using type R3 specimen. Strain rate shall be .005 ± .002 in/in/min through 0.2 per cent strain.

8.5 Tensile properties of each separately cast specimen or specimen sectioned from a critical area of a 1A casting shall meet or exceed the following minimum values:

Ultimate tensile strength	140,000 ps
Yield tensile strength (.2% offset)	122,000 ps
Elongation	5 per cer
Reduction of area	10 per cer

9. IDENTIFICATION:

9.1 Unless otherwise specified, each casting shall be identified with the part number and a vendor identification symbol approved by the purchaser by the use of raised figures in a location indicated on the drawing. When no location is shown on the drawing, the number shall be so located as not to be machined off in finishing to the required casting dimensions. Such numbers shall not be at indicated tool point locations.

10. CHEMICAL REMOVAL OF SURFACE MATERIAL

10.1 If pickling is specified, castings shall be pickled to remove .015 inch minimum material thickness per surface. Foreign material, such as particles of mold, adhering to the casting surface shall be removed prior to pickling. Castings shall not be peened, abrasive blasted or otherwise finished after pickling, unless otherwise specified.

11. CERTIFICATION:

11.1 Three copies of a quality certification shall accompany or precede each lot of castings. The certification shall include results of analyses in accordance with paragraph 6.2, the results of tensile tests in accordance with paragraphs 8.3 and 8.4, the vendors heat number, the thickness of material removed by pickling in accordance with paragraph 10.1, the quantity of castings constituting that lot, the casting part number, and the purchase order number.

12. DEFINITIONS:

12.1 A lot consists of castings of the same heat, the same configuration, the same condition, processed at the same time, and submitted for inspection at the same time.

12.2 A heat consists of the material produced in one melting and pouring cycle.

DEVELOPMENT OF MINIMUM PROPERTY VALUES

A group of 196 heats of cast Ti-6Al-4V alloy were studied to establish minimum property values for separately cast test bars, for design purposes. The heats were all those produced prior to the production run which were within the composition limits established by the specification (page F3) and for which mechanical properties data were available, with the exception of a small number of experimental low-interstitial heats which were poured during study of melting practice.

The ultimate tensile strength, yield strength, elongation, and reduction of area values for these heats were averaged and the standard deviations determined by conventional statistical analysis methods as shown in the appendix to this report.

Both "A" and "B" design values were determined. For a "normal" distribution, "A" values assure to a 95% confidence level that 99 percent of the distribution will exceed the "A" value given. The "B" design value assures to the same confidence level that 90 per cent of the distribution will exceed the "B" value. Although mechanical property distributions are not "normal" in that the distribution curve is slightly skewed toward the high-value end of the curve, this analysis method is convenient and the small error involved is in the conservative direction.

In accordance with Convair Astronautics Document AZS-27-274 "Statistical Determination of Strength Properties", 2.573 standard deviations were subtracted from the property averages to establish "A" design values and 1.452 standard deviations were subtracted from the averages to establish "B" values. This method is usually applied to strength values, but is also suitable for establishing the ductility minimums. The averages, "A" values, and "B" values obtained were as follows:

	Average	"A" Minimum	"B" Minimum
Ultimate Tensile Strength, KSI	146.8	135.0	140.0
Yield Strength, KSI, .2% Offset	129.8	116.0	122.0
Elongation, per cent	8.0	3.2	5.3
Reduction of Area, per cent	15.3	5.7	9.6

COMPRESSION, BEARING, AND SHEAR PROPERTIES

Room temperature compression, bearing, and shear tests were conducted to provide basic properties values for design purposes. Tensile tests from the same heats were also conducted for reference. The results were as follows:

Tensile Tests

Heat Number	Ultimate Tensile Strength, KSI	Yield Strength, KSI (.2%)	Elong. Per Cent	R.A., Per Cent
P441	152.5	138.0	9	17
P483	141.3	129.0	12	18
P494	143.5	130.5	10	17

Compression Tests

Heat Number	Yield Strength, KSI (.2%)	Modulus of Elasticity, KSI
P441	141.0	18.3
P483	148.7	17.9
P494	135.5	17.7

Bearing Tests

Heat Number	Ultimate Bearing Strength, KSI	Yield Bearing Strength, KSI*	Hole Diameter, Inches	Edge Margin, Inches
P441	239.1	215.9	.1599	.2566
P483	225.0	194.1	.1600	.2573
P494	235.0	208.9	.1599	.2574

* Based on offset of 2 per cent of hole diameter

Shear Tests

Heat Number	Ultimate Shear Stress, KSI
P441	96.3
P483	90.8
P494	97.3

DEVELOPMENT OF REFERENCE RADIOGRAPHS

X-ray reference radiographs were prepared from specimens machined from the discs which were cast during the feeding studies. The radiographs of the discs of proper thickness (1/4, 1/2, and 1 inch thicknesses) were examined and sections which represented reasonable gas and shrinkage porosity quality gradients were selected and machined from the discs. Other casting imperfections found in steel, aluminum, and magnesium alloy castings (such as heavy inclusions, dross, micro-shrinkage, segregation, internal cracks, and internal cold shuts) were not experienced in the titanium alloy castings, with the exception of mold material (graphite) inclusions. This defect was not often observed, and when it was found, it was similar in appearance on the radiograph to shrinkage porosity. Consequently, the defects shown in the shrinkage porosity reference radiographs can be applied to graphite inclusions, since the appearance and stress concentration effects of these types of defects are similar. The reference radiographs are attached to the back cover of this report so that they may be readily removed for use. These radiographs were prepared to a film density of 1.9 to 2.2 (American Standard Printing Density P2-3) so that they may be directly compared to typical casting radiographs.

DEVELOPMENT OF DIMENSIONAL TOLERANCE CRITERIA

Nine dimensions were selected from the Development Bracket and the Flap Track Link for analysis of deviations from the desired dimensions. The dimensions were selected to enable separation of the effects of parting plane causes of deviation from the basic tolerance characteristics of the rammed graphite mold casting process. Fifty of each part were studied.

There are several obvious sources of dimensional variance in castings. Examples are; deviation of the pattern dimensions from the desired nominal dimensions, the inaccuracy of the established average shrinkage of mold and metal, the variations in mold and metal shrinkage from the established average, the inconsistencies in mold ramming and drawing practice from mold to mold, the inability of the foundry to establish the proper pattern dimensional corrections after a casting trial (due to the impracticality of pouring enough trial casting to establish true process average dimensions), variations in casting cleanup practice (removal of gates, risers, flash, etc.), variations in pouring temperature and practice, and variations in mold material quality and in mixture ratios.

The effects of these causes of dimensional variation are cumulative and each cause represents a separate avenue for potential improvement in dimensional quality.

The dimensions selected for study represent three general types of tolerances. Four simple dimensions which were not across the parting plane were selected for establishment of a basic tolerance. These dimensions varied from .2 to 9.6 inches. Three dimensions of similar magnitude but across and parallel to the parting plane were selected to separate the effects of pattern and mold mismatch. Two dimensions which were across and perpendicular to the parting plane were studied to separate the effects of poor parting plane fitup other than mismatch.

The results of these studies are in Table J24 and frequency distribution bar charts for each of the dimensions studied are presented as Figures F1 through F9. Recommended minimum design tolerances were computed from these data. The actual values for each dimension were averaged and the standard deviation was then calculated as explained in the Appendix. Three standard deviations were used to establish the recommended minimum tolerances. Such a tolerance will make approximately 99.7 per cent of the dimensions in a normal distribution acceptable, provided that the average of the distribution is exactly the desired nominal dimension. Obviously, it never will be; therefore, the actual number of rejected dimensions will be greater than the 0.3 per cent implied, the amount dependent on how close the foundry can make their average approach the desired nominal dimensions. The usual practice is to cast one or two trial pieces, inspect them, and make pattern corrections. This practice will reveal only large errors, since any dimension on one individual part will rarely indicate the average of a large number of pieces.

General rules for recommended design dimensional tolerances for dimensions up to ten inches were derived from the results of this study, as follows:

(a) For simple dimensions under one inch that do not cross the mold parting plane, use a basic dimensional tolerance of plus or minus .015 inch. If the dimension exceeds one inch, add .005 inches to the basic tolerance for each whole inch. Examples are 0.620 ± .015, 1.135 ± .020, 4.720 ± .035.

(b) For dimensions that cross the parting plane and are essentially perpendicular to it, add .008 inch to the tolerance calculated as in (a) above. Examples are 0.620 ± .023, 1.135 ± .028, 4.720 ± .043.

(c) For dimensions that cross the parting plane and are essentially parallel to it (i.e. mismatch), add .020 inch to the tolerance calculated as in (a) above. Examples are .620 ± .035, 1.135 ± .040, 4.720 ± .055.

These dimensional tolerances represent minimums. Larger tolerances should be used when practical. It is anticipated that some improvement in available minimum tolerances (particularly in mismatch) will occur as the mold preparation process becomes mechanized. All rammed molds in this program were manually prepared with the aid of a pneumatic rammer.

FIGURE F1

DIMENSION DISTRIBUTION IN DEVELOPMENTAL BRACKET

This dimension is basic, both surfaces being in the same mold half. The desired dimension was .200 ± .015 inches.

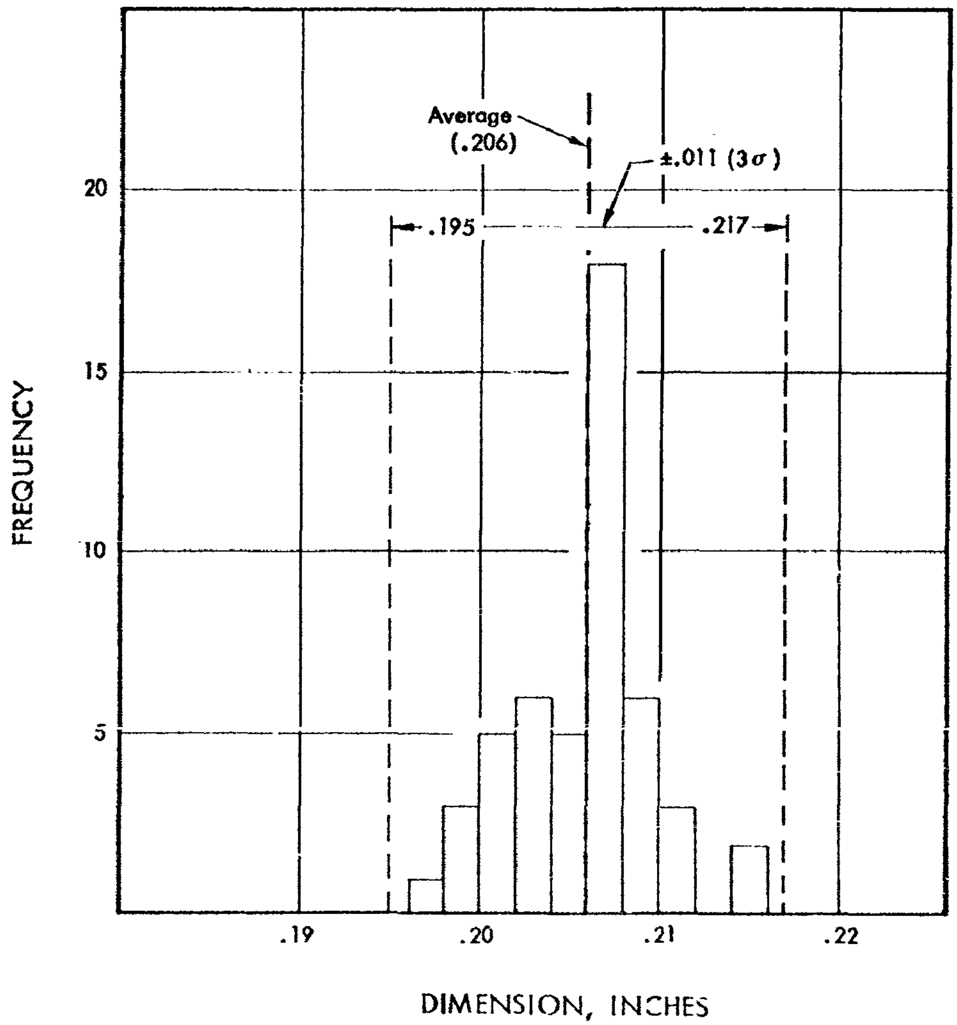


FIGURE F2

DIMENSION DISTRIBUTION IN DEVELOPMENTAL BRACKET

This dimension is basic, both surfaces being in the same mold half. The desired dimension was .650 ± .015 inches.

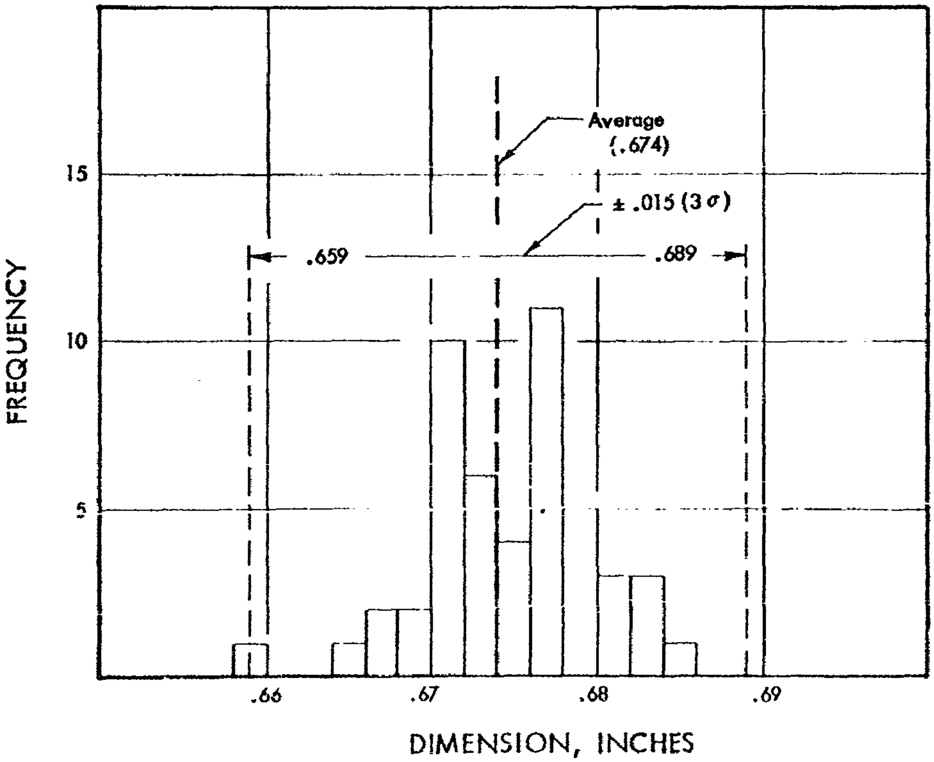


FIGURE F3

DIMENSIONAL DISTRIBUTION IN DEVELOPMENTAL BRACKET

This dimension is basic, both surfaces being in the same mold half. The desired dimension was 3.050 ± .015 inches.

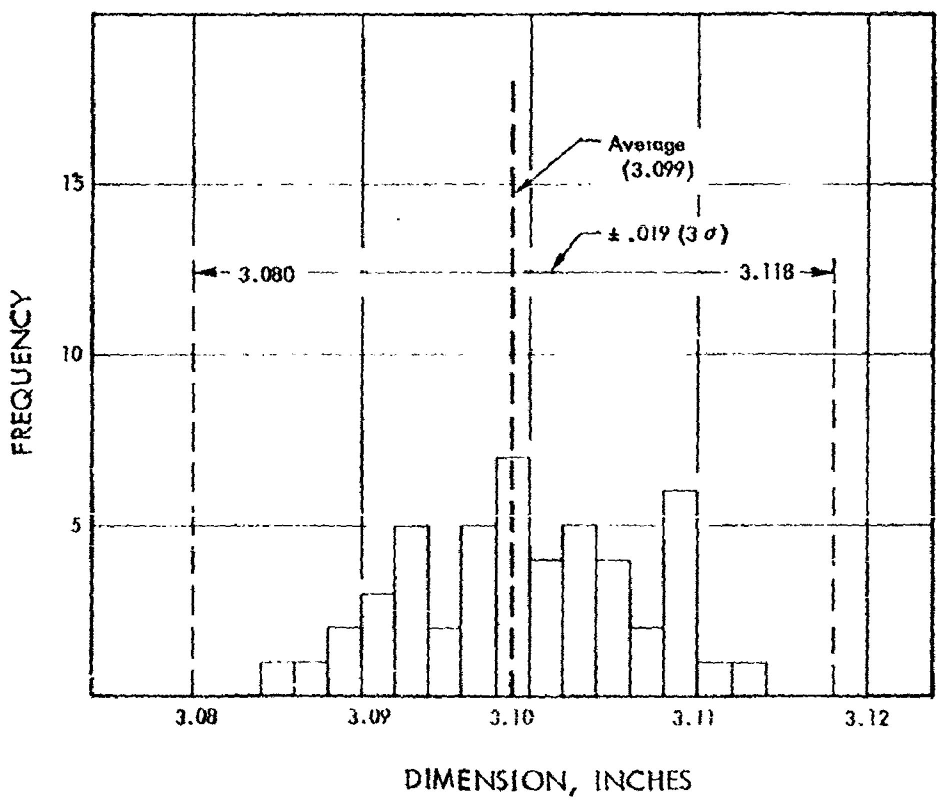


FIGURE F4

DIMENSIONAL DISTRIBUTION IN FLAP TRACK LINK

This dimension is basic, both surfaces being in the same mold half. This dimension was not directly specified on the engineering drawing, but is controlled by two cumulative dimensions. It was selected because it was convenient to measure and represents a large dimension on the part.

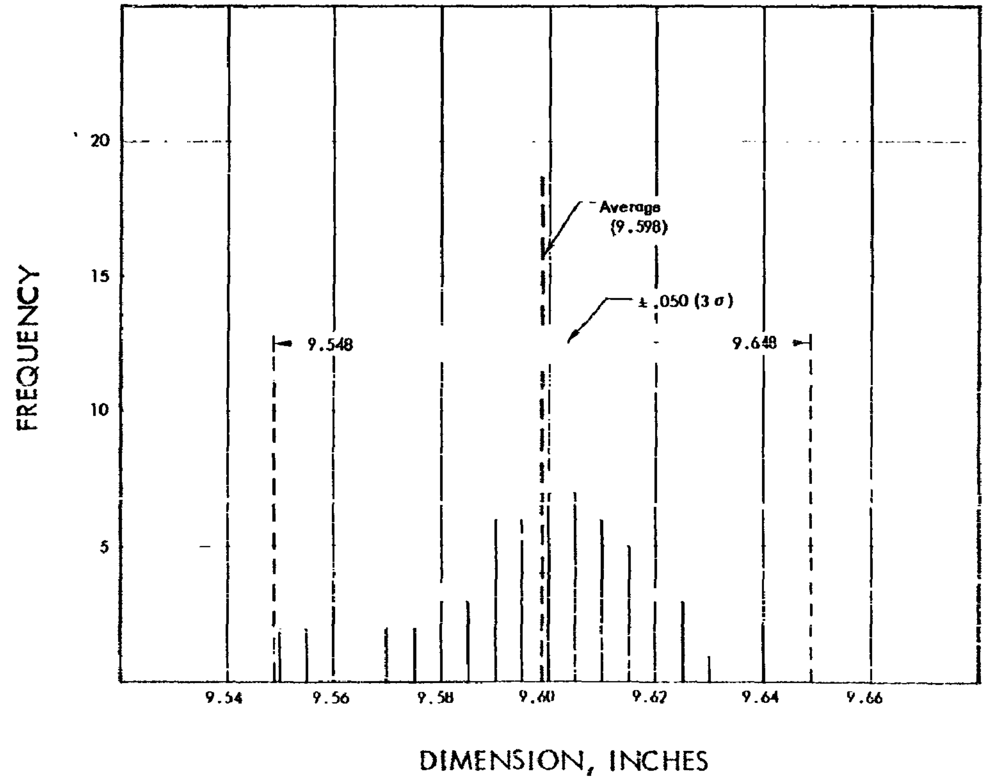


FIGURE F5

DIMENSIONAL DISTRIBUTION OF DEVELOPMENTAL BRACKET

This dimension is across the parting plane and is perpendicular to it. It represents the basic tolerance plus the added dimensional variations resulting from misfit of the mold parting plane. It does not involve mismatch. The desired dimension was 1.520 + .025 − .015 inches.

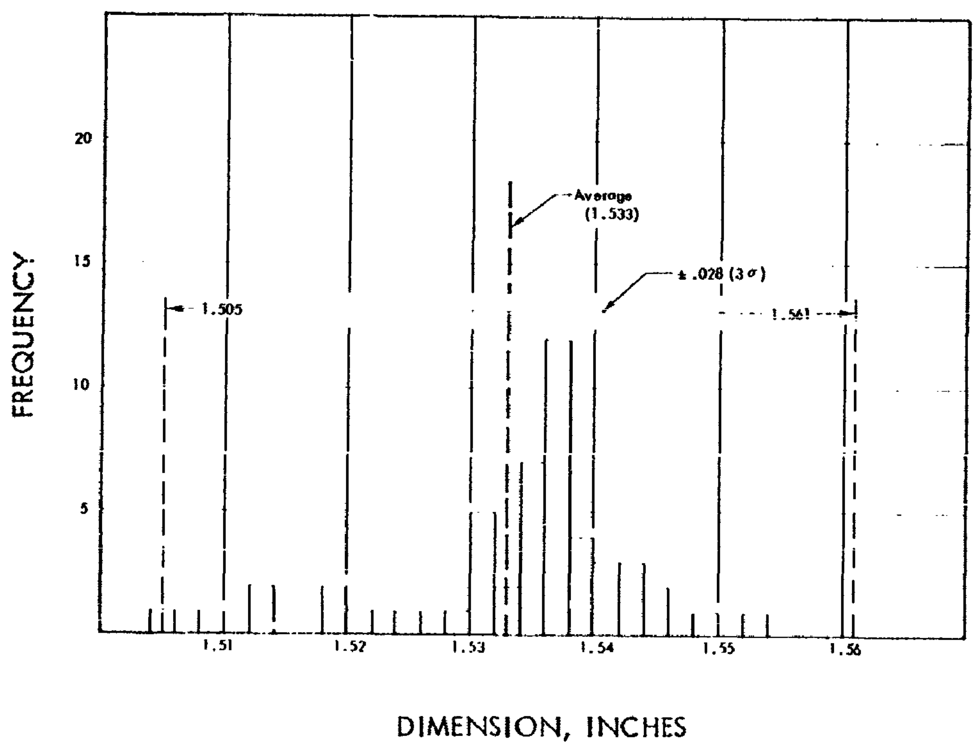


FIGURE F6

DIMENSIONAL DISTRIBUTION OF DEVELOPMENTAL BRACKET

This dimension is across the parting plane and is perpendicular to it. It represents the basic tolerance plus the added dimensional variations resulting from misfit of the mold parting plane. It does not involve mismatch. The desired dimension was 2.520 + .025 - .015 inches.

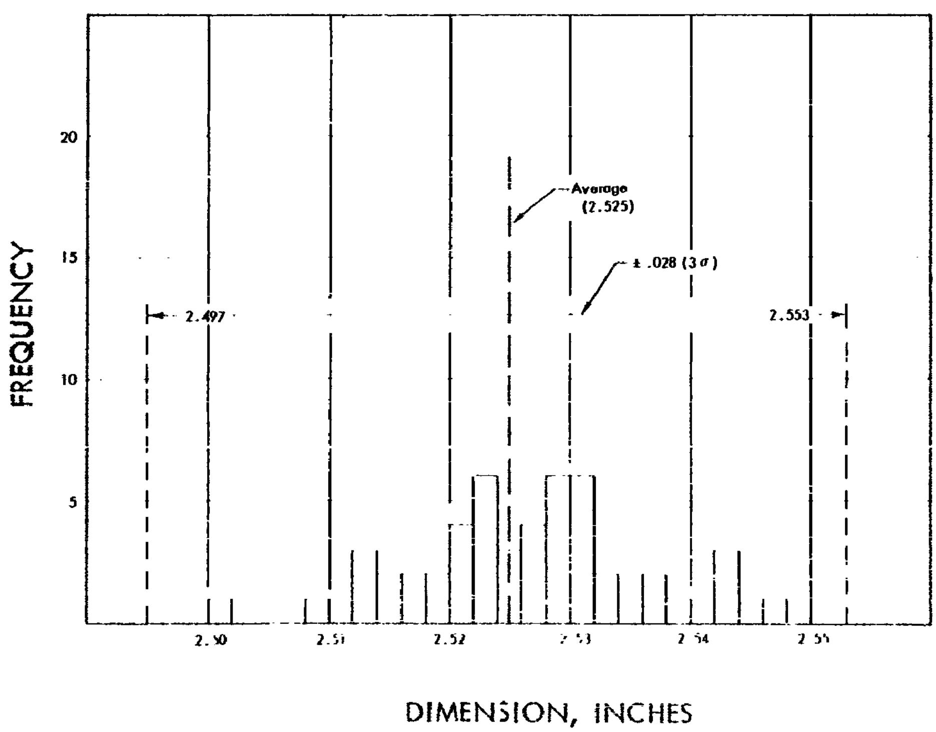


FIGURE F7

DIMENSIONAL DISTRIBUTION OF DEVELOPMENTAL BRACKET

This dimension is across the parting plane and is parallel to it. It represents the basic dimensional tolerance plus the added variations resulting from pattern and mold mismatch. The desired dimension was not directly specified. It was measured for comparison with Figure F2 to separate mismatch effects.

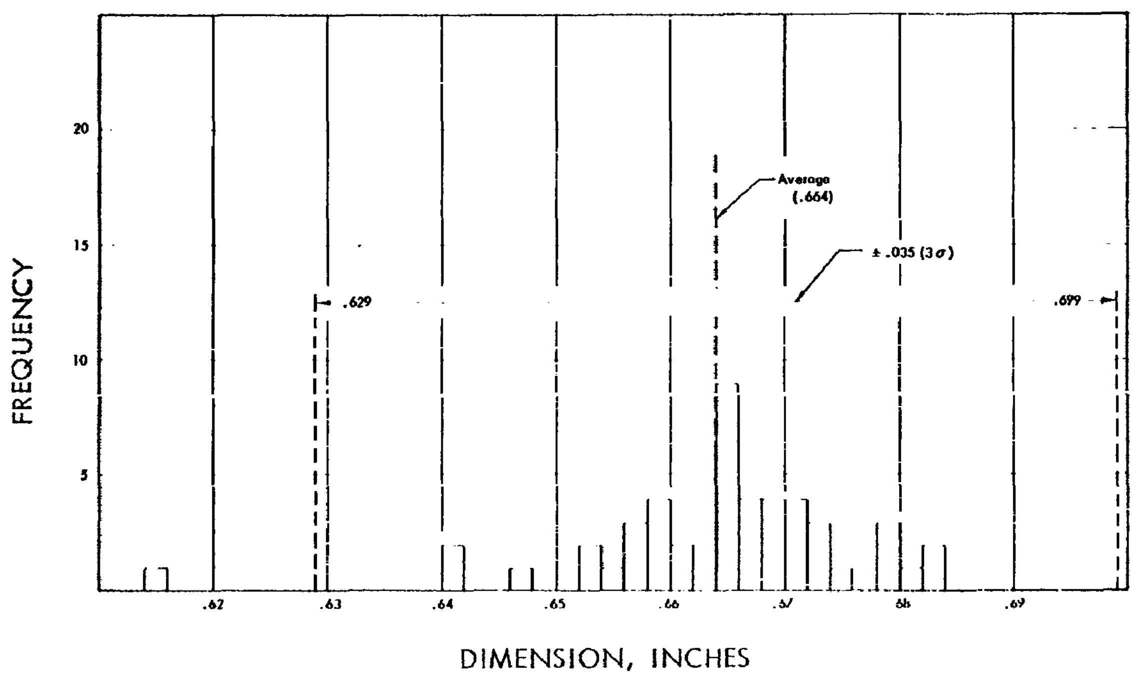


FIGURE F8

DIMENSIONAL DISTRIBUTION OF DEVELOPMENTAL BRACKET

This dimension is across and parallel to the parting plane. It represents the basic tolerance plus effects of pattern and mold mismatch. The desired dimension was 3.050 ± .015 inches.

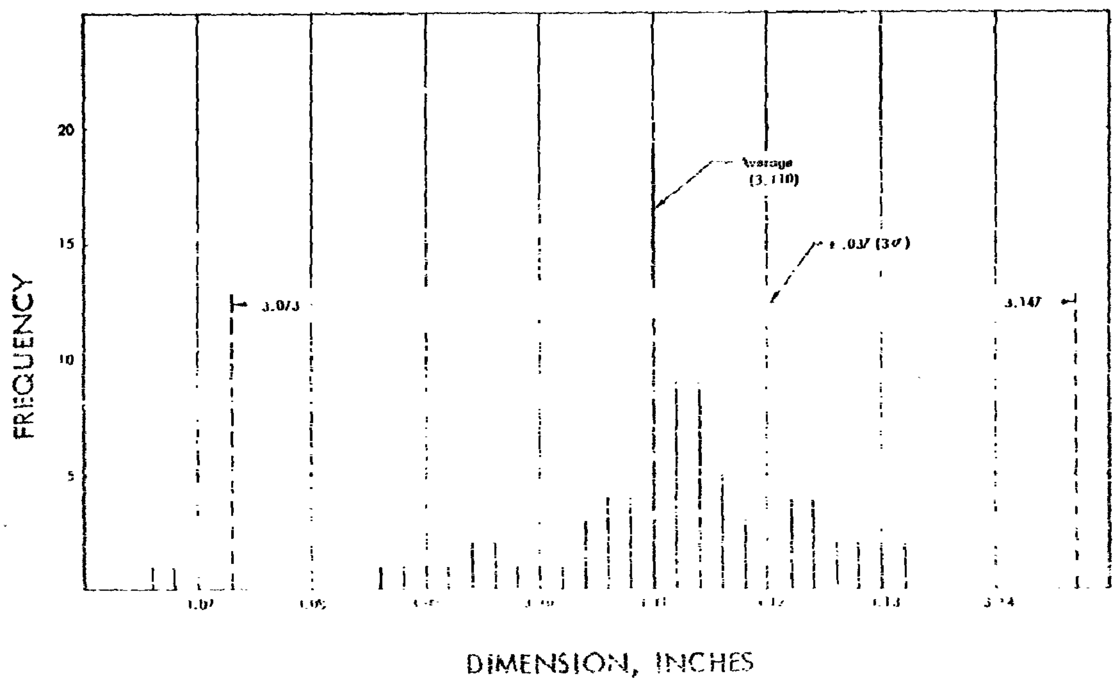
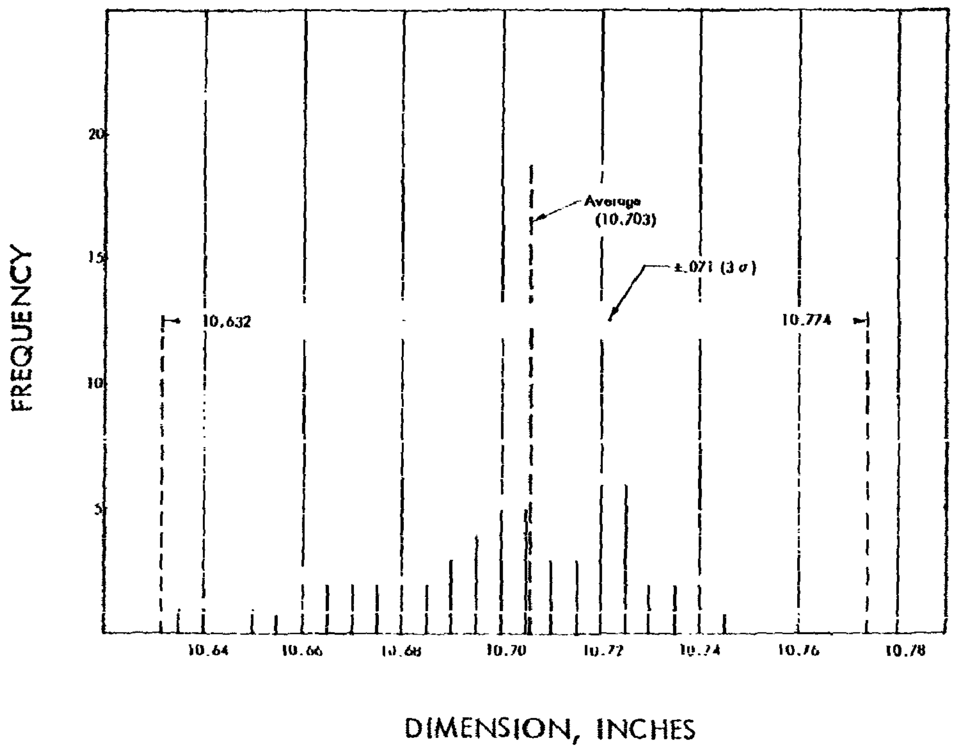


FIGURE F9

DIMENSIONAL DISTRIBUTION OF FLAP TRACK LINK

This dimension is across and parallel to the parting plane. It represents the basic tolerance plus effects of pattern and mold mismatch. The desired dimension was 10.630 ± .050 inches.



CONCLUSIONS

SECTION G

The following conclusions are based on the development work performed during this program. They are listed in the same order as the corresponding discussions in this report, except for the first three conclusions which are of a general nature.

1. A complete commercially feasible process was developed for production of titanium alloy castings of the type, sizes, and quality required for aircraft and missile application.

2. A practical demonstration of the process was accomplished by production of quantity lots of several airframe structural shapes.

3. A procurement specification, quality control procedure, inspection standards, and design criteria were established to permit production application of titanium alloy castings.

4. A vacuum, consumable-electrode, arc furnace with water-cooled copper, tilt pour crucible is suitable for melting and pouring of production heats of titanium alloys.

5. Preparation of melting electrode stock may be satisfactorily done by inert-gas shielded arc welding of pressure-compacted titanium sponge mechanically mixed with the proper alloying additions, or by similar welding of titanium solids from previous melting operations. Care in welding must be exercised to minimize oxygen and nitrogen contamination of the electrode stock.

6. Foundry and other scrap may be satisfactorily recycled to produce aircraft quality titanium castings, provided additional low-interstitial stock is added to dilute the interstitial content. It will be necessary to occasionally discard foundry scrap if the interstitial level becomes too high. This requirement can be minimized if electrode welding is conducted in an inert gas chamber.

7. An expendable rammed graphite mold has been found suitable for production casting of titanium alloys. Properties of the mold were developed and are presented and discussed in Section B of this report.

8. A graphite-base shell mold was developed, which with further development aimed at increasing its resistance to penetration, offers considerable potential as a production mold. At the present stage of development, shell graphite molds are suitable for small shapes.

9. Development of an investment graphite mold suitable for casting of titanium was partially accomplished. The successful development of such a mold appears feasible if based on the use of graphite.

10. Used rammed graphite mold materials were satisfactorily reused to make new molds.

11. Feeding characteristics were determined for titanium alloy Ti-6Al-4V cast in rammed and machined graphite molds.

12. Shrinkage porosity in cast titanium appears as distinct voids on the X-ray film, rather than as cloudy low-density areas.

13. Less taper is generally required in rammed than in machined graphite molds, for equivalent soundness.

14. Increasing the amount of taper progressively improves feeding distance in rammed molds. In the case of machined graphite molds the feeding distance decreased until taper exceeded three or four degrees, and then increased.

15. The effectiveness of taper decreases as the section thickness in increased.

16. The tapers required to cast sound sections were established in relation to thickness and are shown in Figure B18.

17. The use of heated molds did not appreciably improve the feeding of cast Ti-6Al-4V but did decrease the gas porosity problem, apparently because of reduced moisture pickup during mold assembly.

18. The feeding distance in shell graphite molds appeared to be significantly superior to rammed and machined graphite molds.

19. The feeding characteristics of centrifuge cast Ti-6Al-4V discs were not significantly different from the similar discs which were statically cast.

20. Castings which are centrifuge cast should be fed such that the metal enters the mold from the trailing side of the casting and from the outside (away from the centrifuge axis). This is necessary to minimize poor casting surface resulting from turbulent metal flow into the mold cavity.

21. Removal of gates and risers from the castings by power saw or abrasive cut-off wheel have been found to be satisfactory. Use of oxy-acetylene torch increases interstitial contamination of the scrap and requires excessive hand grinding to clean up the casting.

22. Grinding and belt sanding is satisfactory for primary clean up of titanium castings. Grit blasting is satisfactory for removal of mold particles and surface oxides. Sand blasting is satisfactory for final clean up.

23. A satisfactory acid solution and processing technique was developed for chemical removal of surface material from titanium castings.

24. For best fatigue properties, 0.015 inch per surface should be chemically removed from Ti-6Al-4V castings, using the solution and process developed.

25. At the present stage of development, unalloyed titanium and Ti-6Al-4V are suitable for "standard" casting alloys.

26. A satisfactory heat treatment to improve the properties of cast Ti-6Al-4V was not developed, the best properties being obtained in the as-cast condition.

27. Ti-2Cu casting alloy has ductility superior to cast unalloyed titanium which has been strengthened to the same level by interstitial additions.

28. The properties of a titanium casting alloy containing four to six per cent aluminum, four to six per cent tin, eight to ten per cent zirconium, and two to four per cent vanadium are slightly better than those of cast Ti-6Al-4V. Additional work is needed to establish the best composition for this alloy.

29. The effects of the interstitial and alloying elements in cast Ti-6Al-4V were determined. Composition limits were established.

30. Elevated temperature tensile properties for as-cast Ti-6Al-4V were determined.

31. Four of the five shapes selected for study as titanium alloy castings were successfully developed and produced. The fifth shape was too large for the available equipment.

32. Properties of the four developed shapes were compared with the corresponding production components by structural testing.

33. Statistically valid minimum design allowables were established for the as-cast Ti-6Al-4V alloy.

34. Minimum dimensional tolerances for design purposes were determined.

SECTION H

RECOMMENDATIONS

The following recommendations are based on the work done during this contract.

1. Further development of an investment casting mold and process is recommended.

2. Further development of casting alloys is recommended, aimed at higher strength properties.

3. Development of composition limits and a casting specification for the four to six per cent aluminum, eight to ten per cent zirconium, and two to four per cent vanadium titanium casting alloy is recommended, to take advantage of the superiority of this alloy over the Ti-6Al-4V casting alloy.

SECTION J

TABLES

TABLE J1

MELTING RECORD

Heat No.	Order No.	Material	MELTING Amps	MELTING Volt	MELTING Time Min.	MELTING Elect. Dia.	MELTING Cruci. Dia. in.	VACUUM - MICRONS Start	VACUUM - MICRONS During Melt	VACUUM - MICRONS After Pour	VACUUM - MICRONS 5 Min. Leak Rate	SKULL WT. Start Lb.	SKULL WT. Finish Lb.	Fluidity Spiral In.	Gross Heat Wt. Lb.	Net Heat Wt. Lb.	Percent Yield	Humidity Percent
F-1	22-1	Ti6Al-4V	12,000	40	3.05	6	9	44		175		6.56			52.25	26.81	51	
F-2	22-1	Ti5Al-4V	12,000	40	4.5	5-6	9	22	170	250		13.75			81.69	27.81	33.5	
F-3	22-1	Ti5Al-4V	12,000	40	3.2	4-5	9	50	125	50		19.0			70.75	29.69	42	
F-4	22-1	Ti6Al-4V	12,000	40	5.0	7	9	37	125	70		15.25			92.75	31.13	34	
F-5	22-2	Ti6Al-4V	12,000	40	6.25	4-5	9	100	175	300		21.25	22.063		99.50	21.19	21	
F-6	22-2	Ti6Al-4V	12,000	40	5.00	4-5	9	105	200	400		30.56			86.31	13.19	15	
F-7	22-1	Ti6Al-4V	12,000	40 42	5.6	4-5	9	40	150 200	250		13.61	15.75	22	97.94	25.19	25.5	
F-8	22-1	Reject-Foured Short																
F-9	22-1	Ti6Al-4V	12,000	42	6.7	4	9	45	125 175	200		18.0		14	92.063	21.0	22.8	
F-10	22-1	Ti6Al-4V	6,000 12,000	40 42	5.8	4	9	50	125 175	200		35.44		16	92.063	18.69	20.4	
F-11	22-1	Ti6Al-4V	12,000	42	4.8	3-7	9	50	175 200	275		27.75	16.31	18.25	90.44	22.063	24.4	
F-12	22-1	Ti6Al-4V	12,000	41	4.9	4-5	9	40	50 175	175		33.31	15.0	14.5	86.13	16.62	19.3	
F-13	22-1	Ti6Al-4V	12,000	40	5.0	4-7	9	37	45 180	180		28.50	17.94	16.75	96.50	18.50	19.2	
F-14	22-1	Ti6Al-4V	12,000	40	5.0	4-9	12	100	125 250	250		37.25	17.88	18.25	118.19	15.063	12.75	
F-15	22-1	Ti6Al-4V	7,000 12,000	40 42	5.35	4-7	9	50	60 150	200		20.75		18.38	91.37	18.0	19.7	
F-16	22-1	Ti6Al-4V	12,000	40	5.35	4-10	12	60	40 175	250		21.50	14.0	16	94.56	18.13	19.2	
F-17	22-1	Ti6Al-4V	12,000	40	5.35	4-7	9	60	70 190	250		22.37	16.25	16	93.37	16.0	17.1	
F-18	22-2	Ti6Al-4V	12,000	40	5.7	4	9	200	200 300	500		16.25	14.13	13	93.62	13.81	14.8	
F-19	22-5	Ti6Al-4V	12,000	40	4.97	4-5	9	200	250	525		24.13	14.0	Reject	97.0	19.88	20.5	
F-20	22-5	Ti6Al-4V	12,000	40	5.0	4-5	9	50	175	225		30.0	14.0	13	92.56	14.25	15.4	
F-21	22-1	Ti6Al-4V	12,000	40	3.5	3-7	9	80	200	250		21.25	13.50		130.25	39.37	30.3	
F-22	22-7	Ti4Al-4Mn	12,000	33 42	5.9	7	9	70	400	100		15.19				9.94		
F-23	22-5	Ti6Al-4V	12,000	40	5.0	4-7	9	70	200	350		21.50	18.62		106.063	15.25	14.5	
F-24	22-7	Ti4Al-4Mn	Reject															
F-25	22-5	Ti6Al-4V	12,000	42	6.0	6-7	12	150	300	750		40.69	24.69	16	127.75	21.75	16.5	
F-26	22-6	Ti5Al-2½Sn	12,000	40	5.4	9	9	100	80 175	200		33.69	22.31	16	101.37	33.81	33.5	
F-27	22-5	Ti6Al-4V	12,000	40	4.75		9	70	100 250	300		38.13	17.0	18.25	96.37	15.37	16.0	
F-28	22-1	Ti6Al-4V	12,000	40	2.9		9	45	175	225		30.88	24.62	None	51.0	28.62	56.5	

TABLE J1 (Continued)

MELTING RECORD

Heat No.	Order No.	Material	MELTING Amps	Volt	Time Min.	Elect. Dia.	Crucible Dia. in.	VACUUM - MICRONS Start	During Melt	After Pour	5 Min. Leak Rate	SKULL WT. Start Lb.	Finish Lb.	Fluidity Spiral In.	Gross Heat Wt. Lb.	Net Heat Wt. Lb.	Percent Yield	Humidity [illegible]
F-29	22-2	Ti6Al-4V	12,000	40	5.4		9	275	350	750		30.0	12.75	14	86.50	11.69	13.5	
F-30	22-1	Ti6Al-4V	12,000	40	4.7		9	70	300	300		25.13	13.50		65.0	13.81	21.4	
F-31	22-[illegible]	Ti6Al-4V	12,000	40	3.7	6	9	50	150	175		17.75	13.50	16	64.19	9.50	15.3	
F-32	22-1	Ti6Al-4V	12,000	42	4.6	4-6	9	45	250	200		33.13	14.37	13.5	93.66	20.62	22	
F-33	22-6	Ti5Al-2½Sn	12,000	40	5.0	4-7	9	70	150 200	175		36.81	19.0		93.66	32.44	34.6	
F-34	22-5	Ti6Al-4V	12,000	42	4.5	6	9	70	200	300		30.50	16.50	14	92.0	15.44	17.9	
F-35	22-2	Ti6Al-4V	12,000	40	4.35	6	9	70	150	350		30.0	15.44	12	83.50	11.66	14.25	
F-36	22-5	Ti6Al-4V	12,000	40 42	5.6	6-9	12	250	300	750		40.0	29.25	Misrun	113.62	20.62	17.7	
F-37	22-2	Ti6Al-4V	12,000	40	4.8		9	150	150 300	500		34.37	16.25	13	100.37	16.56	16	
F-38	22-12	Ti13V-11Cr-2½Al	12,000	40	5.3	7	9	40	40 .00	150		6.19 (Turnings)	13.19	10	80.37	30.19	37.6	
F-39	22-[illegible]	Ti6Al-4V	12,000	40	3.2		9	100	200 300	250		34.0	13.0	None	74.25	42.13	56.7	
F-40	22-2	Ti6Al-4V	12,000	40	5.27		9	150	200 300	500		31.44	17.0	10	90.37	16.66	18.7	
F-41	22-[illegible]	Ti6Al-4V	12,000	42	3.92		9	70	70 250	275		26.13	10.86	16	75.50	15.50	20.5	
F-42	22-2	Ti6Al-4V	12,000	42	5.5	6	9	300	350	600		25.75	16.75	10	103.50	17.44	16.9	
F-43	22-2	Ti6Al-4V	12,000	40	3.75		12	65	290	250		33.31	28.81	12	70.37	10.13	14.4	
F-44	22-12	Ti13V-11Cr-2½Al	12,000	42	2.63		9	75	150	200		21.053	10.50	12	50.0	21.0	42	
F-45	22-5	Ti6Al-4V			5.3	6	12	150	225	500		54.62	20.75	16	146.25	24.063	16.25	
F-46	22-13	Ti13V-11Cr-4Al	12,000	36	5.65	7	9	45	70	175		5.75 (Turnings)	12.81	12.6	80.31	29.81	37.2	
F-47	22-2	Ti6Al-4V	12,000	40	5.75		9	225	225 325	600		32.81	18.86	13	102.0	12.94	12.7	
F-48	22-[illegible]	Ti6Al-4V	12,000	40	4.05		9	80	250	275		31.0	14.75	16	81.75	14.56	16.65	
F-49	22-[illegible]	Ti6Al-4V	12,000	42	1.3		9	70	175	175		20.8	12.86	None	31.0	16.063	51.75	
F-50	22-5	Ti6Al-4V	12,000	40	6.36	6	12	200	250	550		34.0	21.86	17	121.62	25.62	21	
F-51	22-5	Ti6Al-4V	12,000	40	6.2		9	55	150	250		20.19	25.19	15	69.0	16.25	23.5	
F-52	22-13	Ti13V-11Cr-4Al	12,000	40	2.05		12	60	60 160	200		17.0	11.0	None	46.19	21.56	44.75	
F-53	22-[illegible]	Ti6Al-4V	12,000	42	5.2		9	60	60 250	225		37.0	16.56	17	53.86	26.75	28.5	
F-54	22-5	Ti6Al-4V	12,000	40	4.3		9	70	70 250	800		23.31	17.94	12.5	86.56	14.86	17.2	
F-55	22-1	Ti13V-11Cr-1½Al	12,000	38	5	7	9	70	10 150	175		11.19	13.56	11	83.62	32.86	39.2	
F-56	22-2	Ti6Al-4V	12,000	40	6.25	6	9	150	150 200	800		23.75	14.81	14.5	98.75	12.19	12.3	
F-57	22-2	Ti6Al-4V	12,000	42	5.5	6	9	125	125 300	600		27.81	20.0	14	92.81	12.37	13.35	

TABLE J1 (Continued)

MELTING RECORD

Heat No.	Order No.	Material	MELTING Amps	MELTING Volt	MELTING Time Min.	MELTING Elec. Dia.	MELTING Crucible Dia. in.	VACUUM - MICRONS Start	VACUUM - MICRONS During Melt	VACUUM - MICRONS After Pour	VACUUM - MICRONS 5 Min. Leak Rate	SKULL WT. Start Lb.	SKULL WT. Finish Lb.	Fluidity Spiral in.	Gross Heat Wt. Lb.	Net Heat Wt. Lb.	Percent Yield	Humidity Percent
P-58	22-1	Ti6Al-4V	12,000	40	1.35		9	150	150 250	400		24.19	16.88	None	18.44	11.31	61.5	
P-59	22-23	CP Ti	12,000	40	4.2	6.5	9	50	0 150	125		10.31	19.37	None	62.75	5.56	8.85	
P-60	22-23	CP Ti	12,000	40	4.5	6.5	9	60	10 175	30		11.0	15.69	None	56.94	5.56	9.78	
P-61	22-11	Ti13V-11Cr 3Al	12,000	42	2.35		9	60	150 175	200		21.0	10.62	None	49.94	23.31	46.75	
P-62	22-10	Ti13V-11Cr	12,000	36 40	5.30	7	12	70	15 225	225		11.0	13.13	10	88.62	32.94	37	
P-63	22-1	Ti5Al-4V	12,000	40	5.25		9	70	225	275		29.31	16.0	6.5	102.13	20.69	20.2	
P-64	22-19	Ti7Al-3Mo	12,000	40	8.62	7	9	70	80 100	170		2.31	19.25	23	88.62	30.69	34.6	
P-65	22-16	Ti5½Al-5½V .45 Fe, 2 Sn .25 Cu	10,000	40	7.80	7	9	50	100 225	175		9.50	22.75	13	84.94	29.69	35	
P-66	22-10	Ti13V-11Cr	12,000	40	5.20		9	55	20 180	150		26.56	5.75	9	60.75	26.69	44	
P-67	22-5	Ti6Al-4V	12,000	42 44	6.40		12	250	350	Off Scale		40.0	19.19	None	132.75	15.0	11.3	
P-68	22-19	Ti7Al-3Mo	2,000	36 38	4.60	7	9	60	15 150	190		31.37	20.25	18.5	93.62	29.75	31.8	
P-69	22-16	Ti5½Al, 5½V, .45Fe, 2Sn, .25Cu	12,000	40- 42	4.75	7 + Recycle	9	30	80- 175	225		32.75	20.0	17	93.37	30.62	32.9	
P-70	22-1	Ti6Al-4V	12,000	40	5.6	Recycle	9	150	300	750		30.52	18.62	14	105.31	17.063	16.2	
P-71	22-1	Ti6Al-4V	12,000	40	5.70	Recycle	9	80	200 300	1000		32.37	15.0	16	96.37	17.56	17.85	
P-72	22-9	Ti6Al-4V	12,000	40	3.00	Recycle	9	35	35 150	150		17.50	11.88	None	55.44	15.063	27.2	
P-73	22-5	Ti6Al-4V	12,000	40	5.45	Recycle	9	100	275 300	550		28.19	17.19	14.5	97.81	16.50	16.9	
P-74	22-1	Ti6Al-4V	12,000	40	4.45	7	9	45	250	300		28.59	17.50	None	84.56	26.25	31.0	
P-75	22-1	Ti6Al-4V	12,000	40	4.63	6	9	50	200	275		26.62	17.0	None	83.56	25.31	30.2	
P-76	22-1	Ti6Al-4V	12,000	40	4.80	6	9	25	250 on Recy. 175 on 6T666	250		26.81	17.56	None	85.56	21.94	25.6	
P-77	22-1	Ti6Al-4V	12,000	40	5.85	7	9	30	30-325	250		27.0	16.66	None	84.88	22.37	26.6	
P-78	22-1	Ti6Al-4V	12,000	40	5.12	Recycle	9	30	150-200	250		25.0	14.31	None	87.50	30.75	35.2	
P-79	22-1	Ti6Al-4V	12,000	40	5.10	Recycle	9	25	25-250	250		24.0	14.69	None	85.37	27.56	32.3	
P-80	22-1	Ti6Al-4V	12,000	40	1.90	Recycle	9	55	55-225	250		30.44	11.61	None	39.0	10.25	26.3	
P-81	22-1	Ti6Al-4V	12,000	40	1.85	Recycle	9	60	60-175	175		16.0	12.19	None	29.37	8.75	29.8	
P-82	22-1	Ti6Al-4V	12,000	40	5.00	Recycle	9	35	35-225	250	8/min.	28.0	14.75	None	82.69	25.44	30.8	
P-83	22-1	Ti6Al-4V	12,000	40	1.95	Recycle	9	28	100	125	5/min.	14.75	11.13	None	31.62	9.21	30.13	
P-84	22-1	Ti6Al-4V	12,000	42	5.95	Recycle	9	50	50-275	200		27.0	13.81	None	85.75	25.19	29.6	
P-85	22-1	Ti6Al-4V	—	—	1.95	Recycle	9	50	150-200	175		15.0	9.75	None	30.19	7.81	25.8	

TABLE J1 (Continued)

MELTING RECORD

Heat No.	Order No.	Material	MELTING Amps	Volt	Time Min.	Elect. Dia.	Crucible Dia in.	VACUUM - MICRONS Start	During Melt	After Pour	5 Min. Leak Rate	SKULL WT. Start Lb.	Finish Lb.	Fluidity Spiral In.	Gross Heat Wt. Lb.	Net Heat Wt. Lb.	Percent Yield	Humidity Percent
[illegible]	[illegible]	[illegible]	[illegible]	42	4.05	Recycle	9	60	70-160	160		9.75		None	20.75	9.62	46.4	
[illegible]	22-	[illegible]	12,000	42	6.00	6	9	150	300-350	750		30.37	16.0	None	57.56	14.56	14.9	
[illegible]	22-	[illegible]	12,000	40	3.33	Recycle	9	50	125-200	225		24.0	14.75	None	51.063	24.50	26.9	
[illegible]	22-	[illegible]	2,000	40	[illegible]	6	9	90	150-200	225		18.0	12.25	None	21.56	9.62	45.7	
[illegible]	22-	[illegible]	2,000	40	6.23	Recycle	9	100	250	400		12.13	15.0	None	75.13	21.063	28.0	
[illegible]	22-5	[illegible]	2,000	40	5.25	Recycle	9	45	160	500	6/min.	18.0	11.19	None	53.0	See foot note.(1)		
[illegible]	[illegible]	[illegible]	12,000	42	4.20	Recycle	9	200	200-300	300		24.0		None	67.063	21.063	24.2	
[illegible]	[illegible]	[illegible]	2,000	42	5.82	Recycle	9	175	175-300	375	14/min.	22.0	11.44	None	91.19	19.88	21.8	
[illegible]	[illegible]	[illegible]	4,000	40	3.50	-	9	170	170-230	500	15/min.	17.0	11.88	None	77.25	21.19	27.4	
[illegible]	[illegible]	[illegible]	4,000	40	4.13	-	9	45	140	170	6/min.	17.25	13.19	None	88.69	24.62	28.0	
[illegible]	[illegible]	[illegible]	4,000	40	4.10	-	9	125	150	300		20.0	11.25	15.375	62.81	13.19	15.9	
[illegible]	[illegible]	[illegible]	4,000	42	--	7	9	170	75	450	18/min.	14.0	10.19	None	72.50	21.0	20.9	
[illegible]	22-	[illegible]	12,000	42	4.75	Recycle	9	100	100-250	760		28.56	13.44	14.5	94.56	15.94	16.9	
[illegible]	[illegible]	[illegible]	12,000	40	3.45	Recycle	9	50	175	160	3/min.	16.88	9.31	None	27.44	9.50	34.5	
[illegible]	[illegible]	[illegible]	2,000	42	4.85	Recycle	9	65	250	600	3/min.	14.0	2.25	14	78.94	21.063	31.8	
[illegible]	[illegible]	[illegible]	4,000	42	4.45	-	9	40	60	170	11/min.	17.50	12.50	None	74.50	24.69	33.2	
[illegible]	[illegible]	[illegible]	4,000	42	[illegible]	Recycle	9	45	160	220	7/min.	14.81	15.81	15.5	75.81	13.063	16.4	
[illegible]	22-	[illegible]	3,000	42	4.82	-	9	150	210	300	10/min.	15.56	12.19	None	75.62	21.25	28.0	
[illegible]	[illegible]	[illegible]	12,000	42	3.00	Recycle	9	150	225	400	10/min.	16.0	12.13	16.750	75.19	10.31	13.0	
[illegible]	[illegible]	[illegible]	2,000	40	5.40	Recycle	9	75	180	240	41/min.	22.50	17.19	None	75.50	24.66	33.0	
[illegible]	[illegible]	[illegible]	11,500	42	5.95	Recycle	9	80	190	500	28/min.	19.25	17.0	17	75.063	22.81	29.0	
[illegible]	[illegible]	[illegible]	13,000	42	[illegible]	Recycle	12	125	240	465	21/min.	32.25	22.50	13.875	133.56	23.063	17.22	
[illegible]	[illegible]	[illegible]	2,000	4	6.27	Recycle	9	60	225	300	35/min.	22.25	17.75	10.50	79.68	13.62	16.58	
[illegible]	22-	[illegible]	,500	42	5.30	Recycle	9	75	160	400	27/min.	23.75	15.25	None	81.37	20.94	25.75	
[illegible]	[illegible]	[illegible]	14,000	42	5.10	7	9	135	165	450	5/min.	21.37	13.063	14.250		See note (2)		
[illegible]	22-	[illegible]	2,000	42	5.25	Recycle	9	140	250	450	18/min.	24.44	18.0	None	84.37	20.94	24.8	
[illegible]	[illegible]	[illegible]	12,000	42	2.00	Recycle	9	65	165	180	7/min.	20.0	12.81	None	38.62	4.62	10.31	
[illegible]	22-	[illegible]	12,000	40	5.25	Recycle	9	85	245	450	5/min.	18.063	14.25	None	77.37	21.37	27.60	
[illegible]	22-	[illegible]	12,500	42	6.15	Recycle	9	55	200	400	17/min.	18.0	19.0	None	93.0	22.37	24.0	
[illegible]	[illegible]	[illegible]	12,500	40	5.40	Recycle	9	40	250	300	14/min.	17.0	115.44	None	88.0	8.62	9.8	
[illegible]	22-5	[illegible]	2,000	42	3.45	Recycle	9	65	175	250	9/min.	15.0	11.56	None	52.19	11.0	21.1-Reject	
[illegible]	22-	[illegible]	12,000	42	6.40	Recycle	9	25	175	250	19/min.	15.0	16.50	None	94.50	24.69	26.1	
[illegible]	22-	[illegible]	12,000	42	4.30	Recycle	9	60	250	400	6/min.	32.25	14.0	None	82.56	22.37	26.1	
[illegible]	22-2	[illegible]	12,500	42	5.75	Recycle	9	100	175	345	12/min.	20.19	18.0	17	64.50	9.62		
[illegible]	22-	[illegible]	N.R.	--	--	Recycle	9	45	125-150	200	27/min.	22.56	15.0	None	87.13	24.69	28.30	

Foot Note: 1. Shell Core collapsed when poured.

2. Contaminated scrap. Plug in mold came loose.

TABLE J1 (Continued)

MELTING RECORD

Heat No.	Order No.	Material	Melting: Amps	Volt	Time Min.	Elect. Dia.	Crucible Dia. in.	Vacuum - Microns: Start	During Melt	After Pour	5 Min Leak Rate	Skull Wt.: Start Lb.	Finish Lb.	Fluidity Spiral in.	Gross Heat Wt. Lb.	Net Heat Wt. Lb.	Percent Yield	Humidity Percent
F-1[illegible]	22-[illegible]	Ti6Al-4V	12,000	40	6.15	Recycle	9	100	175	350	24/min.	16.62	15.86	None	92.19	22.37	24.2	
F-1[illegible]	22-[illegible]	Ti6Al-4V	12,000	40	5.80	Recycle	9	100	175	400	28/min.	18.62	12.50	None	84.0	23.19	27.5	
F-12[illegible]	22-[illegible]	Ti6Al-4V	12,000	40	6.75	Recycle	9	60	150	410	27/min.	16.0	16.19	None	85.0	22.69	25.8	
F-12[illegible]	22-[illegible]	Ti6Al-4V	12,000	40	5.75	Recycle	9	70	160	350	30/min.	19.0	16.37	None	86.50	22.063	25.6	
F-12[illegible]	22-[illegible]	Ti6Al-4V	12,000	40	5.30	Recycle	9	70	160	350	12/min.	25.0	13.0	None	84.25	21.75	25.8	
F-12[illegible]	22-[illegible]	Ti6Al-4V	12,000	40	6.19	Recycle	9	175	175-240	400	12/min.	17.0	11.25	None	87.50	21.81	25.0	
F-12[illegible]	22-[illegible]	Ti6Al-4V	12,000	40	5.20	Recycle	9	60	160	250	24/min.	30.19	11.37	None	85.37	23.62	23.8	
F-129	22-5	Ti6Al-4V	12,000	40	6.30	Recycle	9	80	175	500	23/min.	19.86	14.19	17.750	99.75	24.25	24.2	
F-1[illegible]		Hit water in pot did not pour							Broke		2/min.	35.0	17.50	16.50	100.0	25.37	25.6	
F-13[illegible]	22-[illegible]	Ti6Al-4V	12,000	40	6.40	Recycle	9	45	175	350	21/min.	15.0	25.0	None	79.0	11.13	14.2	
F-13[illegible]	22-5	Ti6Al-4V	12,000	40	5.64	Recycle	9	250	Gage	350	22/min.	25.0	13.69	None	92.62	21.69	23.40	
F-13[illegible]	22-[illegible]	Ti6Al-4V	12,000	40	6.52	Recycle	9	40	160	600	14/min.	23.0	13.69	None	86.37	25.13	29.2	
F-13[illegible]	22-[illegible]	Ti6Al-4V	12,000	40	5.46	Recycle	9	175	250									
F-13[illegible]		No record.																
F-13[illegible]		Reject Electrode broke																
F-137	22-[illegible]	Ti6Al-4V	12,000	40	6.90	Recycle	9	65	350	500	5/min.	12.81	22.56	16.0	115.37	12.94	11.1	
F-13[illegible]	22-[illegible]	Ti6Al-4V	12,000	40	6.20	Sample Slices 6"	9	Electrode Broke did not pour										
F-1[illegible]	22-1[illegible]	Ti-8V-5Fe	2,000	40	5.66	7	9	75	120	155	5/min.	10.13	14.44	None	61.13	23.62	38.6	
F-140	22-1[illegible]	Ti-8V-5Fe-1Al	2,000	40	6.29	7	9	60	60	125	18/min.	10.0	18.0	4.5	80.0	23.44	29.2	
F-14[illegible]	22-[illegible]	Ti6Al-4V	4,000	40	3.47	Recycle	9	65	200	235	9/min.	17.37	10.13	None	39.56	5.13	12.9	
F-14[illegible]	22-[illegible]	Ti6Al-4V	4,000	40	5.51	Recycle	12	75	200	600	8/min.	40.0	33.0	15.5	100.50	17.44	16.6	
F-13[illegible]	22-[illegible]	Ti6Al-4V	2,000	40	6.0	Recycle	9	250	215	750	15/min.	14.75	15.19	None	88.81	23.37	37.5	40
F-14[illegible]	22-[illegible]	Ti6Al-4V	2,000	40	5.65	Recycle	12	100	200	300	10/min.	36.37	16.44	None	112.13	23.56	4.7	
F-1[illegible]	22-[illegible]	Ti5Al-2½[illegible]	2,500	40	3.53	7	9	150	200	250	20/min.	10.25	9.0	None	48.25	21.13	44.7	
F-1[illegible]	22-[illegible]	Ti6Al-4V	2,000	40	1.45	Recycle	9	120	175	200	10/min.	14.0	8.94	None	18.44	9.37	50.1	31
F-14[illegible]	22-31	Ti-[illegible]	2,000	40	3.80	"	9	260	190	250	10/min.	9.50	6.25	16	38.94	11.62	30.5	
F-14[illegible]	22-2[illegible]	Ti-4Al-3Mo-1V	2,500	40	3.72	7	9	160	50	150	10/min.	10.0	8.69	22	50.0	11.44	22.4	
F-14[illegible]	22-2[illegible]	Ti6Al-4Mo	3,500	40	3.97	"	9	150	80	200	3/min.	10.0	8.94	24	56.13	11.62	20.6	
F-14[illegible]	22-2[illegible]	Ti-6¾Al-3½Mo-1V	2,000	36	6.10	7	9	90	140	210	7/min.	10.0	14.56	17.25	82.0	22.063	26.9	
F-15[illegible]	22-[illegible]	Ti-[illegible]	2,000	40	4.26	7	9	100	185	250	10/min.	9.0	8.13	14.75	62.37	11.25	17.56	
F-15[illegible]	22-1[illegible]	Ti6Al-2Nb-1Ta	2,000	36		7	9	90	150	250	4/min.	8.0	10.56	22	61.69	13.69	22.1	
F-1[illegible]	22-2	Ti-[illegible]	12,000	40	4.93	7	9	200	250	750	10/min.	6.50	9.37	15	62.0	14.69	23.6	
F-1[illegible]	22-[illegible]	Ti6Al-4V	12,000	40	4.75	5"x14	12	50	350	400	2/min.	22.50	18.25	None	88.86	25.37	28.6	
F-1[illegible]	22-[illegible]	Ti6Al-4V	12,000	40	5.40	Recycle	12	90	200	300	8/min.	40.0	22.81	None	96.37	25.44	26.4	
F-155	22-2	Ti6Al-4V	12,000	42	5.20	Recycle	9	200	400	1,000	5/min.	22.37	15.81	None	92.0	11.063	12.1	
F-156	22-[illegible]	Ti6Al-4V	12,000	42	5.10	Recycle	9	200	265	400	5/min.	27.[illegible]5	14.56	13	90.44	10.62	11.8	
F-15[illegible]	22-[illegible]	Ti6Al-4V	12,000	40	6.38	Recycle	9	200	250	425	3/min.	26.0	18.19	None	100.50	13.62	12.9	
F-15[illegible]	22-6	Ti6Al-4V	12,000	42	5.20	Recycle	12	130	250	300	2/min.	33.31	19.063	None	98.44	13.44	13.7	44
F-15[illegible]	22-[illegible]	Ti6Al-4V	12,000	42	5.65	Recycle	12	300	400	1,000	10/min.	28.19	22.62	None	105.13	12.56	11.9	
F-1[illegible]	22-[illegible]	Ti6Al-4V	12,000	42	3.08	Recycle	9	35	100	200	2/min.	11.56	19.69	None	34/44	5.62	16.0	37

TABLE J1 (Continued)

MELTING RECORD

Heat No.	Order No.	Material	MELTING Amps	Volt	Time Min.	Elect. Dia.	Crucible Dia. in.	VACUUM - MICRONS Start	During Melt	After Pour	5 min. Leak Rate	SKULL WT. Start Lb.	Finish Lb.	Fluidity Spiral in.	Gross Heat Wt. Lb.	Net Heat Wt. Lb.	Percent Yield	Humidity Percent
F-10[illegible]	22-2	TiCAl-4V	12,000	42	3.06	Recycle	9	35	100	200	2/min.	11.56	19.69	None	34.44	5.62	16.0	37
[illegible]	22-[illegible]	TiCAl-4V	12,000	42	5.69	Recycle	12	275	400	750	15/min.	16.50	14.75	None	93.88	25.75	27.6	
F-102	22-[illegible]	TiCAl-4V	12,000	42	6.32	Recycle	9	175	225	300	10/min.	16.75	13.75	None	76.37	25.50	33.5	54
F-103	22-[illegible]	TiCAl-4V	12,000	42	6.25	Rectang.	9	25	250	500	7/min.	24.62	18.31	None	96.13	26.37	27.7	29
F-10[illegible]	22-35	5Mo-6V-2[illegible]	12,500	40	2.57	7	9	40	50	90	2/min.	9.0	9.0	None	40.31	14.44	35.8	35
F-[illegible]	22-25	2Fe-2Cr-2Mo	12,500	40	4.35	7	9	70	60	60	3/min.	10.0	13.25	None	59.44	21.44	36.2	30
F-1[illegible]	22-2[illegible]	6Al-1Mo-1V	12,500	42	4.49	7	9	30	40	40	5/min.	10.0	9.69	17	63.44	26.25	41.4	29.5
F-1[illegible]	22-[illegible]	TiCAl-4V	12,000	40	6.60	Rectang.	9	50	125	300	4/min.	19.75	18.88	None	87.69	23.81	27.3	34
F-1[illegible]	22-	TiCAl-4V	12,000	42	5.20	Recycle	9	200	250	500	7/min.	25.62	17.69	None	91.37	24.75	27.0	30
F-[illegible]	22-[illegible]	TiCAl-4V	12,000	42	5.60	Bar Stk	9	35	250	600	3/min.	22.50	10.75	None	97.0	23.88	24.6	34
F-[illegible]	22-	Ti6Al-4V	10,000	40	2.29	Recycle	9	70	-	-	12/min.	14.62	56.50	None	Elect.	Broke-No	Pour	36
F-[illegible]	22-[illegible]	Ti6Al-4V	12,500	42	6.37	Recycle	9	60	200	750	3/min.	14.50	11.56	None	66.50	24.44	26.2	37
F-1[illegible]	22-[illegible]	Ti6Al-4V	12,500	42	6.56	Recycle	9	250	350	850	20/min.	14.81	13.31	None	67.68	24.37	27.7	37
F-[illegible]	22-1	Ti6Al-4V	12,500	42	6.34	Recycle	9	190	250	750	20/min.	13.19	13.75	None	81.0	23.44	26.9	37.5
F-[illegible]	22-	TiCAl-4V	12,000	42	5.31	Recycle	9	165	500	1,000	15/min.	30.0	18.50	None	99.75	24.56	24.6	34
F-[illegible]	22-	Ti6Al-4V	12,000	44	3.98	Recycle	9	200	350	1,000	10/min.	44.56	14.063	None	90.44	24.75	26.6	35
F-[illegible]	22-	Ti6Al-4V	12,000	42	4.95	Recycle	9	150	350	1,000	20/min.	28.19	14.13	None	83.25	25.50	30.7	39
F-[illegible]	22-	Ti6Al-4V	12 000	42	4.95	Recycle	12	100	250	350	10/min.	23.81	22.50	None	86.063	26.56	31.2	37
F-[illegible]	22-[illegible]	Ti6Al-4V	12,000	42	4.39	Recycle	9	100	150	200	6/min.	13.69	20.69	None	70.50	26.62	37.6	36
F-[illegible]	22-[illegible]	Ti6Al-4V	12,000	42	5.21	Recycle	12	35	110	250	2/min.	28.50	25.19	None	87.44	27.31	31.3	37
F-18[illegible]	22-2c	[illegible] Al Ti	12-[illegible]000	36	5.00	7	9	45	95	150	4/min.	10.50	6.81	None	74.31	16.81	26.2	35
F-1[illegible]	22-33	12 Mo Ti	12,000	42	2.73	7	9	60	50	100	6/min.	12.19	7.75	6	39.44	9.19	23.3	34
F-[illegible]	22-4c	3 Mo [illegible] Be	12,000	42	3.61	7	9	45	50	100	3/min.	11.62	22.56	None	40.19	14.61	35.3	35
F-1[illegible]	22-4c	6Al-4V-1Si	12,500	40	4.13	7	9	70	80	200	5/min.	11.56	9.94	10	55.37	15.56	26.1	33
F-1[illegible]	22-[illegible]	6Al-4V	12,000	42	6.32	Recycle	9	225	300	1,000	15/min.	27.62	14.50	None	99.0	25.25	25.5	33
F-1[illegible]	22-	6Al-4V	11,250	42	6.90	Recycle	9	105	300	1,000	6/min.	17.25	13.50	None	90.75	24.25	27.1	34
F-1[illegible]	22-1	6Al-4V	12,500	42	6.80	Recycle	9	160	600	750	16/min.	17.25	20.13	None	99.19	12.31	12.4	36
F-[illegible]	22-5	6Al-4V	12,000	42	3.32	Recycle	9	125	250	750	10/min.	25.0	10.44	None	47.063	21.81	46.4	52
F-[illegible]	22-[illegible]	6Al-4V	13,000	42	2.62	Recycle	9	70	250	1,000	6/min.	17.0	8.19	None	31.94	6.81	21.7	40
F-[illegible]	22-3c	6Al	13,000	42	4.0	7	9	50	25	95	7/min.	11.0	14.44	14	54.25	22.50	35.1	36
F-[illegible]	22-3	6Al	13,000	40	3.37	7	9	90	70	150	20/min.	13.0	13.37	1.7	65.81	21.44	32.1	
F-[illegible]	22-[illegible]	6Al-4V	13,500	42	10.07	Recycle	12	250	400	1,000	5/min.	30.0	37.56	None	193.94	28.13	14.1	28
F-[illegible]	22-3[illegible]	6Mo-7½V	12,000	36	3.32	7	9	50	35	85	6/min.	10.0	8.86	9	39.063	8.56	21.9	54
F-[illegible]	22-3c	2.0V-2Mo	12,500	40	2.92	7	9	60	70	90	15/min.	12.0	6.81	11	41.69	8.86	21.3	51
F-[illegible]	22-[illegible]	6Al-4V	14,000	42	10.86	8	12	180	400	1,000	5/min.	44.13	45.56	15	192.0	31.25	16.3	22
F-[illegible]	22-1	6Al-4V	12,500	41	4.66	Recycle	12	200	450	1,000	9/min.	46.13	33.13	None	93175	25.69	27.4	25
F-9[illegible]	22-1	6Al-4V	12,000	42	5.25	Recycle	12	200	450	1,000	9/min.	45.37	23.56	None	102.0	25.56	25.0	25
F-[illegible]	22-[illegible]	6Al-4V	14,000	42	4.99	Recycle	9	100	350	700	12/min.	30.0	15.0	17	94.37	9.94	10.5	45
F-[illegible]	22-6	6Al-4V	14,000	42	5.14	Recycle	9	45	400	1,000	20/min.	25.0	13.31	15	97.56	13.50	13.8	36
F-[illegible]	22-6	6Al-4V	13,000	42	5.44	Recycle	9	150	300	500	12/min.	30.0	19.0	14	89.44	12.88	14.4	42
F-200	22-	6Al-4V	12,500	42	4.79	Recycle	12	175	300	750	4/min.	34.50	27.50	None	94.50	25.50	27.0	25

TABLE J1 (Continued)

MELTING RECORD

Heat No.	Order No.	Material	MELTING Amps	MELTING Volt	MELTING Time Min.	MELTING Elect. Dia.	MELTING Crucible Dia. in.	VACUUM - MICRONS Start	VACUUM - MICRONS During Melt	VACUUM - MICRONS After Pour	VACUUM - MICRONS 5 Min. Leak Rate	SKULL WT. Start Lb.	SKULL WT. Finish Lb.	Fluidity Spiral In.	Gross Heat Wt. Lb.	Net Heat Wt. Lb.	Percent Yield	Humidity Percent
F-201	22-1	6Al-4V	15,000	42	8.34	8	12	175	350	1,000+	6/min.	34.62	14.69	None	81.19	23.0	12.7	27
F-202	22-4	Ti-2Cu	13,000	36	2.61	7	9	30	60	70	8/min.	9.94	9.56	None	37.75	6.50	17.2	44
F-203	22-37	Ti-15V-2Mo	13,000	42	2.34	7	9	40	65	10	5/min.	10.0	7.37	13	40.94	9.0	22.0	39
F-204	22-38	Ti-25V	13,000	40	2.86	7	9	60	30	10	7/min.	11.0	5.69	15	40.13	9.063	22.6	37
F-205	22-39	Ti-20V	13,000	42	2.79	7	9	45	50	70	7/min.	11.56	7.50	15	41.13	9.13	21.9	32
F-206	22-2	6Al-4V	14,000	42	10.17	Recycle	12	160	420	1,000	5/min.	44.25	32.88	19	96.50	23.50	12.1	28
F-207	22-1	6Al-4V	12,500	42	2.65	Recycle	9	100	300	400	10/min.	13.31	7.31	None	20.56	9.50	46.4	38
F-208	22-1	6Al-4V	13,000	42	4.86	Recycle	12	60	250	400	20/min.	24.81	15.0	None	90.25	26.88	39.8	28
F-209	22-2	6Al-4V	13,000	42	9.58	Recycle	12	-	-	-	5/min.	34.50	30.81	14	176.44	23.25	13.0	29
F-210	22-5	6Al-4V	12,000	42	6.15	Recycle	9	50	300	725	11/min.	25.0	15.69	17	95.37	11.56	12.1	31
F-211	22-5	6Al-4V	12,500	42	5.36	Recycle	9	90	275	500	4/min.	15.31	14.25	None	70.31	15.0	21.3	30
F-212	22-1	6Al-4V	12,500	42	5.72	Recycle	9	60	275	400	6/min.	13.25	12.44	None	88.37	27.37	30.9	38
F-213	22-1	6Al-4V	13,000	42	4.47	Recycle	9	100	350	550	6/min.	15.0	10.0	None	65.37	8.063	12.3	38
F-214	22-1	6Al-4V	14,000	41	4.70	Recycle	9	32	250	500	1/min.	18.13	12.81	None	88.61	25.94	29.2	33
F-215	22-1	6Al-4V	13,000	42	4.84	Recycle	9	30	300	310	8/min.	22.50	14.13	None	88.88	27.25	20.7	42
F-216	22-1	6Al-4V	12,500	42	2.2	Recycle	9	35	200	250	9/min.	12.0	5.88	None	19.37	5.44	28.3	36
F-217	22-4	6Al-4V	12,000	42	6.16	Recycle	9	125	350	1,000	6/min.	19.13	5.44	17	92.81	10.50	11.3	37
F-218	22-2	6Al-4V	13,000	42	5.00	Recycle	9	100	300	1,000	10/min.	24.37	13.19	None	91.88	10.62	11.6	34
F-219	22-2	6Al-4V	-	-	-	Recycle	9	150	300	1,000	8/min.	24.0	31.62	None	Contaminated -	No pour		35
F-220	22-2	6Al-4V	15,000	44	10.	Recycle	12	110	255	770	7/min.	17.88	18.75	14	148.75	17.88	11.6	34
F-221	22-5	6Al-4V	15,500	43	6.04	7	12	325	500	1,000	17/min.	24.0	17.69	None	130.56	21.25	15.6	34
F-222	22-45	6Al-8Zr-1Cu	13,000	38	3.35	7	9	30	60	125	7/min.	17.0	9.25	16	54.75	11.13	20.3	44
F-223	22-42	6Al-2Cu	12,500	36	2.75	7	9	75	100	150	6/min.	11.0	9.25	None	37.75	5.063	13.4	45
F-224	22-6	6Al-4V	12,500	42	5.45	Recycle	9	50	350	700	4/min.	33.0	20.81	13	82.69	9.44	11.4	30
F-225	22-6	6Al-4V	1[illegible],500	42	6.52	Recycle	9	150	275	450	11/min.	23.0	19.62	14	95.94	13.063	14.2	40
F-226	22-7	6Al-13	13,000	42	3.7	7	9	120	175	350	10/min.	10.81	9.50	None	46.44	8.13	17.5	35
F-227	22-3	6Al-4V	1[illegible],500	42	4.8	Recycle	9	55	260	500	7/min.	17.88	12.56	21	64.13	15.50	24.2	35
F-228	22-3	6Al-4V	1[illegible],000	42	2.45	Recycle	9	50	175	1,000	8/min.	20.19	63.56	None	Electrode Broke -	No pour		32
F-229	22-3	6Al-4V	12,000	42	4.45	Recycle	9	105	275	500	4/min.	17.0	11.063	15	71.31	9.50	13.3	36
F-230	22-50	13Sn-10Zr-2Al	12,000	36	4.9	7	9	125	160	210	7/min.	10.0	9.25	15	54.44	9.62	16.7	37
F-231	22-4	6Al-4V	1[illegible],000	42	2.56	Recycle	9	45	200	1,000	9/min.	20.0	11.69	None	38.75	13.50	34.6	38
F-232	22-1	6Al-4V	12,000	42	4.65	Recycle	9	60	250	600	15/min.	17.69	11.75	None	72.88	10.0	13.7	35
F-233	22-40	5Mo-6V-2Ni-2Al	12,500	40	2.90	7	9	40	50	100	7/min.	9.0	10.0	10	38.0	8.50	22.4	28
F-234	22-49	6Al-6V-2Sn	13,000	39	3.44	7	9	50	-	-	7/min.	6.0	5.56	18	55.62	9.50	17.0	34
F-235	22-1	6Al-4V	12,500	42	4.95	Recycle	9	65	200	500	11/min.	19.50	11.81	None	68.50	9.13	13.3	38
F-236	22-51	13Sn-10Zr-4Al	12,500	39	3.58	7	9	50	100	250	5/min.	12.0	7.62	14	55.063	8.62	15.6	32
F-237	22-3	6Al-4V	13,000	42	3.25	Recycle	9	90	180	-	6/min.	20.0	70.69	None	Electrode Broke -	No pour		32
F-238	22-3	6Al-4V	12,000	41	4.90	Recycle	9	80	275	530	6/min.	20.0	10.25	19	73.62	15.063	20.4	-
F-239	22-3	6Al-4V	15,000	42	8.56	Recycle	9	35	250	1,000	10/min.	20.0	18.063	14	100.81	19.13	19.0	35
F-240	22-5	6Al-4V	12,500	42	4.49	Recycle	9	85	300	750	6/min.	25.0	14.37	14	87.75	12.13	13.8	33

TABLE J1 (Continued)

MELTING RECORD

Heat No.	Order No.	Material	MELTING Amps	Volt	Time Min.	Elect. Dia.	Crucible Dia. in.	VACUUM - MICRONS Start	During Melt	After Pour	5 Min. Leak Rate	SKULL WT. Start Lb.	Finish Lb.	Fluidity Spiral In.	Gross Heat Wt. Lb.	Net Heat Wt. Lb.	Percent Yield	Humidity Percent
[illegible]	[illegible]	6Al-4V	14,000	43	6.75	Recycle	9	105	375	1,000	5/min.	11.13	14.37	19	100.0	11.19	10.9	34
[illegible]	[illegible]	6Al-4V	13,000	42	5.95	Recycle	9	75	325	1,000	4/min.	17.25	20.44	20	100.31	11.37	11.3	40
[illegible]	[illegible]	6Al-4V	15,000	43	6.14	7	12	75	300	650	13/min.	17.69	14.37	13	110.56	11.81	10.2	33
F244	[illegible]	6Al-4V	14,000	42	5.60	Recycle	12	225	500	1,000	25/min.	27.37	15.88	18½	102.50	10.69	10.4	35
[illegible]	[illegible]	6Al-4V	11,000	43	7.06	7	12	30	37	89	8/min.	11.50	19.37	None	134.063	117.37	67.3	34
[illegible]	[illegible]	6Al-4V	14,000	43	4.6	Recycle	12	50	300	750	2/min	22.31	12.50	15	93.19	8.88	9.5	42
[illegible]	[illegible]	6Al-4V	12,000	42	6.20	Recycle	9	80	300	750	5/min.	18.75	0.37	14	95.44	9.0	9.4	36
[illegible]	[illegible]	6Al-4V	12,000	43	5.65	Recycle	9	80	260	700	8/min	23.0	6.13	14	87.44	9.0	10.3	40
[illegible]	[illegible]	6Al-4V	14,000	43	3.	[illegible]	9	37	54	54	6/min.	8.0	6.31	None	46.063	4.50	9.7	29
[illegible]	[illegible]	6Al-4V	15,000	43	6.10	Recycle	12	45	250	1,000	2.4/min.	17.0	7.0	None	102.88	19.37	18.8	43
[illegible]	[illegible]	6Al-4V	14,000	41	3.90	Recycle	9	35	250	500	6/min.	10.0	8.56	13	56.81	9.19	16.1	38
[illegible]	[illegible]	6Al-4V	12,000	42	3.24	Recycle	9	40	75	100	1.6/min.	9.25	6.063	None	38.62	4.44	11.6	39
[illegible]	[illegible]	6Al-4V	12,000	42	5.67	Recycle	9	75	300	1,000	4/min.	20.0	15.25	None	89.75	7.37	8.2	32
[illegible]	[illegible]	6Al-4V	12,000	41	3.	Recycle	9	80	200	300	7/min.	13.31	8.37	None	30.0	2.50	8.3	31
[illegible]	[illegible]	6Al-4V	12,000	42	3.10	Recycle	9	29	81	115	6/min.	10.37	5.61	None	31.19	4.69	15.0	32
[illegible]	[illegible]	6Al-4V	12,000	42	4.57	Recycle	9	100	250	750	5/min.	22.0	16.75	None	73.50	36.69	49.9	41
[illegible]	[illegible]	6Al-4V	13,000	42	5.20	Recycle	9	88	275	750	3/min.	30.0	13.063	None	44.19			38
[illegible]	[illegible]	6Al-4V	12,000	42	2.70	Recycle	9	50	200	200	10/min.	7.50	3.063	None	17.94	2.63	14.9	42
[illegible]	[illegible]	6Al-4V	12,000	4[illegible]	1.6	Recycle	9	38	93	112	1/min.	6.25	4.37	None	27.13	3.88	14.8	32
[illegible]	[illegible]	6Al-4V	13,000	42	6.45	Recycle	12	150	300	1,000	5/min.	21.62	16.50	16	36.31	22.19	20.4	41
[illegible]	[illegible]	6Al-4V	12,500	42	3.90	Recycle	9	125	250	1,000	5/min.	16.0	9.19	None	46.13	12.75	27.6	33
[illegible]	[illegible]	6Al-4V	1[illegible],000	41	6.67	Recycle	12	70	300	900	7/min.	21.50	17.44	None	67.37	15.44	17.7	45
[illegible]	[illegible]	6Al-4V	12,000	41	4.15	Recycle	9	60	250	500	4/min.	20.0	10.88	None	67.19	9.44	14.0	34
[illegible]	[illegible]	6Al-4V	12,000	42	4.50	Recycle	9	75	250	400	3/min.	24.50	13.50	15	70.69	12.13	17.1	32
[illegible]	[illegible]	6Al-4V	12,000	42	5.33	Recycle	9	35	250	600	7/min.	23.0	15.13	15	65.69	6.94	10.4	30
[illegible]	[illegible]	6Al-4V	13,000	43	.90	Recycle	9	110	200	275	7/min.	7.50	4.75	None	12.44	2.44	19.5	32
[illegible]	[illegible]	6Al-4V	14,000	42	2.61	Recycle	9	51	56	92	4/min.	9.0	6.0	None	35.063	4.50	12.8	31
[illegible]	[illegible]	6Al-4V	12,500	42	1.6	Recycle	9	125	175	275	9/min.	7.0	4.56	None	12.31	2.50	20.3	34
[illegible]	[illegible]	6Al-4V	13,000	42	5.9	Recycle	9	60	300	450	7/min.	21.0	15.94	None	69.50	25.44	26.5	40
[illegible]	[illegible]	6Al-4V	12,500	43	.94	Recycle	9	50	175	200	5/min.	7.0	4.61	None	11.62	2.44	20.9	30
[illegible]	[illegible]	6Al-4V	12,500	42	2.45	Recycle	9	200	150	175	4/min.	8.31	6.31	None	32.75	4.37	13.3	32
[illegible]	[illegible]	6Al-4V	12,500	42	1.9	Recycle	9	40	200	250	7/min.	8.0	4.88	None	13.0	2.50	19.2	32
[illegible]	[illegible]	6Al-4V	11,000	40	5.75	Recycle	9	80	240	400	5/min.	20.0	17.13	None	85.69	25.44	29.7	39
[illegible]	[illegible]	6Al-4V	12,000	42	2.7	Recycle	9	45	200	300	3/min.	20.0	7.063	None	33.50	8.25	24.8	34
F275	[illegible]	6Al-4V	13,000	42	6.30	Recycle	9	120	175	1,000	5/min.	[illegible]	21.62	None	93.69	13.94	14.9	40
[illegible]	[illegible]	6Al-4V	1[illegible],500	42	.55	Recycle	9	70	125	175	4/min.	7.0	4.88	None	10.69	2.25	21.1	40
[illegible]	[illegible]	6Al-4V	12,000	42	3.40	Recycle	9	75	220	300	5/min.	17.0	10.94	None	42.62	[illegible]	19.7	33
[illegible]	[illegible]	6Al-4V	12,000	42	6.40	Recycle	9	200	350	[illegible]	15/min.	26.0	16.0	None	92.56	[illegible]	14.3	46
[illegible]	[illegible]	6Al-4V	12,000	41	6.30	Recycle	9	200	350	[illegible]	[illegible]/min.	22.0	17.31	None	65.69	15.[illegible]	18.3	36
[illegible]	[illegible]	6Al-4V	12,000	42	1.92	Recycle	9	125	175	[illegible]	[illegible]/min.	13.75	5.69	None	26.13	4.50	17.2	39

TABLE J1 (Continued)

MELTING RECORD

[illegible]	[illegible]	[illegible]	MELTING Amps	Volt	Time Min.	Elect. Dia.	Crucible Dia. in.	VACUUM - MICRONS Start	During Melt	After Pour	5 Min. Leak Rate	SKULL WT. Start Lb.	Finish Lb.	Fluidity Spiral in.	Gross Heat Wt. Lb.	Net Heat Wt. Lb.	Percent Yield	Humidity Percent
[illegible]	[illegible]	[illegible]	12,000	42	5.50	Recycle	9	75	300	700	3/min.	21.0	15.44	None	65.75	16.94	19.8	30
[illegible]	[illegible]	[illegible]	12,000	42	1.42	Recycle	9	100	150	200	5/min.	11.0	5.0	None	20.0	4.66	24.3	31
[illegible]	[illegible]	[illegible]	12,000	42	1.30	Recycle	9	150	200	250	4/min.	7.0	4.62	None	13.0	3.25	25.0	35
[illegible]	[illegible]	[illegible]	12,000	42	3.25	Recycle	9	125	200	1,000	7/min.	23.0	6.37	None	42169	12.88	30.1	35
[illegible]	[illegible]	[illegible]	14,000	42	5.70	5	9	75	300	500	7/min.	6.0	6.13	16½	96.25	9.62	10.0	34
[illegible]	[illegible]	[illegible]	[illegible]	44	5.16	5 sq.	9	125	450	750	7/min.	6.0	6.13	15	96.75	9.56	9.7	3[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	4[illegible]	6.55	Recycle	9	45	200	750	5/min.	17.0	19.66	17	52.0	17.31	12.3	[illegible]9
[illegible]	[illegible]	[illegible]	[illegible]	3[illegible]	4.20	7	9	55	250	400	5/min.	10.75	14.25	6½	46.94	9.13	16.6	3[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	42	5.26	Recycle	9	60	300	750	3/min.	25.0	16.56	[illegible]	85.62	10.13	11.1	4[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	42	.5[illegible]	Recycle	9	40	120	145	.4/min.	6.66	4.75		17.62	4.37	20.4	3[illegible]
[illegible]	[illegible]	[illegible]	[illegible],000	44	6.25	Recycle	12	100	275	1,000	10/min.	31.0	23.[illegible]3	16	115.15	20.94	17.0	4[illegible]
[illegible]	[illegible]	[illegible]	[illegible],000	44	7.1[illegible]	Recycle	12	50	250	1,000	4/min.	25.0	22.62	17	130	[illegible].19	7.5	2[illegible]
[illegible]	[illegible]	[illegible]	[illegible],000	42	5.09	Recycle	9	50	200	600	4/min.	30.0	17.62		90.[illegible]	29.37	32.6	3[illegible]
[illegible]	[illegible]	[illegible]	[illegible],000	44	5.60	Recycle	9	125	250	750	5/min.	32.0	15.0		105.[illegible]3	24.13	22.8	3[illegible]
[illegible]	[illegible]	[illegible]	[illegible]000	42	6.15	Recycle	9	40	275	600	9/min.	23.0	15.31		90.[illegible]	42.19	47.[illegible]	3[illegible]
[illegible]	[illegible]	[illegible]	[illegible],000	44	3.2	-	9	50	225	350	3/min.	10.44	9.15	17	53.0	9.37	16.0	3[illegible]
[illegible]	[illegible]	[illegible]	[illegible]000	42	5.19	Recycle	9	50	275	375	3/min.	25.0	15.23		66.0	27.19	32.4	2[illegible]
[illegible]	[illegible]	[illegible]	[illegible]000	44	3.6	-	9	35	25	120	4/min.	10.0	6.13	22	30.75	9.25	32.1	3[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	4[illegible]	3.29	-	9				5/min.	10.25	12.25	9½	51.50	9.37	18.1	40
[illegible]	[illegible]	[illegible]	[illegible]000	42	3.66	-	9				2/min.	10.61	12.053	[illegible]	27.55	9.81	35.0	
[illegible]	[illegible]	[illegible]	[illegible]000	42	3.4	-	9	55	60	200	5/min.	10.75	12.0	[illegible]	46.17	9.56	19.6	39
[illegible]	[illegible]	[illegible]	[illegible]000	44	[illegible].37	7	9	30	50	150	2/min.	10.0	7.11	11	54.4	9.7	15.9	30
[illegible]	[illegible]	[illegible]	[illegible]000	4[illegible]	[illegible].31	7	9	50	35	125	3/min.	9.7	9.7	None	49.6	9.1	19.0	31
[illegible]	[illegible]	[illegible]	[illegible]000	42	.96	Recycle	9	47	107-125	125	1.6/min.	5.2	3.14	None	9.14	[illegible].3	21.6	--
[illegible]	[illegible]	[illegible]	3,500	42	4.90	Recycle	12	70	300	450	5/min.	37.0	20.25	None	105.0	19.16	17.5	30
[illegible]	[illegible]	[illegible]	15,000	42	7.50	Recycle	12	50	175	1,000	5/min.	30.0	21.14	15	155.[illegible]4	16.31	11.6	31
[illegible]	[illegible]	[illegible]	12,000	4[illegible]	7.55	Recycle	12	90	275	1,000	4/min.	36.0	28.12	15	141.15	17.24	12.[illegible]	32
[illegible]	[illegible]	[illegible]	3,500	42	7.20	Recycle	12	90	175	1,000	6/min.	41.0	26.4	18	156.6	17.72	11.3	36
[illegible]	[illegible]	[illegible]	14,000	44	7.30	Recycle	12	60	275	1,000	8/min.	30.0	25.4	13	135.7	13.53	9.5	36
[illegible]	[illegible]	[illegible]	[illegible]000	42	7.70	Recycle	12	100	290	--	5/min.	40.0	26.7	15	144.[illegible]	15.99	11.9	28
[illegible]	[illegible]	[illegible]	12,000	42	5.34	Recycle	9	125	270	750	6/min.	26.0	17.7	None	68.8	42.12	47.2	[illegible]
[illegible]	[illegible]	[illegible]	12,000	40	5.40	Recycle	9	25	200	300	1/min.	20.0	16.5	None	79.0	25.15	31.8	34
[illegible]	[illegible]	[illegible]	13,000	44	4.9[illegible]	Recycle	12	160	350	750	9/min.	30.0	17.31	16	100.64	14.55	14.4	30
[illegible]	[illegible]	[illegible]	12,000	43	2.66	Recycle	9	35	125	175	1.2/min.	12.67	6.14	18	36.14	2.19	5.7	36
[illegible]	[illegible]	[illegible]	2,000	42	3.02	Recycle	9	40	175	225	3/min.	21.0	7.14	None	26.9	11.62	-43.5	42
[illegible]	[illegible]	[illegible]	13,000	44	4.6[illegible]	Recycle	12	125	450	750	7/min.	30.0	21.0	15	66.1	19.04	22.[illegible]	28
[illegible]	[illegible]	[illegible]	12,000	42	4.60	Recycle	12	55	250	350	6/min.	30.0	16.7	16	101.4	20.10	19.6	33
[illegible]	[illegible]	[illegible]	12,000	42	5.31	Recycle	12	35	250	325	2/min.	25.0	16.13	None	91.15	27.25	29.8	[illegible]
[illegible]	[illegible]	[illegible]	12,500	42	5.15	Recycle	12	110	325	1,000	6/min.	34.0	26.9	None	99.4	41.59	41.3	[illegible]
[illegible]	[illegible]	[illegible]	13,000	42	6.70	Recycle	12	60	475	750	5/min.	25.0	20.15	None	110.6	16.51	16.7	40
[illegible]	[illegible]	[illegible]	14,000	44	6.2	Recycle	12	50	400	450	1/min.	32.12	19.4	None	110.1	24.40	22.1	30

TABLE J1 (Continued)

MELTING RECORD

Heat No.	Order No.	Material	MELTING Amps	MELTING Volt	MELTING Time Min.	MELTING Elect. Dia.	MELTING Crucible Dia. in.	VACUUM - MICRONS Start	VACUUM - MICRONS During Melt	VACUUM - MICRONS After Pour	VACUUM - MICRONS 5 Min. Leak Rate	SKULL WT. Start Lb.	SKULL WT. Finish Lb.	Fluidity Spiral in.	Gross Heat Wt. Lb.	Net Heat Wt. Lb.	Percent Yield	Humidity Percent
F321	22-[illegible]	6Al-4V	13,000	44	6.40	Recycle	12	50	250	575	1/min.	25.0	16.5	None	104.1	19.30	18.5	29
F322	22-[illegible]	6Al-4V	13,500	43	6.52	Recycle	12	160	500	1,000	12/min.	39.0	26.2	17	123.1	16.80	13.6	32
F323	[illegible]	6Al-4V	16,000	43	6.72	Recycle	12	100	350	1,000	4/min.	22.0	20.1	None	126.1	30.94	25.0	39
F324	22-[illegible]	6Al-4V	14,000	45	6.56	Recycle	12	115	500	1,000	5/min.	50.0	21.15	None	136.16	26.77	21.1	35
F325	22-[illegible]	6Al-4V	14,000	42	7.02	Recycle	12	110	450	1,000	2/min.	30.6	22.5	None	127.2	29.98	23.6	31
F3[illegible]	22-[illegible]	6Al-4V	12,500	42	5.80	Recycle	12	50	300	500	3/min.	23.0	25.4	None	79.7	19.42	15.6	29
F32[illegible]	22-[illegible]	6Al-4V	14,000	42	6.95	Recycle	12	50	300	500	3/min.	31.0	23.0	None	121.6	28.64	23.5	29
F3[illegible]	22-[illegible]	6Al-4V	12,000	44	6.70	Recycle	12	50	300	600	3/min.	25.0	19.64	None	116.9	26.27	22.0	37
F329	22-[illegible]	6Al-4V	12,500	40	6.60	7	9	50	225	500	3/min.	17.0	18.19	None	92.50	28.88	31.2	28
F33[illegible]	22-[illegible]	6Al-4V	14,000	43	5.95	Recycle	12	110	275	400	4/min.	18.50	22.50	19	104.4	9.16	6.79	42
F33[illegible]	22-[illegible]	6Al-4Sn-6Zr	10,000	40	3.75	Recycle	9	50	175	210	1/min.	13.6	6.8	15	42.0	4.63	11.0	36
F33[illegible]	22-[illegible]	6Al-4V	13,000	42	2.75	Recycle	9	45	55	125	1.2/min.	8.19	6.44	None	36.10	5.3	14.6	38
F33[illegible]	22-[illegible]	6Al-4V	15,000	43	5.76	Recycle	9	90	210	500	4/min.	14.0	15.11	None	48.90	16.6	29.1	39
F334	22-[illegible]	6Al-4V	12,000	42	1.52	Recycle	9	80	80	175	1.4/min.	10.0	6.75	None	29.0	4.50	15.2	30
F33[illegible]	22-[illegible]	6Al-4V	12,000	42	5.90	Recycle	9	50	125	350	3/min.	20.0	20.36	None	90.14	20.7	23.0	32
F33[illegible]	22-[illegible]	6Al-4V	12,000	42	2.55	Recycle	9	50	125	250	3/min.	20.0	9.0	None	31.0	11.04	36.6	34
F337	22-7[illegible]	6Al-4V	12,500	41	5.75	Recycle	9	70	275	600	3/min.	30.0	14.50	11	96.0	25.66	27.0	40
F33[illegible]	22-[illegible]	6Al-4V	12,000	42	1.80	Recycle	12				4/min.	25.0		No Pour - Electrode Broke				29
F33[illegible]	22-[illegible]	7Al-3Mo-3V-3Fe-3Sn	[illegible] 000	32-42	5.90	7	9	75	210	325	5/min.	5.87	8.25	6	50.94	9.61	18.9	44
F34[illegible]	22-[illegible]	6Al-4V	14,000	42	7.10	Recycle	12	125	200	300	5/min.	25.0	23.0	31	126.75	11.61	10.7	35
F34[illegible]	22-[illegible]	[illegible]	14,000	42	6.55	Recycle	12	80	40-340	400	5/min.	42.14	35.0	None	132.1	30.78	23.2	30
F342	22-[illegible]	6Al-4V	14,000	43	4.55	Recycle	12	150	300	525	6/min.	35.0	17.50	15	100.24	26.67	27.6	37
F34[illegible]	22-[illegible]	6Al-4V	12,000	42	5.39	Recycle	9	45	125	750	4/min.	11.0	24.75	18	71.56	12.54	17.5	43
F34[illegible]	22-[illegible]	6Al-4V	13,500	42	4.75	Recycle	12	75	175	245	4/min.	24.0	16.75	None	86.82	20.78	31.2	29
F34[illegible]	22-[illegible]	6Al-4V	14,000	43	5.82	Recycle	12	120	250	300	2/min.	20.0	15.37	17	101.1	15.36	15.1	35
F346	22-[illegible]	6Al-4V	14,000	43	5.55	Recycle	12	90	250	290	4/min.	22.0	23.25	18	101.18	10.36	9.76	41
F34[illegible]	22-[illegible]	6Al-4V	14,000	41	5.80	Recycle	12	55	150	225	2/min.	20.0	18.68	None	90.6	20.65	22.8	32
F34[illegible]	22-5[illegible]	6Al-4V-[illegible]	14,000	40	3.09	7	9	90	220	375	3/min.	6.75	9.31	21	50.69	9.74	19.2	38
F34[illegible]	22-6[illegible]	6Al-2Mo-3Cr-3Sn-2Zr	14,000	40	3.35	7	9	45	110	250	3/min.	11.0	8.0	12	53.19	9.67	18.2	44
F350	22-6[illegible]	7Al-2Mo-5W-5Ta-3Cr-3Sn-2Zr	14,000	42	3.24	7	9	50	155	325	7/min.	10.81	8.06	11	51.68	10.04	20.2	44
F35[illegible]	22-6[illegible]	4Al-2Mo-2Cr-2V-2Fe-4Sn-2Zr	14,000	4[illegible]	3.5	7	9	80	125	205	5/min.	12.0	9.50	8	51.75	10.49	20.2	40
F352	22-6[illegible]	2Al-5Fe-[illegible]-2Sn-5Zr	14,000	42	3.17	7	9	65	150	215	4/min.	10.0	6.75	2½	53.13	9.99	18.8	39
F353	22-67	6Al-5Fe-6V-2Sn	14,000	42	4.34	7	9	115	130	215	4/min.	3.62	8.25	4	55.19	9.55	17.3	38
F354	22-68	2Al-5Fe-6V	13,000	38	5.00	7	9	80	110	160	4/min.	11.0	9.93	8	53.0	9.74	18.3	40
F355	22-7[illegible]	6Al-4V	14,000	38	3.80	7	9	65	145	200	2/min.	12.94	9.75	16	53.94	9.81	16.1	44

TABLE J1 (Continued)

MELTING RECORD

[illegible]	[illegible]	[illegible]	Melting [illegible]	[illegible]	Time Min.	Elect. Size	Crucible Dia. in.	Vacuum – Microns Start	During Melt	After Pour	[illegible] Leak Rate	Skull Wt. Start Lb.	Finish Lb.	Fluidity Spiral in.	Gross Heat Wt. Lb.	Net Heat Wt. Lb.	Percent Yield	Humidity Percent
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	5	73	[illegible]	225	5/min.	[illegible]	9.27	16	55.75	9.66	16.0	29
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	5	62	100	175	3/min.	11.43	9.25	15	53.58	6.66	16.5	44
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	9	60	75	165	3/min.	26.0	14.4	6½	62.56	9.36	14.9	42
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	5	50	70	120	2/min.	13.62	6.50	10	54.12	10.0	16.5	36
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	5	[illegible]	225	500	3/min.	20.0	9.12	None	51.94	16.25	35.1	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	35	275	700		31.0	17.62	14	100.62	35.97	35.6	34
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	75	215	455	3/min.	11.0	6.75	None	[illegible]	6.61	21.7	40
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	50	225	[illegible]	4/min.	31.0	25.25	None	[illegible]	19.41	16.6	35
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	9	75	120	310	4/min.	10.50	3.0	None	51.67	6.67	13.2	35
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	5	64	75	360	4/min.	16.0	11.69	10½	62.6	6.99	14.4	44
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	5	41	250	405	3/min.	20.0	9.12	None	67.75	6.62	9.77	42
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	9	41	225	475	2/min.	16.0	11.19	None	66.12	13.26	22.0	4[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	17	75	154	4/min.	35.0	47.75	None	50.6	10.36	20.3	29
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	40	275	450	3/min.	30.0	16.75	None	75.56	10.36	13.5	16
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	40	225	250	2.5/min.	33.75	17.67	None	69.61	10.04	14.4	33
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	50	275	255	2-3.5/min.	32.0	20.0	None	94.37	13.47	14.1	33
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	42	125-130	154	3.6/min.	6.50	4.79	None	24.25	4.75	15.5	40
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	35	225	250	3/min.	35.0	15.37	13	[illegible]	12.6	15.6	33
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	38	275	390	2/min.	35.0	6.6	14	[illegible]	13.75	14.2	43
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	5	40	125-130	100	4/min.	7.25	[illegible]	None	19.66	4.61	23.1	32
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	9	35	120	150	3/min.	7.12	3.37	None	15.36	2.50	16.2	34
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	20	75	250	3/min.	20.0	21.37	16½	[illegible]	26.19	23.5	40
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	47	210	350	5/min.	30.0	[illegible]	14	96.61	11.46	12.6	23
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	70	265	450	10/min.	30.0	16.69	14	69.69	13.24	16.9	19
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	55	325	500	4/min.	32.5	21.75	17	100.25	6.30	6.26	39
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	30	95	13	13/min.	31.0	16.9	16	100.33	9.49	9.42	25
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	50	490	300	12/min.	30.0	22.12	None	85.43	10.05	11.2	33
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	55	290	350	5/min.	35.0	26.0	None	92.62	16.46	19.5	30
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	55	290	440	6/min.	20.0	16.50	None	95.94	16.66	19.4	28
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	35	150	400	20/min.	30.0	15.06	None	96.62	15.95	15.6	22
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.95	Recycle	12	35	255	475	11/min.	34.0	19.0	None	96.0	16.16	16.9	22
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	45	210	500	9/min.	32.0	23.45	None	107.4	18.54	17.2	19
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.05	Recycle	12	50	210	700	10/min.	32.0	16.67	None	94.5	16.64	19.9	18
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	50	210	560	6/min.	30.0	17.31	None	95.62	20.05	20.0	16
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	50	275	475	10/min.	35.0	20.3	None	91.56	19.91	21.6	20
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	42	255	500	3/min.	22.0	20.61	None	83.44	19.73	23.6	19
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.20	Recycle	12	65	335	800	6/min.	25.0	16.50	None	94.69	20.66	21.6	30
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	35	290	550	2.6/min.	44.0	19.0	None	112.75	20.46	16.2	39
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	56	200	375	7/min.	17.50	17.75	None	89.56	21.21	23.7	30
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Recycle	12	45	250	350	2/min.	16.25	16.0	None	84.66	22.12	26.0	44

TABLE J1 (Continued)

MELTING RECORD

Heat No.	Order No.	Material	Melting: Amps	Melting: Volt	Melting: Time Min.	Melting: Elect. Dia.	Melting: Crucible Dia. in.	Vacuum – Microns: Start	Vacuum – Microns: During Melt	Vacuum – Microns: After Pour	Vacuum – Microns: 5 Min. Leak Rate	Skull Wt.: Start Lb.	Skull Wt.: Finish Lb.	Fluidity Spiral in.	Gross Heat Wt. Lb.	Net Heat Wt. Lb.	Percent Yield	Humidity Percent
F39[illegible]	22-62	6Al-4V	14,000	42	4.51	Recycle	12	55			6/min.	22.37	16.44	None	81.25	21.72	25.4	35
F39[illegible]	22-62	6Al-4V	14,000	4[illegible]	4.60	Recycle	12	57	245	310	1.4/min.	26.25	19.12	None	86.12	21.87	24.6	35
F39[illegible]	22-6	6Al-4V	14,000	4[illegible]	5.55	Recycle	12	[illegible]	275	390	5/min.	32.0	19.06	15	106.63	[illegible]1.99	[illegible].0	33
F39[illegible]	22-6	6Al-4V	14,000	62	5.13	Recycle	12	45	455	565	7/min.	25.0	16.56	16	92.32	8.43	9.14	3
F40[illegible]	22-62	6Al-4V	15,000	4[illegible]	5.09	Recycle	12	42	310	350	4/min.	26.0	15.75	None	97.25	18.97	19.5	34
F40[illegible]	22-[illegible]	6Al-4V	14,000	42	5.50	Recycle	12	2[illegible]	315	395	4/min.	16.0	16.15	16	95.31	15.80	16.6	32
F40[illegible]	22-62	6Al-4V	12,000	42	5.59	Recycle	12	45	255	255	3.8/min.	24.25	16.68	None	96.69	19.09	19.8	32
F403	22-6	6Al-4V	12,500	42	4.62	Recycle	12	100	280	725	6/min.	21.19	16.0	16½	81.82	9.43	11.6	32
F404	22-6	6Al-4V	12,500	42	5.42	Recycle	12	35	320	405	3/min.	26.75	17.62	19	101.0			32
F40[illegible]	22-5	6Al-4V	14,000	44	6.32	Recycle	12	110	290	750	10/min.	25.0	20.19	17	109.15	5.0	4.56	37
F40[illegible]	22-1[illegible]	3Cr-15V-3Al	14,000	42	5.35	7" round & Recycle	9	51	115	475	2/min.	27.0	17.67	8	86.35	19.20	21.7	52
F40[illegible]	22-6	5Al-2½Sn	2,000	40	3.92	Recycle	9	100	330	400	8/min.	21.0	12.25	13	64.16	21.26	33.1	33
F40[illegible]	22-7[illegible]	5Al-4V	2,000	40	5.64	Recycle	9	75	335	460	6/min.	15.50	12.25	20	70.13	23.40	33.4	27
F40[illegible]	22-39A	5Mo-5V-2[illegible]	2,500	36	2.55	7	9	60	250	290	6/min.	15.61	10.18	6	42.69	4.55	10.7	26
F41[illegible]	22-62	6Al-4V	3,000	42	4.55	Recycle	12	70	250	310	5/min	25.0	19.56	None	65.5	18.75	22.0	28
F4[illegible]	22-5	6Al-4V	14,000	4[illegible]	4.87	Recycle	12	52	275	1,000	5/min.	25.0	21.31	None	64.63	2.75	4.26	28
F4[illegible]	22-5	6Al-4V	14,000	45	5.00	Recycle	12	35	260	1,000	3.4/min.	25.0	22.12	None	65.3	2.50	3.83	30
F4[illegible]	22-5	6Al-4V	15,000	40	5.55	Recycle	12	80	340	750	6/min.	27.0	15.50	21	111.63	5.00	4.49	34
F4[illegible]	22-5	6Al-4V	14,000	43	5.70	Recycle	12	85	290	750	4/min.	29.0	43.22	None	113.0	12.87	11.4	34
F4[illegible]	22-6	6Al-4V	12,500	44	4.80	Recycle	12	80	350	430	20/min.	35.	15.	15	100.87	6.87	6.79	42
F4[illegible]	22-62	6Al-4V	13,500	42	4.92	Recycle	12	45	215	220	4.2/min.	19.62	17.50	None	66.56	15.54	22.1	37
F417	22-62	6Al-4V	11,000	4[illegible]	1.50	Recycle	9	– No Pour –			5/min.	13.75						40
F41[illegible]	22-5	6Al-4V	12,500	41	3.51	Recycle	9	125	305	700	7/min.	10.0	8.75	None	45.25	15.24	33.7	37
F419	22-[illegible]	6Al-4V	14,000	43	4.65	Recycle	12	51	240	1,000	9/min.	16.67	[illegible]7.46	None	51.25	4.43	8.64	26
F42[illegible]	22-63	6Al-4V	12,500	42	3.10	Recycle	9	75	210	295	7/min.	11.0	5.86	None	23.9	6.61	27.6	26
F42[illegible]	22-5	6Al-4V	12,000	4[illegible]	4.76	Recycle	9	55	210	575	2/min.	17.0	13.56	None	75.55	13.12	17.4	39
F42[illegible]	22-5	6Al-4V	14,000	4[illegible]	5.36	Recycle	12	50	175	350	6/min.	24.0	17.50	16	92.57	12.75	13.7	37
F42[illegible]	22-5	6Al-4V	14,000	42	5.70	Recycle	12	70	280	500	7/min.	34.0	16.25	14	106.06	5.0	4.71	47
F42[illegible]	22-5	6Al-4V	13,000	40	5.21	Recycle	12	110	290	400	7/min.	30.0	16.56	13	96.15	12.81	12.6	52
F4[illegible]	22-[illegible]	6Al-4V	12,500	40	5.76	Recycle	9	100	305	750	10/min.	15.50	14.0	17½	78.25	3.93	11.2	34
F42[illegible]	22-[illegible]	6Al-4V	13,000	42	4.30	Recycle	9	80	30	525	8/min.	13.0	11.62	16	73.81	11.62	15.6	31
F42[illegible]	22-[illegible]	6Al-4V	12,500	40	4.72	Recycle	9	51	255	500	3/min.	13.0	14.75	None	75.94	9.12	12.0	37
F42[illegible]	22-6[illegible]	C.P. Ti	13,000	42	5.76	Recycle	9	100	350	1,000+	8/min.	10.0	15.87	None	82.0	21.37	26.0	38
F429	22-64	C.P. Ti	13,000	40	5.85	Recycle	9	65	115	750	5/min.	11.0	17.0	None	80.13	21.15	26.4	46
F430	22-64	C.P. Ti	12,000	40	5.32	Recycle	9	80	210	700	10/min.	15.0	16.81	None	81.12	23.04	28.4	35
F431	22-64	C.P. Ti	12,500	40	4.59	Recycle	9	45	225	310	4/min.	17.0	16.25	13	73.25	9.37	12.8	35
F432	22-64	C.P. Ti	14,000	40	6.13	Recycle	12	45	170	260	1/min.	20.0	24.0	12	76.12	9.24	12.1	46
F43[illegible]	22-64	C.P. Ti	11,000	41	6.72	Recycle	12	100	390	1,000+	4/min.	20.0	19.56	None	85.37	9.42	11.0	43
[illegible]	22-69	6Al-4V-1Mo-1Cr	12,000	40	3.92	7	9	90	160	245	4/min.	11.0	11.12	15	45.75	10.0	21.9	28
[illegible]	22-1[illegible]	13V-11Cr-1½Al	13,000	40	3.50	7" round & Recycle	9	90	525	600	8/min.	15.19	10.62	None	56.13	9.06	16.3	35

TABLE J1 (Continued)

MELTING RECORD

Heat No.	Order No.	Material	MELTING Amps	Volt	Time Min.	Elect. Dia.	Crucible Dia. in.	VACUUM - MICRONS Start	During Melt	After Pour	5 Min. Leak Rate	SKULL WT. Start Lb.	Finish Lb.	Fluidity Spiral In.	Gross Heat Wt. Lb.	Net Heat Wt. Lb.	Percent Yield	Humidity Percent
[illegible]	[illegible]	[illegible]	12,500	40	4.54	Recycle	9	73	400	510	2.6/min.	18.75	13.18	None	76.19	19.26	25.3	34
[illegible]	[illegible]	[illegible]	12,000	43	4.72	Recycle	9	60	155	350	2/min.	13.0	11.62	12	72.61	30.22	41.7	44
[illegible]	[illegible]	[illegible]	12,500	42	3.50	Recycle	9	85	200	310	10/min.	30.0	11.56	None	61.8	12.12	19.6	31
[illegible]	[illegible]	[illegible]	14,000	44	2.50	Recycle	9	100	245	300	10/min.	12.0	8.19	None	40.0	6.75	16.6	29
[illegible]	[illegible]	[illegible]	14,000	40	4.32	Recycle	12	60	150	225	6/min.	22.0	20.31	None	84.62	22.32	26.2	38
[illegible]	[illegible]	[illegible]	14,000	42	4.60	Recycle	9	55	175	205	4/min.	15.0	11.19	15	70.87	9.24	13.1	48
[illegible]	[illegible]	[illegible]	14,000	40	5.07	Recycle	12	65	240	375	6/min.	25.0	16.31	13	90.12	9.81	10.8	35
[illegible]	[illegible]	[illegible]	14,000	42	4.20	Recycle	12	59	245	350	6/min.	26.0	14.06	17	76.31	6.74	8.8	39
[illegible]	[illegible]	[illegible]	12,500	37	4.60	Recycle	12	70	190	210	7/min.	16.0	15.62	14	62.25	6.62	6.0	42
[illegible]	[illegible]	[illegible]	12,000	42	4.62	Recycle	12	50	250	275	5/min.	25.0	16.56	None	80.81	20.40	25.2	41
[illegible]	[illegible]	[illegible]	14,000	42	5.21	Recycle	12	78	300	550	5.21/min.	39.25	20.25	19	109.50	27.56	25.2	37
[illegible]	[illegible]	[illegible]	14,000	42	4.40	Recycle	12	100	380	760	10/min.	36.0	16.62	21	110.06	34.00	3[illegible]	45
[illegible]	[illegible]	[illegible]	14,000	42	5.00	Recycle	12	150	400	750	10/min.	35.0	20.0	18	123.37	32.17	26.6	47
[illegible]	[illegible]	[illegible]	14,000	43	4.51	Recycle	12	55	310	650	4/min.	36.0	14.31	None	100.68	12.75	12.7	43
[illegible]	[illegible]	[illegible]	14,000	42	6.20	Recycle	9	65	290	350	5/min.	28.0	23.12	14	124.62	12.75	10.2	46
[illegible]	[illegible]	[illegible]	[illegible]	38	[illegible]	Recycle	9	73	200	--	6/min.	20.0	23.0	None				46
[illegible]	[illegible]	[illegible]	[illegible]	42	5.63	Recycle	12	75	210	500	6/min.	17.0	19.75	15	75.67	11.11	14.7	33
[illegible]	[illegible]	[illegible]	[illegible]	42	4.20	Recycle	12	55	240	485	1/min.	20.0	22.67	14	62.31	9.12	[illegible]	30
[illegible]	[illegible]	[illegible]	[illegible]	42	4.30	Recycle	9	65	240	375	3/min.	12.0	11.0	None	67.62	12.25	18.2	30
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.50	Recycle	9	75	250	1,000	7/min.	20.0	3.67	14	65.50	9.06	13.0	46
[illegible]	[illegible]	[illegible]	14,000	39	6.60	Recycle	14	200	228	400	9/min.	26.0	16.86	17	110.50	25.06	[illegible]	42
[illegible]	[illegible]	[illegible]	14,000	42	5.54	Recycle	12	105	450	625	7/min.	39.0	22.36	15½	120.66	26.50	21.9	54
[illegible]	[illegible]	[illegible]	13,000	42	4.03	Recycle	13	40	275	400	.6/min.	30.0	16.06	15	83.12	8.93	10.7	40
[illegible]	[illegible]	[illegible]	14,000	42	4.60	Recycle	12	65	245	430	4/min.	25.0	15.31	17	91.12	15.16	16.6	42
[illegible]	[illegible]	[illegible]	14,000	39	5.05	Recycle	12	100	375	750	9/min.	33.0	13.6	15½	104.13	14.77	14.1	40
[illegible]	[illegible]	[illegible]	14,000	[illegible]	7.25	Recycle	12	65	250	405	9/min.	25.0	27.25	23	140.44	24.50	10.7	39
[illegible]	[illegible]	[illegible]	14,000	42	6.50	Recycle	12	93	215	375	7/min.	35.0	32.0	None	135.12	23.96	17.2	36
[illegible]	[illegible]	[illegible]	14,000	42	6.10	Recycle	12	55	290	600	7/min.	42.0	24.31	20	155.38	24.43	15.0	40
[illegible]	[illegible]	[illegible]	14,000	[illegible]	6.35	Recycle	12	70	300	625	5/min.	32.0	26.06	15	144.50	24.43	16.9	35
[illegible]	[illegible]	[illegible]	14,000	42	7.05	Recycle	12	90	320	625	11/min.	32.0	24.58	18	155.37	24.25	15.6	36
[illegible]	[illegible]	[illegible]	14,000	[illegible]	7.[illegible]	Recycle	12	38	290	700	3/min.	26.0	26.25	16	148.63	24.32	16.2	47
[illegible]	[illegible]	[illegible]	14,000	4[illegible]	7.18	Recycle	12	83	290	700	6/min.	30.0	29.38	18	145.75	24.16	16.5	46
[illegible]	[illegible]	[illegible]	14,000	40	7.00	Recycle	12	5	290	1,000+	2.4/min.	28.0	27.63	17	145.81	24.16	16.4	51
[illegible]	[illegible]	[illegible]	15,000	40	5.25	Recycle	12	--	325	600	1/min.	28.25	46.75	15	131.12	24.10	16.3	53
[illegible]	[illegible]	[illegible]	14,000	42	6.30	Recycle	12	55	240	1,000	2/min.	37.65	22.50	20	166.50	24.60	14.7	54
[illegible]	[illegible]	[illegible]	14,000	40	6.24	Recycle	12	75	290	325	5/min.	24.25	24.0	16	101.12	26.60	26.0	39
[illegible]	[illegible]	[illegible]	12,500	38	4.61	Recycle	9	100	275	700	8/min.	25.0	21.87	12	82.18	9.12	11.0	43
[illegible]	[illegible]	[illegible]	14,000	[illegible]	4.05	Recycle	12	45	240	355	6/min.	25.62	[illegible].06	14½	77.25	9.26	11.9	45
[illegible]	[illegible]	[illegible]	14,000	40	4.86	Recycle	12	65	340	390	5/min.	22.0	8.65	11	62.16	9.00	14.4	37
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.67	Recycle	12	35	300	385	.6/min.	19.00	17.37	None	52.06	9.00	14.5	36

TABLE J1 (Continued)

MELTING RECORD

Heat No.	Order No.	Material	MELTING Amps	Volt	Time Min.	Elect. Dia.	Crucible Dia. in.	VACUUM - MICRONS Start	During Melt	After Pour	5 Min. Leak Rate	SKULL WT. Start Lb.	Finish Lb.	Fluidity Spiral In.	Gross Heat Wt. Lb.	Net Heat Wt. Lb.	Percent Yield	Humidity Percent
F476	22-2	6Al-4V	12,000	39	5.70	Recycle	9	60	290	400	1/min.	10.00	14.37	13	68.19	9.00	13.1	40
F477	22-62	6Al-4V	14,000	41	4.42	Recycle	12	65	340	365	5/min.	25.50	17.31	None	77.56	20.91	27.0	44
F478	22-54	C.P. Ti	12,500	42	4.60	Recycle	12	100	245	700	13/min.	53.00	21.25	18	130.75	9.67	7.3	45
F479	22-1	6Al-4V	12,000	40	2.64	Recycle	9	48	290	350	1.2/min.	15.00	7.44	None	43.88	7.61	17.2	37
F480	22-65	6Al-4V	10,000	39	1.45	4" Square	9	120	295	600	5/min.	11.00	7.37	None	17.88	5.87	32.8	42
F481	22-5	6Al-4V	14,000	42	6.30	Recycle	12	85	305	750	5/min.	25.00	21.75	17	108.75	25.62	23.6	49
F482	22-9	6Al-4V	14,000	40	5.25	Recycle	12	45	230	625	6/min.	26.00	26.25	17	96.75	27.50	28.5	50
F483	22-1	6Al-4V	12,000	40	5.95	Recycle	9	70	145	425	2/min.	12.00	15.31	None	79.37	9.13	11.5	38
F484			Cancelled															
F485	22-2	6Al-4V	12,000	40	5.22	Recycle	9	45	165	300	7/min.	15.00	13.75	14	76.50	16.86	22.3	50
F486	22-4	6Al-4V	14,000	42	5.60	Recycle	12	100	270	500	7/min.	22.38	27.50	14	94.56	8.18	6.6	47
F487	22-62	6Al-4V	12,000	40	5.45	Recycle	9	45	175	240	3/min.	17.50	12.50	None	79.00	21.22	26.8	40
F488	22-60A	[illegible]	14,000	36	3.60	7" Round	9	57	175	240	.8/min.	8.00	11.38	None	52.68	9.12	17.2	47
F489	22-60A	[illegible]	14,000	40	3.75	Recycle & 7" Round	9	37	185	250	7/min.	13.50	10.88	7.50	61.62	9.18	14.8	38
F490	22-62	6Al-4V	14,000	41	5.25	Recycle	12	46	256	230	1.6/min.	32.44	24.56	None	83.69	20.53	24.5	53
F491	22-6	5Al-2½Sn	14,000	41	4.00	7	12	45	140	450	3/min.	18.56	14.60	16	74.87	14.97	19.9	49
F492	[illegible]	[illegible]	14,000	40	4.40	Recycle	12	45	170	750	1/min.	21.50	10.25	10	83.00	31.66	38.0	44
F493	22-65	6Al-4V	13,000	39	1.50	6	12	50	200	290	4/min.	9.44	9.00	None	20.18	5.87	29.0	53
F494	22-2	6Al-4V	12,000	41	4.90	Recycle	9	55	245	900	2/min.	15.00	14.31	15	81.25	17.18	21.1	48
F495	22-2	6Al-4V	12,000	41	6.30	Recycle	9	85	275	900	7/min.	20.00	15.50	13	93.68	17.10	18.2	51
F496	22-6	6Al-4V	14,000	41	5.20	Recycle	9	75	290	900	7/min.	21.00	14.87	15	94.56	9.12	9.6	47
F497	22-6	6Al-4V	14,000	42	4.80	Recycle	12	38	22-295	750	1.4/min.	30.00	15.00	15	92.00	8.99	9.7	53
F498	22-5	6Al-4V	12,000	39	6.30	Recycle	9	60	255	400	7/min.	15.00	20.25	13	93.69	11.62	12.4	51
F499	22-5	6Al-4V	14,000	44	4.85	Recycle	12	38	260	450	4/min.	35.00	23.75	14	102.12	11.99	11.7	42
F500	22-3	6Al-4V	14,000	41	7.03	Recycle	9	49	205	1,000	11/min.	14.00	14.87	15.50	97.38	13.18	13.5	54
F501	22-5	6Al-4V	12,000	40	3.15	Recycle	9	37	500		2.8/min.	30.00	94.64					48
F502	22-62	6Al-4V	14,000	40	4.55	Recycle	12	70	210	245	7/min.	16.00	16.00	None	82.68	22.74	27.5	44
F503	22-1	6Al-4V	12,000	40	3.67	Recycle	9	65	340	625	7/min.	11.00	8.50	None	47.25	12.36	26.1	43
F504	22-62	6Al-4V	12,000	43	4.90	Recycle	9	65	290	345	5/min.	17.00	11.19	None	76.37	22.74	29.7	53
F505	22-62	6Al-4V	12,000	42	5.45	Recycle	9	45	335	390	3/min.	15.00	12.75	None	77.37	22.91	29.5	51
F506	22-62	6Al-4V	12,000	40	4.77	Recycle	9	32	175	255	2.4/min.	18.00	13.94	None	77.12	23.47	30.4	46
F507	22-62	6Al-4V	12,000	42	4.80	Recycle	9	42	240	305	3/min.	24.56	17.12	None	76.50	23.03	30.1	44
F508	22-62	6Al-4V	14,000	42	4.65	Recycle	9	85	220-290	345	7/min.	15.50	11.25	None	80.00	23.10	28.8	42
F509	22-1	6Al-4V	12,000	40	2.90	Recycle	9	35	310	700	9/min.	25.00	11.63	None	48.44	7.43	15.0	35
F510	22-91	6Al-4V	14,000	37	3.25	7	9	35	145	290	13/min.	11.06	9.38	11½	54.12	9.06	14.8	45
F511	22-1	6Al-4V	12,000	42	5.10	Recycle	9	32	300	1,000	1.4/min.	30.00	18.06	None	85.56	30.72	35.8	56
F512	22-2	6Al-4V	12,000	41	3.75	Recycle	9	65	240	375	2/min.	21.00	10.50	None	61.12	12.05	19.7	57
F513	22-96	C.P. Ti	14,000	40	3.35	7	9	57	32-98	102	16/min.	11.38	13.12	14	51.00	4.82	9.4	53
F514	22-97	C.P. Ti	14,000	39	3.67	7	9	37	15-89	120	2/min.	11.62	13.00	12	50.62	5.16	10.1	48
F515	22-103	C.P. Ti	10,500	40	3.45	7	9	40	70	125	2/min.	10.25	15.37	9	49.68	5.06	10.1	45

TABLE J1 (Continued)

MELTING RECORD

Heat No.	Order No.	Material	MELTING Amps	Volt	Time Min.	Elect. Dia.	Crucible Dia. in.	VACUUM - MICRONS Start	During Melt	After Pour	5 Min. Leak Rate	SKULL WT. Start Lb.	Finish Lb.	Fluidity Spiral in.	Gross Heat Wt. Lb.	Net Heat Wt. Lb.	Percent Yield	Humidity Percent
[illegible]	[illegible]	[illegible]	11,000	36	3.44	7	9	30	20-85	180	2/min.	10.50	13.31	6	49.16	4.81	9.6	52
[illegible]	[illegible]	[illegible]	11,500	40	3.60	7	9	45	22-65	98	2.8/min.	10.44	12.62	9	61.06	4.93	9.6	52
[illegible]	[illegible]-100	[illegible]	11,500	40	3.70	7	9	41	20-51	102	1.6/min.	10.00	12.81	None	51.00	4.81	9.4	56
[illegible]	[illegible]-95	[illegible]	11,000	39	3.50	7	9	45	25-150	180	6/min.	11.75	12.81	6	50.25	5.12	10.1	54
F52	[illegible]	[illegible]	11,000	39	4.21	7	9	33	15-105	160	2/min.	8.21	17.37	11	47.56	4.81	10.1	38
[illegible]	[illegible]	Ti-Al-Cv-2Fe	11,500	32	5.36	7	9	72	125	195	5/min.	5.00	8.50	6½	48.43	5.93	20.5	52
[illegible]	[illegible]	Ti-13Cr-[illegible]-5Al	Cancelled															
[illegible]	[illegible]	Ti-[illegible]	11,000	40	5.60	7	9	40	20-90	195	2/min.	10.75	12.25	8	51.12	9.12	17.8	57
[illegible]	[illegible]	[illegible]	11,000	41	4.50	Recycle	9	44	290	650	2/min.	25.00	11.50	14	77.00	6.81	8.7	48
[illegible]	[illegible]	[illegible]	11,000	42	5.22	Recycle	9	95	390	900	5/min.	30.00	15.87	15	55.50	11.62	12.1	44
[illegible]	[illegible]	[illegible]	11,500	40	3.50	7	9	125	490	550	3½/min.	20.00	13.75	None	53.16	7.80	14.6	44
[illegible]	[illegible]	[illegible]				Recycle	9	- No Pour -			10/min.	25.00		- Electrode Broke -				
[illegible]	[illegible]	[illegible]	11,000	42	6.12	7	12	55	675	750	15/min.	30.00	25.25	14	142.56	9.30	6.2	40
[illegible]	[illegible]	[illegible]	11,000	40	6.55	Recycle	12	40	475	750	2/min.	30.00	26.43	15	108.12	30.46	28.0	35
[illegible]	[illegible]	[illegible]	11,000	42	4.85	Recycle	9	49	30-290	650	14/min.	35.50	12.00	14	75.37	9.16	12.1	43
[illegible]	[illegible]	[illegible]	11,500	39	6.70	Recycle	12	65	195	600	3/min.	35.00	21.61	11	113.12	26.37	23.3	52
[illegible]	[illegible]	[illegible]	11,500	40	6.55	Recycle	9	105	490	600	7/min.	22.37	19.00	13	99.75	13.93	13.9	54
[illegible]	[illegible]	[illegible]	11,000	42	5.60	Recycle	9	45	195	450	4/min.	20.00	14.50	None	50.49	7.25	14.3	52
[illegible]	[illegible]	[illegible]				Recycle	9	55	450	495	3/min.	20.00	15.50	None	57.81	6.61	11.7	42
[illegible]	[illegible]	[illegible]	11,000	40	5.74	Recycle	9	125	200	350	10/min.	60.25	4.75	None	55.00	7.31	13.3	49
[illegible]	[illegible]	[illegible]	11,000	40	3.60	Recycle	9	100	200	350	8/min.	20.00	14.50	None	56.66	7.37	13.0	46
[illegible]	[illegible]	[illegible]	11,000	4[illegible]	4.51	Recycle	9				15/min.	16.25	9.00	10½	54.14	12.24	22.6	52
[illegible]	[illegible]	[illegible]	11,000	39	2.66	Recycle	12	- No Pour -			3.6/min.	16.00	69.00	None	- Electrode Broke -			
[illegible]	[illegible]	[illegible]	11,500	42	6.16	Recycle	12	35	350	300	4/min.	36.75	31.00	14	105.06	20.61	19.6	43
[illegible]	[illegible]	[illegible]	11,500	39	5.74	Recycle	9				.6/min.	35.64	24.37	None	97.87	11.61	11.8	55
[illegible]	[illegible]	[illegible]	11,500	41	3.59	Recycle	12	70	200-750	800	16/min.	16.00	18.12	6	64.12	4.50	7.0	50
[illegible]	[illegible]	[illegible]	11,000	40	5.20	Recycle	12	44	325	850	2.8/min.	22.00	26.00	3	89.56	7.43	8.2	42
[illegible]	[illegible]	[illegible]	14,000	37	5.15	Recycle	12	100	250	550	6/min.	27.00	13.64	None	85.44	9.24	10.8	54
[illegible]	[illegible]	[illegible]	11,000	42	1.75	Bar Stock	9	55	100	200	10/min.	10.00	5.18	None	21.66	5.81	26.7	46
[illegible]	[illegible]	[illegible]	14,000	42	4.46	Recycle	12	60	150-275	500	10/min.	23.00	15.12	None	74.12	4.62	6.2	40
[illegible]	[illegible]	[illegible]	14,000	41	4.12	Recycle	12	50	150-300	500	7/min.	26.00	19.87	None	65.60	4.62	7.0	37
[illegible]	[illegible]	[illegible]	12,500	40	2.75	Recycle	12	- No Pour -			3.6/min.	17.00	49.75	- Arc Penetrated Crucible -				
[illegible]	[illegible]	[illegible]	14,000	44	5.10	Recycle	12	80	200-350	750	8/min.	16.50	16.00	None	77.56	4.62	5.9	46
[illegible]	[illegible]	[illegible]	14,000	44	4.12	Recycle	12	35	300-500	1000	3/min.	16.00	17.50	None	69.06	11.36	16.4	46
[illegible]	[illegible]	7Al-[illegible]	14,000	39	4.66	6' Round	9	20	35	60	4/min.	9.25	9.87	12½	50.16	10.10	20.1	52
[illegible]	[illegible]	6Al-[illegible]	14,500	40	5.18	Recycle	12	65	200-350	500	10/min.	18.06	17.25	None	50.81	4.62	9.0	44
[illegible]	[illegible]	6Al-[illegible]	14,000	44	3.42	Recycle	12	70	150-325	600	7/min.	18.00	12.62	None	52.12	4.74	9.0	48
[illegible]	[illegible]-89	6Al-[illegible]	13,500	44	3.32	Recycle	12	20	300-750	525	9/min.	23.00	12.93	None	31.81	10.00	31.4	47
[illegible]	[illegible]	6Al-[illegible]	14,000	44	4.30	Recycle	12	60	250-400	500	6/min.	18.00	10.50	None	55.50	4.75	8.0	38
[illegible]	[illegible]	6Al-[illegible]	14,000	44	4.65	Recycle	12	25	300-500	1000	6/min.	18.00	14.62	None	75.44	9.64	13.0	46

TABLE J1 (Continued)

MELTING RECORD

Heat No.	Order No.	Material	MELTING Amps	Volt	Time Min.	Elect. Dia.	Crucible Dia. in.	VACUUM - MICRONS Start	During Melt	After Pour	5 Min. Leak Rate	SKULL WT. Start Lb.	Finish Lb.	Fluidity Spiral In.	Gross Heat Wt. Lb.	Net Heat Wt. Lb.	Percent Yield	Humidity Percent
P556	22-89	6Al-4V	12,500	41	2.16	Recycle	9	40	250	325	.8/min.	10.50	5.87	None	27.61	.36	1.3	43
P557	23-2	6Al-4V	14,000	44	3.10	Recycle	12	110	350	750	7/min.	16.00	14.18	None	[illegible]	5.98	11.2	36
F558	23-2	6Al-4V	14,000	44	3.54	Recycle	12	22	450	750	5/min.	25.87	13.37	None	50.00	5.30	10.6	44
F559	23-[illegible]	6Al-4V	14,000	42-46	6.79	Recycle	12	30	250	750	9/min.	18.00	21.50	None	103.88	21.10	20.3	41
P560	23-[illegible]	6Al-4V	14,000	44	3.66	7''Recycle	12	60	245	420	10/min.	18.00	12.87	None	63.37	5.22	6.2	49
F561	23-2	6Al-4V	14,000	44	5.92	Recycle	12	70	350	750	1.6/min.	18.00	18.00	None	109.50	9.84	8.9	46
F562	23-2	6Al-4V	15,000	42-46	5.15	Recycle	12	50	280	750	9/min.	18.00	15.62	None	66.56	14.35	16.0	30
F563	23-[illegible]	6Al-4V	16,000	42	12.12	Recycle	16	45	350	1,000	1/min.	70.00	58.25	None	277.00	74.00	26.0	48
P564	23-4	6Al-4V	14,000	44	5.12	Recycle	12	50	325	600	6/min.	18.00	15.75	None	95.06	11.22	11.0	36
P56[illegible]	23-4	6Al-4V	14,000	44	5	Recycle	12	55	310	750	5/min.	18.00	17.64	None	90.3[illegible]	10.50	10.0	49
F566	22-89	6Al-4V	12,000	40-46	3.25	Recycle	9	55	200	250	4/min.	10.00	6.37	None	37.52	-	-	62
P56[illegible]	23-2	6Al-4V	14,500	44	4.40	Recycle 7'	12	60	175-350	500	6/min.	20.00	16.18	None	80.00	5.48	6.80	60
F56[illegible]	23-4	6Al-4V	14,000	44	5.45	Recy.5-6'	12	150	175-250	400	5/min.	18.75	17.00	None	89.25	10.66	12.0	48
F56[illegible]	23-[illegible]	6Al-4V	15,000	44	7.24	Recy.7-6'	12	100	250	550	6/min.	27.00	27.51	None	146.87	44.66	30.0	59
F57[illegible]	23-2	6Al-4V	14,500	44	4.82	Recycle 6'	12	17	175	550	2/min.	20.00	14.25	None	80.62	-	-	46
F57[illegible]		6Al-4V	-	-	5.11	Recycle 7'	12	20	175	500	2/min.	18.00	14.62	None	74.87	10.66	14.0	46
P574	23-4	6Al-4V	14,000	44	5.04	Recycle 7'	12	50	300	550	3/min.	18.00	15.00	None	82.37	-	-	46
F57[illegible]	23-4	6Al-4V	-	-	5.27	Recycle 7	12	60	175	500	4/min.	20.00	15.50	None	75.00	10.66	13.0	46
F574	23-[illegible]	6Al-4V	15,000	42-44	5.30	Recycle 7'	12	15	200	500	1/min.	18.00	16.70	None	91.37	14.11	15.0	55
F57[illegible]	23-2	6Al-4V	15,000	42-44	3.52	Recycle 7'	12	80	80	500	4/min.	20.00	15.12	None	60.69	10.54	17.0	59
F57[illegible]	23-4	6Al-4V	15,000	44	5.60	Recycle 7'	12	15	175	500	2/min.	19.75	15.00	None	61.69	-	-	52
F577	23-2	6Al-4V	15,000	44	7.80	3''Sq.Blks.	12	90	165	500	2/min.	30.00	27.62	None	142.00	22.61	15.0	50
F57[illegible]	23-3	6Al-4V	15,000	42	4.65	3' Chunks	12	80	175	550	3/min.	20.00	18.37	None	89.50	14.21	15.0	59
F57[illegible]	21--1A		15,000	40-42	2.20	Recycle 4	9	60	150	350	4/min.	20.75	9.75	None	42.00	11.36	27.0	47
F5[illegible]	23-3	6Al-4V	15,000	44	6.63	7'63''Bars	12	43	175-250	750	1/min.	20.00	16.32	None	66.52	13.76	15.0	46
F5[illegible]	23-2	6Al-4V	15,000	44	7.65	7' Sq.Stock	12	190	750	1,000	1/min.	20.00	26.50	None	135.12	36.36	26.0	-
F5[illegible]	23-4	6Al-4V	15,000	43-44	4.95	7' 6T949	12	100	350	750	5/min.	20.00	18.37	None	88.00	15.48	17.0	46
F5[illegible]	23-2	6Al-4V	14,500	44	-	6' 6T949	12	40	350	-	2/min.	40.00	50.00	- Electrode Broke During Run -				
F584	23-2	6Al-4V	15,000	44	4.76	7' Square	12	150	175	200	2/min.	20.00	17.87	None	73.75	13.96	16.0	47
F585	23-3	6Al-4V	15,000	40-44	7.44	Recycle	12	20	250	1,000	2/min.	20.00	26.12	6	140.00	41.24	29.0	57
F586	23-2	6Al-4V	15,000	44	6.22	6T949	12	40	350	750	2/min.	20.00	19.50	6	106.75	16.34	15.0	66
F587	23-2	6Al-4V	14,000-15,000	42-44	3.95	6''Recy. 4''Recy.	12	65	350	850	2/min.	26.50	13.00	6	64.87	9.86	15.0	58
F58[illegible]	23-2	6Al-4V	15,000	44	6.89	Recycle	12	40	350	1,000	4/min.	25.00	22.31	6	118.25	23.24	19.0	60
F58[illegible]	23-2	6Al-4V	15,500	42-44	7.95	7' Recy.	12	30	250-350	1,000	4/min.	31.00	29.62	6	145.00	22.20	15.0	54
F590	23-3	6Al-4V	14,000	44	5.75	6' Recy.	12	50	250-350	1,000	4/min.	16.12	21.25	6	93.75	14.52	15.0	60
F59[illegible]	23-2	6Al-4V	16,000	42-48	12.10	7'' Recy.	16	40	250-350	1,000	2/min.	42.00	44.12	6	269.00	45.36	16.1	82
F592	23-4	6Al-4V	13,000	44	5.75	Recycle	12	100	300-500	1,000	4/min.	22.87	19.00	-	102.81	10.62	10.0	74
F593	23-3	6Al-4V	13,500	44	6.05	7' Recy.	12	40	150-300	1,000	3/min.	27.49	18.00	-	100.00	-	-	55
F594	23-3	[illegible]	13,500	44	6.50	6' Recy.	12	80	350	1,000	4/min.	32.63	34.31	6	160.25	36.62	22.0	-
F59[illegible]	23-2	[illegible]	13,500	42	7.90	7 Recy.	12	50	150-300	1,000	4/min.	23.93	24.12	6	116.65	11.62	09.0	34

TABLE J1 (Continued)

MELTING RECORD

Heat No.	Proc. No.	Material	Melting: Amps	Melting: Volt	Melting: Time Min.	Melting: Elect. Dia.	Melting: Crucible Dia. in.	Vacuum – Microns: Start	Vacuum – Microns: During Melt	Vacuum – Microns: After Pour	Vacuum – Microns: 5 Min. Leak Rate	Skull Wt.: Start Lb.	Skull Wt.: Finish Lb.	Fluidity Spiral in.	Gross Heat Wt. Lb.	Net Heat Wt. Lb.	[illegible]	Humidity Percent
[illegible]	[illegible]	[illegible]	13,500	40-42	-	7 Recy.	9	100	150-200	225	4/min.	11.00	8.50	3	49.31	10.48	21.0	35
[illegible]	[illegible]	[illegible]	-	-	-	7 Recy.	9	40	-	-	2/min.	9.18	8.00	3	48.75	10.48	21.0	35
[illegible]	[illegible]	[illegible]	13,500	42-44	5.55	[illegible] Recy.	12	100	250-300	550	2/min.	39.66	19.37	6	103.18	11.86	11.0	41
[illegible]	[illegible]	[illegible]	13,500	42-44	5.00	7 Recy.	12	30	40-100	500	5/min.	26.75	19.00	6	98.00	39.36	40.0	31
[illegible]	[illegible]	[illegible]	13,500	44	6.20	Recycle	12	30	150-300	600	[illegible]/min.	24.50	18.56	6	91.96	14.62	15.0	
[illegible]	[illegible]	[illegible]	18,000	44	14.33	6	16	20	100-350	750	2/min.	35.50	45.00	-	168.50	73.75	[illegible]	42
[illegible]	[illegible]	[illegible]	19,000	44	10.40	7	16	20	100-350	500	2/min.	37.49	35.62	-	184.50	23.24	7.5	39
[illegible]	[illegible]	[illegible]	-	-	[illegible]	6	16	0	350	1,000	5/min.	43.0	45.0	-	220.00	112.24	51.2	45
[illegible]	[illegible]	[illegible]	18,000	42-44	14.12	10	16	70	500-700	1,000	7/min.	30.0	46.0	-	252.00	51.62	20.5	40
[illegible]	[illegible]	[illegible]	9,000	42-44	15.00	6 Recy.	16	5	100-250	750	3/min.	16.25	35.0	-	197.00	32.56	16.5	37
[illegible]	[illegible]	[illegible]	12,000	30	6.3	7	9	50	150	450	4/min.	6.66	11.61	10	53.25	12.0	24.6	43
[illegible]	[illegible]	[illegible]	12,000	30	7.0	7	9	125	125-150	150	5/min.	7.45	10.0	10.5	55.[illegible]	12.0	[illegible]	44
[illegible]	[illegible]	[illegible]	-	-	-	10	16	-	-	-	10/min.	76.	56.	-	323.0	44.42	13.7	38
[illegible]	[illegible]	[illegible]	20,000	43	15.0	10	16	-	-	-	10/min.	53.	56.	-	325.0	44.40	13.65	45
[illegible]	[illegible]	[illegible]	20,000	43	15.6	10	16	300	750	1,000	10/min.	45.31	55.25	-	122.0	44.40	15.75	50
[illegible]	[illegible]	[illegible]	19,500	43	5.50	10	16	200	200-250	1,000	5/min.	74.32	55.43	-	325.0	44.40	13.65	47
[illegible]	[illegible]	[illegible]	20,000	44	7.05	7	16	225	200-225	2,000	5/min.	41.50	49.12	-	298.0	64.24	26.3	55
[illegible]	[illegible]	[illegible]	20,000	42	-	10	16	250	350	2,000	5/min.	61.32	49.67	-	303.52	64.24	[illegible]	46
[illegible]	[illegible]	[illegible]	20,000	44	4.2	10	16	275	375	2,000	5/min.	61.87	50.67	-	300.52	64.24	27.6	46
[illegible]	[illegible]	[illegible]	20,000	36-42	16.62	12	16	250	300-350	3,000	5/min.	30.0	72.62	-	-	75.0	-	50
[illegible]	[illegible]	[illegible]	12,000	40-42	-	6	16	200	200-350	750	5/min.	24.0	104.62	-	112.50	-	-	46
[illegible]	[illegible]	[illegible]	22,500	36	17.6	12	16	50	250-300	3,000	3/min.	66.0	54.31	-	341.36	46.1	7.4	49
[illegible]	[illegible]	[illegible]	23,500	46	16.5	12	16	80	200	-	2/min.	67.15	53.0	-	313.0	64.59	20.6	46
[illegible]	[illegible]	[illegible]	23,000	36-41	[illegible]	12	16	60	60-300	3000	2/min.	46.57	56		363	65.16	17.9	42
[illegible]	[illegible]	[illegible]	23,000	35-41		12	16				4/min.	74.31	65.31		361	64.26	17.0	40
[illegible]	[illegible]	[illegible]	22,000	40-42		10 Recycle	16	90	90-1000		4/min.	50.0	64.61		376	23.64	6.6	40
[illegible]	[illegible]	[illegible]	23,500	40-36		12 Recycle	16	200	200-1000	3000	3/min.	59.07	42.0		294.77	34.96	[illegible]	4
[illegible]	[illegible]	[illegible]	22,000	36	15.[illegible]	12 Recycle	16	100	100-700	3000	4/min.	40.0	47.07		299.47	17.06	19.2	39
[illegible]	[illegible]	[illegible]	20,000	36		12 Recycle	16	110	110-1000	3000	4/min	50.0	75.12		320.0	63.07	15.5	36
[illegible]	[illegible]	[illegible]	[illegible],000	42	16.3	12 Recycle	16	130	130-1000	3000	6/min	50.0	62.5		322.0	44.4	7.2	40
[illegible]	[illegible]	[illegible]	14,000	46		6 Recycle	12	120	150	175	2/min	9.12	13.37	13.5	59	10.73	16	
[illegible]	[illegible]	[illegible]	14,000	46		6 Recycle	14	150	150-200	200	4/min.	10.2	11.0	14	61.66	10.93	[illegible]	47
[illegible]	[illegible]	[illegible]	14,000	36-40		6 Recycle	12	120	170-200		6/min.	7.10	10.36		64	10.42	16.3	39

TABLE J2

MECHANICAL PROPERTIES OF
RECYCLED LOW INTERSTITIAL 6Al-4V

HEAT NO.		YIELD STRENGTH 0.2% OFFSET	ULTIMATE TENSILE STRENGTH	ELONGATION	REDUCTION IN AREA %	BHN
22-43-P245-	1A	104,000	124,800	13	33.6	269.3
	B	103,000	124,000	10	24.6	
	C	105,000	124,200	9	22.4	
22-43-P249-	1A	102,000	122,200	10	19.0	269.3
	B	104,000	124,200	10	21.7	
	C	104,000	124,000	10	24.6	
22-43-P252-	2A	106,000	127,600	10	20.4	276.5
	B	107,000	127,600	11	25.2	
	C	104,000	126,000	9	22.4	
22-43-P255-	3A	107,000	128,000	13	27.2	277.0
	B	107,000	126,800	10	25.9	
	C	106,000	126,800	10	21.7	
22-43-P259-	1A	109,000	128,000	13	32.4	279.6
	C	108,000	128,000	12	24.4	
22-43-P289-	5A	106,000	126,000	12	31.9	277.0
	B	104,000	122,000	9	20.8	
	C	105,000	122,000	12	31.9	
22-43-P267-	2A	109,000	130,000	12	26.5	271.6
	B	110,000	131,200	12	23.9	
	C	110,000	130,000	10	19.7	
22-43-P271-	1A	109,000	128,000	13	29.2	279.0
	B	110,000	128,400	12	26.5	
	C	108,000	128,000	10	24.6	
22-43-P280-	2A	110,000	128,000	8	22.4	277.0
	B	110,000	130,000	11	27.0	
	C	109,000	130,000	13	34.4	
22-43-P282-	4A	Too	93,200	0	0	282.3
	B	Brittle	96,000	0	0	
	C		72,000	0	0	
22-43-P332-C	1A	105,000	125,200	12	18.1	272.0
	B	102,000	123,600	12	33.6	
	C	104,000	124,000	12	27.0	

TABLE J2 (Continued)

MECHANICAL PROPERTIES OF
RECYCLED LOW INTERSTITIAL 6Al-4V

HEAT NO.	YIELD STRENGTH 0.2% OFFSET	ULTIMATE TENSILE STRENGTH	ELONGATION	REDUCTION IN AREA %	BHN
22-43-P334-C2A	109,000	128,800	10	28.5	290.1
B	110,000	128,800	11	27.7	
C	110,000	128,000	11	29.2	
22-43-P372-C3A	110,000	131,600	11	26.5	279.2
B	110,000	131,600	12	23.2	
C	112,000	131,200	11	26.5	
22-43-P375-C4A	114,000	133,200	8	15.0	287.2
B	116,000	134,400	10	19.7	
C	115,000	134,800	11	26.5	
22-43-P376-C5A	117,000	137,200	13	26.5	296.0
B	119,000	136,200	10	21.0	
C	118,000	136,200	11	21.0	

TABLE J3

EXPERIMENTAL RAMMED GRAPHITE MOLD MIXTURES

MIX NO.	GRAPHITE USED			PITCH	LAUNDRY STARCH	CORN FLOUR	CEMENT C-3	RAW LINSEED OIL	WATER
	BB5	Reclaim BB5	Classified Turnings						
1	69			10	5		8		8
2	70.5			10	5.25		8.25		6
3		80.5		5.8	5.8		4.6		3.3
4		75		7.0	5.0		6.0		7.0
5		70		10	5.0		8.0		7.0
6		73.7		10.1		3.04	8.1		5.05
7	83.7				7.1				10.1
8	76.1			11					12.9
9	79.3						9.2		11.5
10	73.5			10.6	5.32				10.6
11	71.1			10.3			8.3		10.3
12	85.8					3.73			10.4
13	75			10.85		3.26			10.85
14		86.25				3.75			10.0
15		86.25				(Truscar) 3.75			10.0
16		70.5*		10	5.25		8.25		6.0
17	70			10	5		8		7
18	73			12.2	6.1				8.7
19	77			10	5			1	7
20	74.76			9.85	4.92			1.97	8.5
21	72			10	5			3	10
22		70 (BB8)		10	5		8		7
23	74			10	5			4	7
24	76			10		3		1	10
25	75			10		3		2	10
26	74			10		3		3	10
27	75			10		4		1	10
28	74			10		4		2	10
29	73			10		4		3	10
30			70	10	5		8		7
31			70	10		3	8		9
32			67.75	9.67	4.84		7.75		10
33			68	10	5		8		9
34			69	10		4	7		10
35			70	10		4	6		10
36			71	10		4	5		10
37			72	10		4	4		10
38			73	10		4	3		10

* 2nd reclaim

TABLE J3 (Continued)

EXPERIMENTAL RAMMED GRAPHITE MOLD MIXTURES

MIX NO.	GRAPHITE USED			DUPONOL G	PITCH	LAUNDRY STARCH	CORN FLOUR	CEMENT C-3	RAW LINSEED OIL	WATER
	BB5	Crescent	Classified Turnings							
39		65		0.938	9.38		2.82	7.5		14.75
40		70			10		3	8		9
41			69	1	10		3	8		9
42			69		10	5		8		8
43			73		10		4	2		11
44			66.2	1.09	10.95	5.47		8.75		7.65
45			68	2	10	5		8		7
46		70			10	5		8		7
17	70				10	5		8		7
30			70		10	5		8		7
47	69.5				9.72	4.85		2.78		8.35
48	72.5			0.98	9.8	4.9			2.94	8.82
49	69			1	10	5		8		7
50			(Calcined Coke 3-15) 70		10	5		8		7
51	70				9.72	4.86		3.89		9.58
52			(Calcined Coke 3-04) 70		10	5		8		7
53			(Calcined Coke 3-15) 76		8	4		6		6
54	71				10	4		8		7
55	72				10	3		8		7
56	73				10			8		9
57	70				10		3	8		9
58	70				10		3	8		9
59		63.75		0.938	9.38	2.82	7.5			9.38
60			66.5		9.38	2.82	5.62			14.7

TABLE J3 (Continued)

EXPERIMENTAL RAMMED GRAPHITE MOLD MIXTURES

MIX NO.	PETROLEUM CALCINED COKE	COAL CALCINED COKE	PETROLEUM RAW COKE	COKE FLOUR	STARCH	PITCH	C-3 CEMENT	WATER	SHRINKAGE In./In.
83		75		5	5	10*		10	0.006
84		70		10		10*		10	$\overline{0.007}$
85		65		15		10*		10	$\overline{0.002}$
86		70		5	5	10*		10	0.012
87		65		10	5	10*		10	0.012
88		60		15	5	10*		10	0.011
89		65		5	5	10*	8	7	0.016
90		60		10	5	10*	8	7	0.015
91		55		15	5	10*	8	7	0.013
92			75	5		10*		10	0.105
93			70	10		10*		10	0.089
94			65	15		10*		10	0.074
95			75		5	10*		10	0.097
96			73.8		5.2	10.5*		10.5	0.105
97			72.2		5.56	11.2*		11.2	0.093
98			75		5	10*		10	0.093
99			73.8		5.2	10.5*		10.5	0.093
100			72.2		5.56	11.2*		11.2	0.159
101				80		10*		10	0.002
102				75		15*		10	-----
103				70		20*		10	-----
104				76.2	4.76	9.52*		9.52	0.023
105				71.6	4.7	14.2*		9.5	0.015
106				66.7	4.77	10.03*		9.5	0.021
107		78				12*		10	0.007
108		80				10*		10	0.008
109		82				8*		10	0.003
110	75			5		10*		10	-----
110A	70			5	5	10*		10	0.019
110B	65			10	5	10*		10	0.016
111	70			10		10*		10	0.002
112	65			15		10*		10	0.005
113		76				12**		12	$\overline{0.016}$
114		78				10**		12	$\overline{0.010}$
115		80				8**		12	$\overline{0.014}$
116		71			5	12**		12	$\overline{0.018}$
117		73			5	10**		12	0.012
118		75			5	8**		12	0.016
119		76				12***		12	$\overline{0.009}$
120		78				10***		12	$\overline{0.001}$
121		80				8***		12	-----
122				78		10***		12	0.003
123				73		15***		12	0.007
124				68		20***		12	0.021
125				73	5	10***		12	0.016
126				68	5	15***		12	0.021
127				63	5	20***		12	0.023
128		71			5	12***		12	0.016
129		73			5	10***		12	0.012
130		75			5	8***		12	0.014
131		67			5	12***	8	8	0.016
132		69			5	10***	8	8	0.016
133		71			5	8***	8	8	0.018

* Foundry Pitch
** Black Diamond Pitch
*** Koppers Pitch

TABLE J3 (Continued)

EXPERIMENTAL RAMMED GRAPHITE MOLD MIXTURES

MIX NO.	GRAPHITE USED Sweco 20	GRAPHITE USED Sweco 40	PITCH	LAUNDRY STARCH	CEMENT C-3	LIQUID BINDER	WATER	SHRINKAGE In/In.
61	70		9	6		10 (7605)	5	
62	75		9	6		8 (7605)	2	0.0105
63	70.5		10.1	5.04		10.1 (7601)	3.5	0.0150
64	71.6		10.2	5.1		10.2 (7101)	1.5	0.0276
65	52	21	10	5	8		5.6	0.0239
66	52	20	10	3	8		7	
67	70 (carbon sand)		10	5	8		7	
	COKE 93-04)							
68	68		12	5	8	7		0.0094
69	70		10	5	8	7		0.0094
70	72		8	5	8	7		0.0063
71	64.8		11.4	4.75	4.75		14.3	0
72	66.7		9.5	4.75	4.75		14.3	0
73	68.6		7.6	4.75	4.75		14.3	0
74	74.3		11.42				14.28	0
75	75.2		10.50				14.3	0.031
76	78		7.6				14.3	0
77	73		12	5		10		0.0125
78	75		10	5		10		0.0019
79	77		8	5		10		0.0078
80	78		12			10		0.0016
81	80		10			10		0
82	82		8			10		0

* Slurry - Petroleum residual

7605 - Amino - Aldehyde

7601 - Urea type - water soluble

7101 - Pheno - Formaldehyde - water dispersing

TABLE J4

GRAIN SIZE DISTRIBUTIONS OF GRAPHITE BASE MATERIALS

U.S. Series Equivalent No.	National Carbon Grade BB 8	Sweco Separator Pass No. 10	Reclaimed (Tumbled Only)	Reclaimed Crushed & Tumbled	Reclaimed Crushed Only	Reclaimed Crushed & Pulverized	2nd Reclaim Crushed	Reclaim Plus 20% Fines
6								
12		0.78						
20	5.44	39.70	0.12	0.26	0.22	2.32	0.32	0.38
30	40.82	40.86	1.46	3.88	5.54	7.10	5.24	1.50
40	32.35	10.62	5.30	13.50	9.88	12.12	15.06	3.10
50	16.72	3.24	31.30	25.96	20.76	20.06	30.28	15.50
70	2.08	1.68	38.75	29.10	26.20	23.56	25.40	23.78
100	.49	1.00	19.72	18.32	18.10	15.66	10.94	17.60
140	.28	0.52	2.90	5.44	6.86	5.14	3.90	6.50
200	.20	0.46	0.84	2.18	3.80	2.96	2.76	4.30
270	.08	0.14	0.08	0.34	2.00	0.96	1.28	3.30
Pan	.22	0.42	0.06	0.92	6.52	8.28	4.74	23.84
Total	98.68	99.42	100.53	99.90	99.88	98.16	99.92	99.80

	Crescent Graphite	Sweco No. 20	Calcined Coke 3-15	Calcined Coke 3-04	Sweco No. 40	Sweco 60% No. 20 40% No. 40	BB 5
6							
12				.04			
20	.06	.10	.08	.60		0.2	0.14
30	9.36	6.62	23.24	1.44	.02	6.4	0.68
40	11.62	22.34	51.58	3.14	.06	18.0	1.22
50	22.66	52.50	21.42	6.16	1.38	32.0	26.44
70	17.74	18.54	3.36	13.34	10.12	22.2	44.28
100	11.12	1.82	.34	27.24	17.84	10.2	24.62
140	6.36	.08	.06	27.80	16.96	4.2	1.44
200	3.50	.02	.02	12.94	12.86	2.4	0.2
270	1.04			3.0	9.44	1.2	0.08
Pan	6.32		.06	3.32	30.76	3.2	0.68
Total	87.98	102.02	100.16	99.02	99.44	100.	99.78

TABLES

TABLE J5

PROPERTIES OF RAMMED GRAPHITE MOLD MIXTURES

MIXTURE NO.	MOISTURE CONTENT, PER CENT	GREEN PERMEABILITY	GREEN HARDNESS		GREEN COMPRESSION STRENGTH	FIRED TENSILE STRENGTH, PSI	FIRED SCRATCH HARDNESS	
			2 x 2 Specimen	Mold			Test Coupon	Mold
1	7.75	150	77	77	10.3	65	75	75
	8.75	145	76	76	9.4	75	76	90
	8.9	90	78	78	10.3	80	82	82
	10.0	95	78	79	10.5	70	82	94
	9.1	105	77	78	9.7	87	83	95
	9.2	100	77	77	9.8	77	82	96
	8.6	80	79		9.8	75	76	98
	8.8	85	79		10.3	70	78	98
	8	97	77	79	9.5	72.5	80	98
	8.3	97	78	79	8.9	85	80	97
	7.8	83	77		10.1	85	80	97
	7.6	90	78		9.9	90	80	98
	8	93	77		10.1	102.5	82	
	8.1	95	78		10.5	85	83	98
	8.75	95	77		9	75	83	95
	8.5	85	78		9.2	95	83	97
	7.5	82	78		9.2	80	80	98
	8.5	85	79		9.6	90	80	
	8.2	107	77		8.9	95	86	96
	8.4	95	79	80	9.6	95	85	98
	9.0	105	77	78	9.7	80	82	97
	8.2	115	77	80	9.5	65	75	96
	7.4	115	77	80	8.7	67.5	75	
	8	115	78	80	9.4	75	75	97
2	7.5	145	77	77	7.2	62.5	75	87
	5.8	160	79	78	9.3	51.5	60	93
	5.5	135	80	80	10.7	75	75	96
	6.5	122	78	78	10.1	60	70	97
	6.75	127	78	80	9.4	50	65	90
3	4.5	170	75	83	5.7	20	20	75
4	6.75	195		80	8.3	45	60	
5	6.2	205		80	8.6	87.5	75	96
6	5.75	155		80	5.5	Broken before test		90
7	9	187		58	4.8	Broken	20	70
8	12	100		68	5.2	20	30	52
9	11.1	155		60	2.9	Broken in firing		0
10	10.2	125		70	4.5	42.5	65	85
11	10.2	90		70	5.9			80
12	9.4	180		70	3.2	Broken	0	20
13	10.3	120		76	6.2	Broken in firing		75
14	10	270		76	4.8	Broken in firing		40
15	9	267		76	4.4	Broken in setup of test		40
16	5.75	270		82	6.7	55	60	93
17	7.6	105	80	80	10.6	46	60	
	6	110	78	80	9.7	50	62	98
	6.3	125	81	80	10.3	47.5	70	98
	6.3	127	79	80	9.7	46	68	97
	7.0	97	79	80	8.9	40	63	97
	6.4	117	79	76	9.3	46	70	96

TABLES

TABLE J5

PROPERTIES OF RAMMED GRAPHITE MOLD MIXTURES

MIXTURE NO.	MOISTURE CONTENT, PER CENT	GREEN PERMEABILITY	GREEN HARDNESS		GREEN COMPRESSION STRENGTH	FIRED TENSILE STRENGTH, PSI	FIRED SCRATCH HARDNESS	
			2 x 2 Specimen	Mold			Test Coupon	Mold
17	7.2	122	78	76	8.0	43	58	95
cont.	7.5	127	79	82	8.6	44	70	
	6.75	150	77	76	7.5	37.5	55	97
	6.75	140	76	80	7.2	47.5	65	
	8	152	76	78	6.7	50	70	97
	7.0	125	77	80	7.1	62.5	70	95
	7.4	130	77	80	7.4	62.5	70	95
	7.3	230	80		7.2	60	65	
	7.3	320	80		7.1	50	60	
	6.75	270	77		5.3			
	6.75	290	77		5.3	45	55	
	6.75	280	78		5.8	40	50	
	7.1	330	78		5.9	30	55	
	7.0	310	79		6.3			
	6.85	330	79		6.9	40	65	
	7.5	300	78		6.5	35	60	
	6.85	270	79		7.5	52.5	60	
	6.5	220	79		6.5	60	70	
	7.9	210	80		6.5	60	70	
	7.6	270	78		7.3	55	70	
	7.5	230	79		6.8	60	70	
	7.75	200	79		7.0	70	75	
	7.75	290	80		7.3	65	70	
	7.75	260	79		6.2	52.5	70	
	8.0	290	79		5.1	40	55	
	7.9	270	80		6.9	55	65	
	7.7	250	79		7.7	65	70	
	8.2	250	79		7.0	60	65	
	8.0	240	80		5.7	50	65	
	8.1	230	79		7.3	60	70	
	8.0	230	80		7.0	52.5	65	
	8.5	250	78		6.7	Broke	30	
	8.8	170	80		7.6	27.5	60	
	8.0	180	79		6.8	35	60	
	8.3	180	78		6.9	25	55	
	9.0	240	79		6.3	30	60	
	8.5	240	77		4.9			
	7.8	220	79		6.3	30	50	
	7.75	250	79		7.1	25	65	
	8.0	200	79		6.9	37.5	70	
	8.2	260	78		5.8	22.5	60	
	8.5	240	78		7.1	35	70	
	7.4	260	79		6.0			
	7.2	250	79		5.5			
	8.6	290	76		4.3			
	7.5	210	79		6.3			
	8.3	260	78		5.3			
	7.6	230	79		6.7			
	8.0	210	79		6.7			

TABLES

TABLE J5

PROPERTIES OF RAMMED GRAPHITE MOLD MIXTURES

MIXTURE NO.	MOISTURE CONTENT, PER CENT	GREEN PERMEABILITY	GREEN HARDNESS		GREEN COMPRESSION STRENGTH	FIRED TENSILE STRENGTH, PSI	FIRED SCRATCH HARDNESS	
			2 x 2 Specimen	Mold			Test Coupon	Mold
17	8.0	250	78		5.0			
cont.	8.0	220	77		4.5			
	8.0	230	78		4.6			
	7.2	260	78		4.0			
	7.5	230	78		5.5			
	8.0	270	78		6.1			
	7.75	220	78		6.4			
	7.0	240	79		6.8			
	6.2	95	79		9.7	85	80	
	7.5	105	81		9.3	60	70	
	7.5	95	80		9.4	67.5	75	
	6.9	125	80		9.1	80	77	
	7.5	117	79		8.9	75	75	
	7.8	120	80		8.1	67.5	75	
	7.8	110	80		9.9	77.5	80	
	7.7	120	80		9.7	75	77	
	7.75	113	80		9.8	77.5	80	
	8.0	120	79		8.3	60	70	
	7.9	123	79		8.1	82.5	80	
	7.75	127	80		9.9	90	75	
	7.9	130	80		9.8	70	75	
	7.5	115	78		6.8	65	75	
	7.9	155	80		9.2	70	77	
	7.2	165	80		9.1	50	65	
	7.5	162	80		9.2	55	70	
	7.5	177	79		7.6	70	75	
	8.3	127	79		9.2	77.5	80	
	8.4	152	80		9.1	45	70	
	8.1	145	79		9.8	60	75	
	8.1	190	80		9.6	70	75	
	8.0	245	79		8.9	72.5	75	
	8.2	245	80		8.4	60	70	
	8.4	195	80		9.0	67.5	75	
	7.4	185	80		9.1	50	65	
	7.8	225	79		8.0	62.5	70	
	7.2	200	80		8.5	67	72	
	7.75	215	80		7.7	52.5	70	
	6.25	192	80		8.6	80	75	
	7.0	220	80		8.1	75	77	
	7.2	147	77	80	8.3	77.5	75	92
	6.75	150	79	80	9.3	70	75	
	6.9	120	79	80	9.0	70	75	
	8.6	115	74	80	7.5	64	85	97
18	6.6	105	78	79	6.9	26	35	92
19	7.7	122	75	76	6.1	27.5	40	92
	6.4	132	75	72	6.2	27.5	45	93
20	7.2	117	72	72	5.6	40	55	95
	9.5	105	70	72	4.4	46	70	95

TABLES

TABLE J5

PROPERTIES OF RAMMED GRAPHITE MOLD MIXTURES

MIXTURE NO.	MOISTURE CONTENT, PER CENT	GREEN PERMEABILITY	GREEN HARDNESS		GREEN COMPRESSION STRENGTH	FIRED TENSILE STRENGTH PSI	FIRED SCRATCH HARDNESS	
			2 x 2 Specimen	Mold			Test Coupon	Mold
21	9.3	105	72	72	5.0	40	60	95
	8.1	107	73	72	4.9	35	55	95
	8.5	90	72	78	4.8	52.5	70	96
	9	80	72	72	5.2	61	75	95
	9.4	82	71	72	5.5	50	72	95
	8.8	90	70		4.3	46	70	
	9.2	75	57	78	5.8	137.5	90	95
	9.5	90	72	78	4.8	167.5	90	95
	8	77	74	76	6.7	116.5	85	94
	9	92	73	76	5.6	75	80	
22	6.1	440	79	80	8.8	52.5	70	95
23	7.2	100	75	73	5.2	35	55	87
24	8.2	107	72	77	4.3	20	25	94
	8.6	95	74	76	3.8	22.5	30	92
25	8.2	100	73	77	4.4	17.5	20	78
	8.5	110	70	76	2.7	30	50	80
26	9.5	110	73	78	4.1	12.5	10	72
	9	75	74	72	4.9	60	70	91
	9.5	87	74	76	4.7	21	30	92
27	7.75	105	75	80	5.7	20	30	85
	7.3	87	75	78	5.1	27.5	40	80
28	8.2	92	74	78	4.0	20	25	94
	8.4	73	76	81	6.0	31.0	55	87
	8.2	77	74	81	6.3	32.5	55	87
	7.5	73	75	78	5.5	32.5	60	93
29	9.2	73	74	78	5.2	60	75	94
	8.75	85	73	78	5.3	52.5	70	94
30	8.0	150	80	80	10.6	41.5	65	
	7.8	200	78	78	10.5	42.5	70	
	7.5	140	77	80	10.8	57.5	80	93
	7.5	92	78	80	8.7	66.5	80	95
	6.5	88	80	80	9.1	45	70	
	7.4	62	78	80	9.2	60	80	
30	7.8	125	80		10.0	55	65	
	7.2	130	80		9.8	45	60	
	9.2	97	80		9.0	35	60	
	10.8	80	78		10.3	60	80	
	9.3	127	80		9.7	40	65	
	9.25	165	79		9.3	45	75	
	7.2	330	79		6.7			
	7.3	410	80		7.2			
	7.75	140	78		6.2			
	9.4	80	80		7.9			
31	9.4	75	75	80	7.1	25	55	
	8.2	75	75	80	8.1	35	75	94
	9.7	60	75	80	8.4	37.5	75	
	9.75	77	75		8.5			
	9.5	72	76		8.6			

TABLE J5

PROPERTIES OF RAMMED GRAPHITE MOLD MIXTURES

MIXTURE NO.	MOISTURE CONTENT, PER CENT	GREEN PERMEABILITY	GREEN HARDNESS		GREEN COMPRESSION STRENGTH	FIRED TENSILE STRENGTH, PSI	FIRED SCRATCH HARDNESS	
			2 x 2 Specimen	Mold			Test Coupon	Mold
31	9.5	72	76		8.6			
cont.	9.9	75	76		8.1			
32	9.4	68	76	78	8.1	38.5	75	97
33	8.7	100	77	78	9.0	35	80	94
34	9.8	75	75	80	9.0	42.5	80	95
35	9.2	77	75	80	8.4	41.5	78	96
36	8.9	93	75	80	8.6	46	75	95
37	10.0	95	75		9.2	40	75	96
38	10.7	78	74	80	8.7			92
39	14.5	17	70		6.5	297	91	
40	10.0	90	72		5.5	70	77	
	10	93	76		6.8	58.75	65	
41	10.3	46	74		5.8	112.5	85	
42	7.8	107	78		9.9	50	72	
	8.4	97	77		10.4	65	78	
	6.9	147	78		9.2	22.5	40	
43	11.3	38	74		8.5	35	65	
44	8.6	31	79		11.1	150	90	
45	8.1	45	79		10.3	152	90	
46	8.0	95	78		9.0	91	80	
47	12.0	75	75		7.5	135	90	
48	6.5	70	80		8.3	102.5	80	
49	7.5	95	80		8.7	166	87	
	8.75	85	80		9.3	145	87	
	7.5	110	79		9.2	87.5	78	
	8.25	110	79		9.2	102.5	85	
	8.20	100	79		8.8	100	85	
	8.2	110	80		8.9	100	85	
	7.9	125	78		7.2	95	80	
	7.9	120	78		8.6	92.5	82	
	8.25	120	78		8.8	100	82	
	7.9	110	79		8.5	107.5	82	
	8.1	130	80		8.2	112.5	84	
	8.1	130	80		8.7	110	80	
	8.1	93	78		9.4	140	85	
	8.5	93	80		9.6	136.5	85	
	7.0	73	80		10.9	169	87	
	7.8	77	80		10.2	115	80	
	7.5	92	80		9.0	166	87	
	8.75	85	79		9.3	145	87	
	7.5	110	79		9.2			
	8.25	110	79		9.1			
	8.2	100	79		8.7			
	8 2	105	79		8.7			
	7.9	122	78		7.3			
	7.9	115	79		8.6			
	8.25	120	78		8.7			

TABLE J5

PROPERTIES OF RAMMED GRAPHITE MOLD MIXTURES

MIXTURE NO.	MOISTURE CONTENT, PER CENT	GREEN PERMEABILITY	GREEN HARDNESS		GREEN COMPRESSION STRENGTH	FIRED TENSILE STRENGTH, PSI	FIRED SCRATCH HARDNESS	
			2 x 2 Specimen	Mold			Test Coupon	Mold
49	7.9	105	79		8.6			
cont.	8.1	125	79		8.4			
	8.1	125	80		8.8			
50	8.3	410	80		9.4	60	75	
51	11.4	115	75		4.8	72.5	75	
52	7.8	77	75		6.7	80	80	
53	6.2	660	76		5.6	35	60	
54	8.7	142	76		6.1	50	65	
55	7.4	143	76		6.1	42.5	55	
56	9.2	102	75		6.2	40	70	
57	11.5	160	73		6.7	45	65	
58	12.7	85	71		4.9	60	80	
59	12.75	83	70		3.7	95	85	
60	14.5	27	74		7.1	85	87	
61	10.7	270	76		9.5	105	85	
62	7.75	390	78		7.6	35	35	
63	8.2	390	78		8.6	42.5	70	
64	5.4	800	70		4.3			
67	7.6	170	78		7.4			
68	7.8	80	78		6.3	72.5	80	
69	8.6	60	73		4.3	54.0	88	
70	8.0	78	75		4.9	42.0	78	
71	2.36	50	66		3.0			
72	3.34	50	65		2.6	120.0	88	
73	2.10	50	65		2.5	95.0	88	
74		31	69		3.4	218.0	96	
75			70		2.9	200.0	96	
76			66		2.5	94.0	83	
77			76		5.2	77.0	86	
79			75		4.7	56.5	75	
80			76		4.7	81.0	83	
81			79		4.8	61.0	79	
82			77		4.5			
83	11.8	32	73		6.1	33.0	42	
84	12.8	19	75		7.5	25.5	41	
85	13.6	18	78		8.1	33.8	54	
86	12.0	37	74		5.4	57.5	76	
87	13.2	36	71		5.2	46.5	74	
88	11.4	23	75		6.4	47.7	73	
89	9.5	39	69		5.9	49.8	74	
90	8.8	48	72		5.2	34.0	56	
91	8.0	32	70		5.4	36.7	43	
92	15.4	7.5	79		12.3	60	92	
93	15.2	6.5	80		12.7			
94	16.7	7	80		12.2	34	84	
95	13.3	21	75		7.7			
96	12.5	49	65		6.3			
97	12.0	53	65		6.8			
98	10.8	[illegible]	[illegible]		5.0			

TABLE J5

PROPERTIES OF RAMMED GRAPHITE MOLD MIXTURES

MIXTURE NO.	MOISTURE CONTENT, PER CENT	GREEN PERMEABILITY	GREEN HARDNESS		GREEN COMPRESSION STRENGTH	FIRED TENSILE STRENGTH, PSI	FIRED SCRATCH HARDNESS	
			2 x 2 Specimen	Mold			Test Coupon	Mold
99	11.9	71	65		6.5			
100	11.8	30	67		6.4			
101	11.8	5	81		11.7	49.4	80	
102	14.8	6	81		12.9	55.0	84	
103	14.8	6	80		12.7	82.5	89	
104	16.0	6.5	78		10.2	51.0	88	
105	12.8	7	78		10.2	67.5	85	
106	13.4	6.5	77		10.0	72.0	81	
107	11.8	35	72		5.7	55.0	64	
108	12.2	36	77		6.1	55.0	59	
109	11.0	40	75		5.4	47.5	66	
110	10.6	5	84		15.0		66	
110A	15.6	9	77		11.2	35.0	83	
110B	14.2	13	77		10.5	26.0	74	
111	13.8	6	82		15.9	45.1	77	
112	13.6	6	83		16.0	43.0	80	
113	12.0	40	74		5.3	44.0	71	
114	13.0	41	75		5.9	40.0	70	
115	12.0	46	72		4.9	31.2	40	
116	13.6	40	69		4.8	77.5	85	
117	12.6	48	68		4.4	62.5	88	
118	11.4	59	70		5.0	48.5	74	
119	9.2	51	69		3.4	32.5	53	
120	10.3	52	68		3.6			
121	9.8	58	70		3.4			
122	17.6	5.5	80		13.7		88	
123	19.6	5.5	80		12.6	82.5	92	
124	21.8	5	80		12.5		93	
125	16.8	7	75		9.0	41.0	86	
126	13.8	6	75		9.8	69.0	89	
127	15.6	6.5	75		9.7	122.0	97	
128	13.4	31	70		4.9	58.5	77	
129	10.2	50	68		3.0	42.0	55	
130	10.8	54	73		4.4	39.5	52	
131	9.2	47	72		5.4	48.5	72	
132	9.6	48	70		5.0	56.0	80	

TABLE J6

SHRINKAGE OF RAMMED GRAPHITE MOLDS

MIX NO.	SHRINKAGE, IN/FT
2	0.128
4	0.198
5	0.198
16	0.188
17	0.125
	0.125
	0.138
	0.136
	0.136
	0.133
	0.140
Ave.	0.133
22	0.188
30	0.141
	0.141
Ave.	0.141
32	0.151
33	0.155
6	0.139
31	0.138
	0.104
	0.0926
	0.0909
	0.0792
Ave.	0.101
34	0.0755
35	0.104
36	0.1035
37	0.0755
38	0.138

MIX NO.	SHRINKAGE, IN/IN
17	0.0110
	0.01185
	0.0122
	0.0120
	0.0145
	0.0145
	0.00805
	0.0145
	0.0145
Ave.	0.0126
30	0.0136
	0.0126
Ave.	0.0131
40	0.00745
	0.01435
Ave.	0.00109
41	0.00825
43	0.00885
44	0.0151
46	0.01385
47	0.0153
48	0.0142
49	0.01535
	0.01450
	0.01450
	0.01450
	0.01450
Ave.	0.01453
51	0.01025
54	0.0152
55	0.0141
56	0.0103
57	0.0107
58	0.0149

MIX NO.	SHRINKAGE, IN/FT
19	0.207
	0.173
Ave.	0.190
20	0.173
	0.132
Ave.	0.152
21	0.138
	0.173
	0.160
	0.159
	0.0834
	0.146
	0.0612
Ave.	0.131
23	0.114
24	0.132
	0.151
Ave.	0.141
25	0.104
	0.0345
Ave.	0.0694
26	0.076
	0.045
	0.104
Ave.	0.075
27	0.0755
	0.0755
Ave.	0.0755
28	0.1385
	0.136
	0.151
Ave.	0.149
29	0.166

TABLE J7

EXPERIMENTAL SHELL GRAPHITE MOLD MIXTURES

Mix No.	Phenol Formal-dehyde %	Pitch %	Graphite Type	Graphite %	Solvent	Mull Time, Minutes
1	12		BB 5	88		4
2	12		Sweco #40	88		5
3	20		BB 5	80		5
4	12	8	BB 5	80		5
5	6	8	BB 5	86	1/2 Pt.	4*
6	12	8	BB 5	80	1/2 Pt.	4*
7	10 (Borden)	10	Carbon Sand	80		4
8	12 (7504)	10	Calcined Coke	78		4
9	10 (7504)	10	Calcined Coke	78		4

* Mulled dry 4 minutes and then mulled until alcohol solvent evaporated.

TABLE J8

EXPERIMENTAL INVESTMENT MOLD MIXTURES

Mix No.	Graphite #50 Mesh	Graphite Grade 39	Darex 56L	Daxad 32	Commercial White Glue	C-3 Cement	Pitch	Water	Comments
1	5 Parts		2 Parts	2¼ Parts					Medium shrinkage 20 hr. set time
2	7 Parts		2 Parts	2 Parts					Medium shrinkage 8 hr. set time
3	7 Parts			2 Parts	2 Parts				High shrinkage strong, 10 hr. set time.
4	7 Parts		2 Parts					1 Part	10 hr. set time hard strength no shrinkage
5	7 Parts				2 Parts			2 Parts	16 hr. set time, hard - no shrinkage
6	70 GM		20 GM			8 GM	10 GM	25 GM	Mold cavity pitted
7	70 GM		20 GM	20 GM		8 GM	10 GM		Mold cavity badly pitted - poor condition
8	70 GM				15 GM	8 GM	10 GM	30 GM	Scabbing, partial collapse of mold walls
9	70 GM		10 GM		6 GM (starch)	8 GM	10 GM	50 GM	Very porous, cavity collapsed.
10	350 GM		100 GM			40 GM	50 GM	125 GM	Air entrapped at cavity surfaces thick slurry.
11 (H-1) (First Coat)	30 GM	40 GM	30 GM			16 GM	20 GM	90 GM	First coat buckled and pulled away from second coat, air entrapped in second coat.
11A (Second Coat)	350 GM		50 GM			40 GM	50 GM	140 GM	
12	350 GM		50 GM			40 GM	50 GM	120 GM	Too stiff to pour well
13	200 GM	150 GM	40 GM				50 GM	270 GM	Molds good. Some air entrapment
14A (F-1) (First coat)	50 GM	38 GM	12 GM			10 GM	12 GM	65 GM	
14B (F-1)	100 CC Tetraethyl orthosilicate, 96 CC denatured ethyl alcohol 24 CC 5% hydrochloric acid. (plus 12 CC of water to control setting time) Added to: 600 GM -#20 Grog, 210 GM -120 mesh Novad. sand, 120 GM -200 mesh silica flour, 1 GM -magnesium oxide.								
15 (H-1)	Kerr crystallite and water								
16 (G-1)	200 GM	150 GM	50 GM			40 GM	50 GM	270 GM	Best mix

TABLE J9

GRAIN SIZE DISTRIBUTION OF RECYCLED MOLD MATERIALS

[illegible]	Per cent Retained on Screens													
Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
[illegible]														
[illegible]						0.2	0.4	0.2	0.4	0.2	.26	0.2		4.0
[illegible]			0.2	1.0	0.8	2.4	2.2	1.8	2.8	3.2	3.24	1.2	0.4	20.0
[illegible]	.184	0.2	1.4	2.4	2.6	3.2	3.2	3.2	5.4	6.4	7.18	3.2	5.8	16.0
[illegible]	1.500	2.2	3.4	5.2	5.6	6.5	5.8	7.6	8.6	11.0	13.34	9.6	12.6	10.8
[illegible]	7.63?	9.2	10.2	13.8	14.4	15.6	15.4	18.8	21.2	22.8	25.86	22.4	20.8	8.4
[illegible]	16.464	8.0	17.8	20.6	20.6	20.6	2?.8	24.2	24.4	23.2	24.12	23.0	18.6	7.6
[illegible]	16.726	8.4	17.8	19.0	18.0	17.4	16.6	16.6	15.6	13.0	11.20	13.0	13.4	7.?
[illegible]	10.970	1.2	11.6	10.6	10.1	9.4	9.2	7.2	6.8	5.4	3.36	6.2	8.4	6.6
[illegible]	6.440	8.8	8.8	7.0	7.2	6.4	6.6	5.4	4.2	3.2	2.40	4.6	5.4	5.6
[illegible]	.160	0.2	0.4	.2	—	0.4	0.2	0.2	—	—	.04	1.0	2.8	0.4
[illegible]	30.320	11.8	16.6	20.0	5.6	4.0	6.8	0.2	3.2	8.4	1.54	2.8	7.6	12.6
[illegible]	92.40	100.	88.2	100.	85.0	86.4	90.2	85.4	92.6	98.8	92.62	87.2	100.	100.
[illegible]	.027HB	.035HB	3/64HB-SL	1/16HB	3/32RD	1/8RD	3/16 RD	3/16 RD	3/16 RD	3/16 RD	1/8 HB			
[illegible]	14,000	12,100	12,100	12,100	12,100	12,100	12,100	8,050	8,050	6,070	6,070	6,070	6,070	6,070
												Calcined Coke	Sweco #20 Graphite	Machined Graphite

[illegible] Unless otherwise noted is rammed graphite.

TABLE J10

FEEDING DISTANCES IN UN-TAPERED MACHINED GRAPHITE MOLDS

HEAT NO.	PLATE THICK-NESS	PLATE DIA-METER	RISER DIA.	UNDER RISER SHRINK	PLATE SHRINK	EDGE SOUND	SOUND BEYOND RISER	TOTAL SOUND	T ÷ Total Sound Thickness
P-7	1 In.	6 In.	1 In.	No Obs	Yes	5/8 "	7/16	1-1/16	1.0625
	7/8			No Obs	Yes	0	13/16	13/16	0.929
	3/4			No Obs	Yes	1/4	5/8	7/8	1.16
	5/8			No Obs	Yes	3/8	9/16	15/16	1.50
P-9	1 In.	6 In.	1.5 In	Yes	Yes	5/8	3/8	1 In.	1.0
	7/8			Yes	Yes	9/16	5/8	1-3/16	1.36
	3/4			No	Yes	5/8	5/8	1-1/4	1.67
	5/8			No	Yes	3/8	7/16	13/16	1.30
	1/2			No	Yes	3/16	3/8	9/16	1.12
P-10	1 In.	6 In.	2 In.	No	Yes	3/4	1/4	1 In.	1.0
	7/8			No	Yes	11/16	13/16	1-1/2	1.71
	3/4			No	Yes	9/16	11/16	1-1/4	1.67
	5/8			No	Yes	5/16	9/16	7/8	1.40
	1/2			No	Yes	1/2	11/16	1-3/16	2.37
P-11	1 In.	6 In.	2.5 In	No	Yes	9/16	1/2	1-1/16	1.0625
	7/8			No	Yes	9/16	1/2	1-1/16	1.21
	3/4			No	Yes	1/4	1/2	3/4	0.75
	5/8			No	Yes	5/16	5/8	15/16	1.50
	1/2			No	Yes	1/4	5/16	9/16	1.12
	3/8		2 In.	No.	Yes	3/8	3/8	3/4	2.0
P-13	1 In.	5 In.	None		Yes	3/16	5/16	1/2	0.5
	7/8				Yes	1-1/16	3/16	1-1/4	1.43
	3/4				Yes	1/2	7/16	15/16	1.25
	5/8				Yes	1/2	1/8	5/8	1.0
	1/2				Yes	1/2	5/16	13/16	1.62
	3/8				Yes	5/16	3/8	11/16	1.83
P-14	1 In.	5 In.	1 In.	Yes	Yes	1/2	1/2	1	1.0
	7/8			Yes	Yes	1	5/16	1-5/16	1.5
	3/4			Yes	Yes	1/2	1/2	1	1.33
	5/8			Yes	Yes	9/16	1/2	1-1/16	1.70
	1/2			Yes	Yes	7/16	3/8	13/16	1.60
	3/8			No	Yes	3/8	7/16	13/16	2.15
P-15	1 In.	5 In.	1.5	Yes	Yes	11/16	7/8	1-9/16	1.56
	7/8			Yes	Yes	5/8	5/16	15/16	1.06
	3/4			Yes	Yes	9/16	3/8	15/16	1.25
	5/8			No	Yes	1/2	5/8	1-1/8	1.8
	1/2			No	Yes	1/4	5/16	9/16	1.12
	3/8			No	Yes	1/8	3/4	7/8	2.30
P-16	1 In.	5 In.	2 In	No	Yes	1/2	5/8	1-1/8	1.125
	7/8			No	Yes	9/16	1/2	1-1/16	1.2
	3/4			No	Yes	1/2	11/16	1-3/16	1.48
	5/8			No	Yes	1/2	5/8	1-1/8	1.80
	1/2			No	Yes	3/8	5/16	11/16	1.37
	3/8			No	Yes	3/16	3/16	3/8	1.00
P-17	1 In.	5 In.	2.5 In.	No	No			1-1/4	1.25
	7/8			No	No			1-1/4	1.43
	3/4			No	No			1-1/4	1.66
	5/8			No	Yes	1/2	5/8	1-1/8	1.8
	1/2			No	Yes	11/16	7/16	1-1/8	2.25
	3/8			No	Yes	1/4	1/2	3/4	2.00

TABLE J11

FEEDING DISTANCES IN TAPERED MACHINED GRAPHITE MOLDS

HEAT NO.	PLATE THICK-NESS	PLATE DIA-METER	PLATE RISER DIA.	TAPER	UNDER RISER SHRINK	PLATE SHRINK	EDGE SOUND	SOUND BEYOND RISER	TOTAL SOUND	T = Total Sound / Thickness
P-74	1/8 In.	6 In.	1 In.	2	no	yes	1/4	3/4	1/2	4.00
	1/4	6	1	2	no	yes	1/4	1/2	3/4	3.00
	3/8	6	1	2	no	yes	3/4	1/2	1-1/4	3.33
	1/2	6	1.5	2	no	yes	3/8	5/8	1	2.00
	5/8	6	1.5	2	no	yes	5/8	3/4	1-3/8	2.20
	3/4	6	2	2	no	yes	3/4	1/2	1-1/4	1.670
	7/8	6	2	2	no	yes	3/4	1/2	1-1/4	1.440
	1	6	2.5	2	no	yes	3/4	1/4	1-1/4	1.250
P-75	1/8 In.	6 In	1 In.	2	no	yes	1/4	1/4	1/2	4.00
	1/4	6	1	2	no	yes	1/4	1/2	3/4	3.00
	3/8	6	1	2	no	yes	1/2	1/4	3/4	2.00
	1/2	6	1.5	2	no	yes	1/2	1/4	3/4	1.50
	5/8	6	1.5	2	no	yes	1/2	1/2	1	1.60
	3/4	6	2	2	no	yes	3/8	1/4	5/8	.834
	7/8	6	2	2	no	yes	5/8	1	1-5/8	1.86
	1	6	2.5	2	no	yes	3/4	1/2	1-1/4	1.250
P-76	1/8 In.	6 In.	1 In.	2	no	yes	1/4	1/4	1/2	4.00
	1/4	6	1	2	no	yes	1/4	1/4	1/2	2.00
	3/8	6	1	2	no	yes	1/2	3/8	7/8	2.33
	1/2	6	1.5	2	no	yes	1/2	1/4	3/4	1.50
	5/8	6	1.5	2	no	yes	1/2	1/2	1	1.60
	3/4	6	2	2	no	yes	1/2	0	1/2	.666
	7/8	6	2	2	no	yes	3/4	1/4	1	1.14
	1	6	2.5	2	no	yes	1/2	1/4	3/4	.75
P-77	1/8 In.	6 In.	1 In.	3	no	yes	1/8	3/8	1/2	4.00
	1/4	6	1	3	no	yes	1/4	1/4	1/2	2.00
	3/8	6	1	3	no	yes	1/4	1/4	1/2	1.33
	1/2	6	1.5	3	no	yes	1/2	1/4	3/4	1.50
	5/8	6	1.5	3	no	yes	1/2	1/2	1	1.60
	3/4	6	2	3	no	yes	3/8	0	3/8	.50
	7/8	6	2	3	no	yes	3/4	1/2	1-1/4	1.43
	1	6	2.5	3	no	yes	3/8	1/2	7/8	.87
P-78	1/8 In.	6 In.	1 In.	3	no	yes	1/8	1/4	3/8	3.00
	1/4	6	1	3	no	yes	1/4	3/4	1	4.00
	3/8	6	1	3	no	yes	1/4	1/4	1/2	1.33
	1/2	6	1.5	3	ro	yes	3/8	1/2	3/8	1.75
	5/8	6	1.5	3	no	yes	1/2	1/4	3/4	1.20
	3/4	6	2	3	no	yes	1/2	3/4	1-1/4	1.67
	7/8	6	2	3	no	yes	5/8	1	1-5/8	1.86
	1	6	2.5	3	no	yes	5/8	1/2	1-1/8	1.125
P-79	1/8 In.	6 In.	1 In.	3	no	yes	1/8	1/4	3/8	3.00
	1/4	6	1	3	no	yes	1/4	1/4	1/2	2.00
	3/8	6	1	3	no	yes	1/4	1/4	1/2	1.33
	1/2	6.	1.5	3	no	yes	0	0	0	0.00
	5/8	6	1.5	3	no	yes	1/2	1/2	1	1.60
	3/4	6	2	3	no	yes	5/8	1/2	1-1/8	1.50
	7/8	6	2	3	no	yes	3/4	1/2	1-1/4	1.43
	1	6	2.5	3	no	yes	5/8	3/4	1-3/8	1.37
P-82	1/8 In.	6 In.	1 In.	4	no	yes		1/4	1/4	2.00
	1/4	6	1	4	no	yes	1/2	3/8	7/8	3.50
	3/8	6	1	4	no	yes	1/2	1/4	3/4	2.00
	1/2	6	1.5	4	no	yes	3/4	0	3/4	1.50
	5/8	6	1.5	4	no	yes	5/8	1/4	7/8	1.40
	3/4	6	2	4	no	yes				
	7/8	6	2	4	no	yes	1/2	1-1/2	2	2.29
	1	6.	2.5	4	[illegible]	yes	[illegible]	[illegible]	[illegible]	1.50
P-84	1/8 In.	6 In.	1 In.	4	no	yes	[illegible]	1/4	3/8	3.00
	1/4	6	1	4	no	yes	[illegible]	1/4	1/2	2.00
	3/8	6	1	4	no	yes	1/2	1/4	3/4	2.00
	1/2	6	1.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3/4	1.50
	5/8	6	1.5	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	3/4	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	7/8	6	2	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE J11 (Continued)

HEAT NO.	PLATE THICKNESS	PLATE DIAMETER	RISER DIA.	TAPER	UNDER RISER SHRINK	PLATE SHRINK	EDGE SOUND	SOUND BEYOND RISER	TOTAL SOUND	T = Total Sound / Thickness
P-88	1/8 in.	6 in.	1 in.	4	no	yes	1/8	3/8	1/2	4.00
	1/4	6	1	4	no	yes	1/4	1/4	1/2	2.00
	3/8	6	1	4	no	yes	1/4	3/8	7/8	2.33
	1/2	6	1.5	4	no	yes	1/2	1/4	3/4	1.25
	5/8	6	1.5	4	no	yes	1/2	0	1/2	1.25
	3/4	6	2	4	no	yes	1/2	3/4	1-1/4	1.67
	7/8	6	2	4	no	yes	5/8	1/2	1-1/8	1.28
	1	6	2.5	4	no	yes	3/4	1/2	1-1/4	1.25
P-95	1/8 in.	6 in.	1 in.	5	yes	yes	1/8	3/4	7/8	7.00
	1/4	6	1	5	yes	yes	1/4	1/4	1/2	2.00
	3/8	6	1.5	5	no	yes	1/2	0	1/2	1.33
	1/2	6	1.5	5	no	yes	1/2	1/2	1	2.00
	5/8	6	1.5	5	no	yes	3/8	7/8	1-1/4	2.00
	3/4	6	2	5	no	yes	1/2	3/4	1-1/4	1.67
	7/8	6	2	5	no	yes	5/8	1/4	1-1/8	1.28
	1	6	2.5	5	no	yes	3/4	3/4	1-1/2	1.50
P-101	1/8 in.	6 in.	1 in.	5	yes	yes	1/8	3/4	7/8	7.00
	1/4	6	1	5	yes	yes	1/4	1/4	1/2	2.00
	3/8	6	1.5	5	no	yes	1/4	1/4	1/2	1.33
	1/2	6	1.5	5	no	yes	1/2	1/4	3/4	1.50
	5/8	6	1.9	5	no	yes	3/4	1/2	1-1/4	2.00
	3/4	6	2	5	no	yes	3/8	3/4	1-1/8	1.50
	7/8	6	2	5	no	yes	3/4	1	1-3/4	2.00
	1	6	2.5	5	no	yes	3/4	1/4	1-1/4	1.25
P-105	1/8 in.	6 in.	1 in.	5	yes	yes		1/2	1/2	4.00
	1/4	6	1	5	yes	yes		1/4	1/4	1.00
	3/8	6	1.5	5	no	yes	1/2	0	1/2	1.33
	1/2	6	1.5	5	no	yes	1/4	1/4	1/2	1.00
	5/8	6	1.9	5	no	yes	1/2	1/2	1	1.60
	3/4	6	2	5	no	yes	3/4	3/4	1-1/2	2.00
	7/8	6	2	5	no	yes	3/4	3/4	1-1/2	1.71
	1	6	2	5	no	yes	3/4	3/4	1-1/2	1.25
P-117	1/8 in.	6 in.	1 in.	6	no	yes	1/4	5/8	7/8	7.00
	1/2	6	1	6	no	yes	1/4	1/2	3/4	3.00
	3/8	6	1.5	6	no	yes	1/2	1/4	3/4	2.00
	1/2	6	1.5	6	no	yes	5/8	1/4	7/8	1.75
	5/8	6	1.5	6	no	yes	5/8	1/2	1-1/8	1.80
	3/4	6	2	6	no	yes	5/8	3/4	1-3/8	1.83
	7/8	6	2	6	no	yes	3/4	3/4	1-1/2	1.72
	1	6	2.5	6	no	yes	3/4	1/4	1	1.00
P-120	1/8 in.	6 in.	1 in.	6	no	yes	1/8	1/2	5/8	5.00
	1/4	6	1	6	no	yes	1/4	1/2	3/4	3.00
	3/8	6	1.5	6	no	yes	1/2	0	1/2	1.33
	1/2	6	1.5	6	no	yes	1/2	1/4	3/4	1.50
	5/8	6	1.5	6	no	yes	1/2	gas	1/2	.80
	3/4	6	2	6	no	yes	1/2	1/4	3/4	1.00
	7/8	6	2	6	no	yes	1/2	1	1-1/2	1.73
	1	6	2.5	6	no	yes		3/4		
P-128	1/8 in.	6 in.	1 in.	6	no	yes	1/4	1/2	3/4	6.00
	1/4	6	1	6	no	yes	1/4	1/4	1/2	2.00
	3/8	6	1.5	6	no	yes	3/8	1/4	5/8	1.66
	1/2	6	1.5	6	no	yes	1/2	1/4	3/4	1.50
	5/8	6	1.5	6	no	yes		1/2	1/2	.80
	3/4	6	2	6	no	yes	1/2	1/4	3/4	1.00
	7/8	6	2	6	no	yes	3/4	1/4	1-1/4	1.67
	1	6	2.5	6	no	yes		0		

TABLE J11 (Continued)

Heat No.	PLATE Thick-ness	Dia-meter	Riser Dia.	Taper	Under Riser Shrink	Plate Shrink	Edge Sound	Sound Beyond Riser	Total Sound	T. Total Sound Thickness
P143	1/8 in.	6 in.	1 in.	7	yes	yes	1/4	1/4	1/2	4.00
	1/4	6	1.5	7	no	yes	1/4	1/4	1/2	2.00
	3/8	6	1.5	7	no	yes	1/4	0	1/4	.66
	1/2	6	2	7	no	yes	1/2	5/8	1 1/8	2.25
	5/8	6	2	7	no	gas	-	-	-	-
	3/4	6	2.5	7	no	gas	-	-	-	-
	7/8	6	2.5	7	no	yes	3/4	3/4	1 1/2	1.80
	1	6	3	7	no	no	-	-	1 1/2	1.50
P153	1/8 in.	6 in.	1 in.	7	yes	yes	3/16	3/8	9/16	4.51
	1/4	6	.5	7	no	yes	1/4	1/4	1/2	2.00
	3/8	6	.5	7	no	yes	1/2	1/2	1	2.67
	1/2	6	2	7	no	yes	1/4	1/8	3/8	.75
	5/8	6	2	7	no	gas	-	-	-	-
	3/4	6	2.25	7	no	yes	5/8	1/2	1 1/8	1.50
	7/8	6	2.5	7	no	gas	-	-	-	-
	1	6	3	7	no	gas	-	-	-	-
P154	1/8 in.	6 in.	1 in.	7	no	yes	1/4	1/4	1/2	4.00
	1/4	6	1.25	7	no	yes	gas	1/4	1/4	1.00
	3/8	6	2	7	yes	yes	3/4	3/8	1 1/8	3.00
	1/2	6	2	7	no	yes	3/4	1/2	1 1/4	2.50
	5/8	6	2	7	no	yes	3/4	5/8	1 3/8	2.20
	3/4	6	2.25	7	no	yes	5/8	5/8	1 1/4	1.67
	7/8	6	2.25	7	no	gas	-	-	-	-
	1	6	3	7	no	no	-	-	1 1/2	1.50
P161	1/8 in.	6 in.	1 in.	8	no	yes	1/8	3/8	1/2	4.00
	1/4	6	1.5	8	no	yes	1/4	1/4	1/2	2.00
	3/8	6	1.5	8	no	yes	1/4	1/4	1/2	1.33
	1/2	6	2	8	no	yes	5/8	3/4	1 3/8	2.75
	5/8	6	2	8	no	yes	1 1/8	3/8	1 1/2	2.40
	3/4	6	2.875	8	no	yes	3/4	1/4	1	1.33
	7/8	6	2.5	8	no	yes	5/8	3/4	1 3/8	1.65
	1	6	3	8	no	no	-	-	1 1/2	1.50
P162	1/8 in.	6 in.	1 in.	8	no	yes	3/16	1/4	7/16	3.50
	1/4	6	1.5	8	no	yes	1/4	3/16	7/16	1.75
	3/8	6	1.5	8	no	yes	1/4	1/4	1/2	1.33
	1/2	6	2	8	no	yes	5/8	3/4	1 3/8	2.75
	5/8	6	2	8	no	yes	3/8	1/2	7/8	1.40
	3/4	6	2.5	8	no	no	-	-	1 3/4	2.33
	7/8	6	2.5	8	no	no	-	-	1 3/4	2.10
	1	6	3	8	no	no	-	-	1 1/2	1.50
P163	1/8 in.	6 in.	1.5 in.	8	no	yes	gas	1/4	1/4	4.00
	1/4	6	1.5	8	no	yes	gas	1/4	1/4	1.00
	3/8	6	1.5	8	no	yes	3/4	1/2	1 1/4	3.33
	1/2	6	2	8	no	yes	3/4	3/16	15/16	1.87
	5/8	6	2	8	no	yes	1/2	3/4	1 1/4	2.00
	3/4	6	2.875	8	no	yes	5/8	3/8	1	1.33
	7/8	6	2.5	8	no	yes	3/4	1/4	1 1/4	1.50
	1	6	3	8	no	no	-	-	1 1/2	1.50
P177	1/8 in.	6 in.	1.5 in.	9	yes	yes	3/16	1/4	7/16	3.50
	1/4	6	1.5	9	no	yes	1/4	1/4	1/2	2.00
	3/8	6	1.5	9	no	yes	3/8	1	1 3/8	3.67
	1/2	6	2	9	no	yes	7/8	1/4	1 1/8	2.25
	5/8	6	2	9	no	yes	1 1/8	3/8	1 1/2	2.40
	3/4	6	2.25	9	no	yes	5/8	3/4	1 3/8	1.83
	7/8	6	2.5	9	no	yes	1	3/4	1 3/4	2.10
	1	6	3	9	no	no	-	-	1 1/2	1.50

TABLE J11 (Continued)

Heat No.	PLATE Thickness	Diameter	Riser Dia.	Taper	Under Riser Shrink	Plate Shrink	Edge Sound	Sound Beyond Riser	Total Sound	T/Total Sound Thickness
P178	1/8 in.	6 in.	1.5 in.	9	yes	yes	1/4	1/2	3/4	6.00
	1/4	6	1.5	9	no	yes	1/4	1/4	1/2	2.00
	3/8	6	1.5	9	no	yes	1/4	1/4	1/2	1.33
	1/2	6	2	9	no	yes	5/8	3/8	1	2.00
	5/8	6	2	9	no	yes	7/8	3/8	1 1/4	2.00
	3/4	6	2.25	9	no	yes	7/8	1/2	1 3/8	1.83
	7/8	6	2.5	9	no	yes	3/4	3/4	1 1/2	1.80
	1	6	3	9	no	no	-	-	1 1/2	1.50
P179	1/8 in.	6 in.	1 in.	9	yes	yes	1/8	1/4	3/8	3.00
	1/4	6	1.5	9	no	yes	1/4	3/8	5/8	2.50
	3/8	6	1.5	9	no	yes	1/2	1/4	3/4	2.00
	1/2	6	2	9	no	yes	3/4	1/2	1 1/4	2.50
	5/8	6	2	9	no	yes	3/4	3/4	1 1/2	2.40
	3/4	6	2.25	9	no	yes	1 1/4	1/2	1 3/4	2.33
	7/8	6	2.5	9	no	no	-	-	1 3/4	2.10
	1	6	3	9	no	no	-	-	1 1/2	1.50
P208	1/8 in.	6 in.	1 in.	10	yes	yes	3/8	1/4	5/8	5.00
	1/4	6	1.5	10	no	yes	3/8	1/4	5/8	2.50
	3/8	6	1.5	10	yes	yes	3/8	1/2	7/8	2.43
	1/2	6	2	10	no	yes	3/4	3/4	1 1/2	3.00
	5/8	6	2	10	no	yes	1	5/8	1 5/8	2.60
	3/4	6	2.5	10	no	yes	1	1/4	1 1/4	1.66
	7/8	6	2.5	10	no	yes	3/4	1/2	1 1/4	1.50
	1	6	3	10	no	no	-	-	1 1/2	1.50
P212	1/8 in.	6 in.	1 in.	10	yes	yes	3/16	3/8	9/16	4.50
	1/4	6	1.5	10	no	yes	1/2	1/4	3/4	3.00
	3/8	6	1.5	10	no	yes	3/8	3/8	3/4	[illegible]
	1/2	6	1.5	10	no	yes	1	1/2	1 1/2	3.00
	5/8	6	2	10	no	yes	5/8	5/8	1 1/4	2.00
	3/4	6	2.5	10	no	no	-	-	1 3/4	2.33
	7/8	6	2.5	10	no	yes	1/2	5/8	1 1/8	1.34
	1	6	3	10	no	no	-	-	1 1/2	1.50
P215	1/8 in.	6 in.	1.5 in.	10	yes	yes	gas	1/8	1/8	1.00
	1/4	6	1.5	10	no	yes	3/8	3/8	3/4	3.00
	3/8	6	1.5	10	no	yes	1/2	3/8	7/8	2.33
	1/2	6	2	10	no	yes	1	3/4	1 3/4	3.50
	5/8	6	2	10	no	yes	7/8	1/2	1 3/8	2.20
	3/4	6	2.5	10	no	yes	5/8	1	1 5/8	2.17
	7/8	6	2.5	10	no	yes	3/4	1/2	1 1/4	1.43
	1	6	3	10	no	no	-	-	1 1/2	1.50
P269	1/8 in.	6 in.	1 in.	11	yes	yes	1/4	1/2	3/4	6.00
	1/4	6	1.5	11	no	yes	3/8	1/2	7/8	2.76
	3/8	6	1.5	11	no	yes	1/2	1/2	1	2.66
	1/2	6	2	11	no	yes	1	3/8	1 3/8	2.75
	5/8	6	2.25	11	no		-	-	1 7/8	3.00
	3/4	6	2.5	11	no	yes	1 1/8	3/8	1 1/2	2.00
	7/8	6	2.5	11	no	yes	1	1/2	1 1/2	1.71
	1	6	3	11	no	gas	-	-	-	-
P273	1/8 in.	6 in.	1 in.	11	yes	yes	1/16	1/4	5/16	2.50
	1/4	6	1.5	11	no	yes	3/8	1/4	5/8	2.50
	3/8	6	1.5	11	[illegible]	yes	1	1/2	1 1/2	4.00
	1/2	6	2	11	no	yes	1 1/8	1/4	1 3/8	2.74
	5/8	6	2.25	11	no	yes	3/4	1	1 3/4	2.80
	3/4	6	2.5	11	[illegible]	gas	-	-	-	-
	7/8	6	2.25	11	yes	gas	1/4	1/4	/4	.857
	1	6	3	11	no	no	-	-	1 /2	1.50
P311	1/8 in.	6 in.	1.5 in.	12	yes	gas	-	-	-	-
	1/4	6	1.375	12	no	yes	1/4	7/8	1 1/8	4.50
	3/8	6	2	12	no	yes	1 1/4	5/8	1 7/8	5.00
	1/2	6	2.5	12	no	yes	1 3/16	3/8	1 9/16	3.13
	5/8	6	2.5	12	no	no	-	-	1 3/4	4.40
	3/4	6	2.5	12	no	no	-	-	1 3/4	3.66
	7/8	6	2.5	12	no	no	-	-	1 3/4	3.15
	1	6	3	12	no	no	-	-	1 1/2	1.50

TABLE J12

FEEDING DISTANCES IN TAPERED RAMMED GRAPHITE MOLDS

HEAT NO.	PLATE THICK-NESS	PLATE DIA-METER	PLATE RISER DIA.	TAPER	UNDER RISER SHRINK	PLATE SHRINK	EDGE SOUND	SOUND BEYOND RISER	TOTAL SOUND	Y = Total Sound / Thickness
P-90	1/8 in.	6 in.	1 in.	0	yes	yes	1/8"	1/8	1/4	2.00
	1/4	6	1	0	yes	yes	1/4	1/8	3/8	1.50
	3/8	6	1	0	yes	yes	1/4	1/4	1/2	1.33
	1/2	6	1.5	0	yes	yes	1/4	0	1/4	.50
	5/8	6	1.5	0	yes	yes	1/2	3/8	7/8	1.40
	3/4	6	2	0	yes	yes	1/2	1	1-1/2	2.00
	7/8	6	2	0	no	yes	3/8	1/2	5/8	.71
	1	6	2.5	0	yes	no	--	4-3/4		
P-92	1/8 in.	6 in.	1 in.	0	yes	yes	1/16	1/8	3/16	1.50
	1/4	6	1	0	yes	yes	1/4	1/4	1/2	2.00
	3/8	6	1	0	yes	yes	1/4	1/4	1/2	1.33
	1/2	6	1.5	0	yes	yes	1/4	1/16	5/16	.624
	5/8	6	1.5	0	yes	yes	3/8	5/16	11/16	1.09
	3/4	6	2	0	no	yes	3/8	1/2	7/8	1.166
	7/8	6	2	0	no	yes	1/2	3/4	1-1/4	1.43
	1	6	2.5	0	yes				gas	
P-93	1/8 in.	6 in.	1 in.	0	yes	yes	1/8	1/8	1/4	2.00
	1/4	6	1	0	yes	yes	1/4	1/4	1/2	2.00
	3/8	6	1	0	yes	yes	1/4	1/4	1/2	1.33
	1/2	6	1.5	0	yes	yes	1/4	1/16	5/16	.624
	5/8	6	1.5	0	yes	yes	3/8	5/16	11/16	1.09
	3/4	6	2	0	yes	yes	3/8	1/2	7/8	1.166
	7/8	6	2	0	yes	yes	3/4	9/16	1-5/16	1.50
	1	6	2.5	0	yes	yes	1	1/2	1-1/2	1.50
P-94	1/8 in.	6 in.	1 in.	1	yes	yes	3/16	1/8	5/16	2.50
	1/4	6	1	1	yes	yes	1/4	1/4	1/2	2.00
	3/8	6	1	1	yes	yes	1/4	1/2	3/4	2.00
	1/2	6	1.5	1	yes	yes	3/8	1/4	5/8	1.25
	5/8	6	1.5	1	yes	yes	1/2	5/16	13/16	1.30
	3/4	6	2	1	yes	yes	5/8	3/4	1-3/8	1.84
	7/8	6	2	1	yes	yes	7/8	3/4	1-5/8	1.86
	1	6	2.5	1	no	no			1-1/2	1.50
P-97	1/8 in.	6 in.	1 in.	1	yes	no	3/16	1/4	7/16	3.50
	1/4	6	1	1	yes	yes	1/4	1/4	1/2	2.00
	3/8	6	1	1	yes	yes	3/8	1/4	5/8	1.67
	1/2	6	1.5	1	yes	yes	1/2	3/4	1-1/4	2.50
	5/8	6	1.5	1	yes	yes	5/8	3/4	1-3/8	2.16
	3/4	6	2	1	no	yes	1/2	5/8	1-1/8	1.50
	7/8	6	2	1	yes	yes	3/4	3/4	1-1/2	1.50
	1	6	2.5	1	no	no				
P-103	1/8 in.	6 in.	1 in.	1	no	yes	3/16	1/8	5/16	2.50
	1/4	6	1	1	no	yes	1/4	1/4	1/2	2.00
	3/8	6	1	1	yes	yes	3/8	1/2	7/8	2.33
	1/2	6	1.5	1	no	yes	1/2	3/8	7/8	1.75
	5/8	6	1.5	1	yes	yes	1/2	1/2	1	1.60
	3/4	6	2	1	no	yes	1/2	1/2	1	1.33
	7/8	6	2	1	yes	yes	3/4	3/4	1-1/2	1.71
	1	6	2.5	1	no	no				
P-109	1/8 in.	6 in.	1 in.	2	yes	yes	3/16	1/8	5/16	2.50
	1/4	6	1	2	yes	yes	1/4	1/4	1/2	2.00
	3/8	6	1	2	yes	yes	1/4	1/4	1/2	1.33
	1/2	6	1.5	2	yes	yes	3/8	1/4	5/8	1.25
	5/8	6	1	2	yes	yes	1/2	1/2	1	1.60
	3/4	6	2	2	no	yes	3/4	3/4	1-1/2	2.00
	7/8	6	2	2	yes	yes	3/4	1	1-3/4	2.00
	1	6	2.5	2	no	no		gas		
P-111	1/8 in.	6 in.	1 in.	2	yes	yes	1/4	1/4	1/2	4.00
	1/4	6	1	2	yes	yes	1/4	1/4	1/2	2.00
	3/8	6	1	2	yes	yes	1/4	1/4	1/2	1.33
	1/2	6	1.5	2	yes	yes	3/8	5/16	11/16	1.37
	5/8	6	1.5	2	yes	[illegible]	1/2	1/4	3/4	1.20
	3/4	6	2	2	[illegible]	yes	7/8	1/2	1-3/8	2.00
	7/8	6	2	2	[illegible]	[illegible]	3/4	1/2	1-1/4	1.43
	1	6	2.5	2	[illegible]	[illegible]				

TABLE J12 (Continued)

HEAT NO.	PLATE THICK-NESS	PLATE DIA-METER	PLATE RISER DIA.	TAPER	UNDER RISER SHRINK	PLATE SHRINK	EDGE SOUND	SOUND BEYOND RISER	TOTAL SOUND	T ÷ Total Sound Thickness
P-113	1/8 in.	6 in.	1 in.	2	yes	yes	3/16	1/4	7/16	3.50
	1/4	6	1	2	yes	yes	1/4	1/4	1/2	2.00
	3/8	6	1	2	yes	yes	1/4	1/4	1/2	1.50
	1/2	6	1.5	2	no	yes	1/2	3/8	7/8	1.75
	5/8	6	1.5	2	yes	yes	5/8	1/4	7/8	1.40
	3/4	6	2	2	no	yes	7/8	3/4	1-3/8	1.83
	7/8	6	2	2	no	yes	7/8	3/4	1-3/8	1.57
	1	6	2.5	no	gas no	yes				
P-114	1/8 in.	6 in.	1.5 in.	3	no	yes	1/8	1/8	1/4	.20
	1/4	6	1.5	3	no	yes	1/4	1/4	1/2	2.00
	3/8	6	1.5	3	no	yes	3/8	1/4	5/8	1.67
	1/2	6	2	3	no	yes	1/2	1/4	3/4	1.50
	5/8	6	2.5	3	no	yes	1/2		1/2	.804
	3/4	6	2.5	3	no	yes	1/2	3/8	7/8	1.167
	7/8	6	2.5	3	no	yes	3/4	3/4	1-1/2	1.71
	1	6	3	3	no	no				
P-118	1/8 in.	6 in.	1.5 in.	3	no	yes	1/8	1/8	1/4	2.00
	1/4	6	1.5	3	no	yes	3/8	1/2	7/8	3.50
	3/8	6	1.5	3	no	yes	1/2	1/2	1	2.67
	1/2	6	2	3	no	yes	3/8	1/2	7/8	1.75
	5/8	6	2	3	no	yes	5/8	1/2	1-1/8	1.85
	3/4	6	2.5	3	no	yes	3/4	3/4	1-1/2	2.00
	7/8	6	2.5	3	no	yes	3/4	3/4	1-1/2	1.71
	1	6	3	3	no	no				
P-121	1/8 in.	6 in.	1.5 in.	3	no	yes	1/8	1/4	3/8	3.00
	1/4	6	1.5	3	no	yes	3/8	1/2	7/8	2.86
	3/8	6	1.5	3	no	yes	1/2	1/2	1	2.66
	1/2	6	2	3	no	yes	1/2	1/2	1	2.00
	5/8	6	2	3	no	yes	1/2	1/2	1	1.60
	3/4	6	2.5	3	no	yes	5/8	3/4	1-5/8	2.17
	7/8	6	2.5	3	no	yes	3/4	1/2	1-1/4	1.43
	1	6	3.5	3	no	gas no				
P-123	1/8 in.	6 in.	1.5 in.	4	no	yes	1/4	1/4	1/2	4.00
	1/4	6	1.5	4	no	yes	3/8	1/4	7/8	2.86
	3/8	6	1.5	4	no	yes	1/2	1/2	1	2.66
	1/2	6	2	4	no	yes	5/8	1/2	1-1/8	2.50
	5/8	6	2	4	no	yes	1/2	1/4	3/4	1.20
	3/4	6	2.5	4	no	yes	5/8	1/2	1-1/8	1.50
	7/8	6	2.5	4	no	yes	1/2	7/8	1-3/8	1.57
	1	6	3.5	4	no	no		1-1/2	1-1/2	1.50
P-124	1/8 in.	6 in.	1.5 in.	4	no	yes	1/4	3/8	5/8	5.00
	1/4	6	1.5	4	no	yes	3/8	1/2	7/8	2.86
	3/8	6	1.5	4	yes	yes	3/8	1/4	5/8	1.66
	1/2	6	2	4	no	yes	1/4	1/2	3/4	1.50
	5/8	6	2	4	no	yes	5/8	3/4	1-3/8	2.20
	3/4	6	2.5	4	no	yes	1/2	1/4	3/4	1.00
	7/8	6	2.5	4	no	no		1-3/4	1-3/4	2.00
	1	6	3.5	4	no	no				
P-125	1/8 in.	6 in.	1.5 in.	4	no	yes	1/8	3/8	1/2	4.00
	1/4	6	1.5	4	no	yes	1/4	3/8	5/8	2.50
	3/8	6	1.5	4	no	yes	1/4	1/2	3/4	2.00
	1/2	6	2	4	no	yes	1/2	1/2	1.	2.00
	5/8	6	2	4	no	yes	1/2	3/4	1-1/4	2.00
	3/4	6	2.5	4	no	yes	5/8	1/2	1-1/8	1.50
	7/8	6	2.5	4	no	no	3/4	1/2	1-1/4	1.43
	1	6	3	4	no	no				

TABLE J12 (Continued)

HEAT NO.	PLATE THICKNESS	PLATE DIAMETER	PLATE RISER DIA.	TAPER	UNDER RISER SHRINK	PLATE SHRINK	EDGE SOUND	SOUND BEYOND RISER	TOTAL SOUND	T = Total Sound Thickness
P-126	1/8 in.	6 in.	1.5 in.	5	no	yes	1/4	1/4	1/2	4.00
	1/4	6	1.5	5	no	yes	3/8	1/4	7/8	3.50
	3/8	6	1.5	5	yes	yes	1/2	1/2	1	2.57
	1/2	6	2	5	no	yes	3/4	5/8	1-3/8	2.75
	5/8	6	2	5	no	yes	3/4	1	1-3/4	2.80
	3/4	6	2.5	5	no	yes	3/4	3/4	1-1/2	1.71
	7/8	6	2.5	5	no					
	1	6	3	5	no					
P-127	1/8 in.	6 in.	1.5 in.	5	no	yes	1/4	1/4	1/2	4.00
	1/4	6	1.5	5	no	yes	3/8	1/2	7/8	3.50
	3/8	6	1.5	5	no	yes	1/2	7/8	1-3/8	3.67
	1/2	6	2	5	no	yes	5/8	3/4	1-3/8	2.75
	5/8	6	2	5	no	yes	3/4	3/4	1-1/2	2.40
	3/4	6	2.5	5	no	yes	3/4	3/4	1-1/2	2.00
	7/8	6	2.5	5	no	no				
	1	6	3	5	no	no				
P-133	1/8 in.	6 in.	1.5 in.	5	no	yes	1/8	1/4	3/8	3.00
	1/4	6	1.5	5	no	yes	3/8	1/2	5/8	2.50
	3/8	6	1.5	5	no	yes	1/2	1/2	1	2.57
	1/2	6	2	5	no	yes	5/8	1/2	1-1/8	2.50
	5/8	6	2	5	no	yes	3/4	1/2	1-1/4	2.00
	3/4	6	2.5	5	no	yes	3/4	3/4	1-1/2	2.00
	7/8	6	2.5	5	no	gas				
	1	6	3	5	no	gas				
P 134	1/8 in.	6 in.	1.5 in.	6	no	yes	1/8	1/2	5/8	5.00
	1/4	6	1.5	6	no	yes	3/8	3/8	3/4	3.00
	3/8	6	1.5	6	no	yes	1/2	1/2	1	2.67
	1/2	6	2	6	no	yes	1/2	3/4	1-1/4	2.50
	5/8	6	2	6	no	yes	5/8	1/2	1-1/8	1.80
	3/4	6	[illegible]	6	no	gas				
	7/8	6	2.5	6	no	gas				
	1	6	3	6	no	gas				
P135	1/8 in.	6 in.	1.5	6	no	yes	gas	3/8	3/8	3.00
	1/4	6	1.5	6	no	yes	3/8	1/2	7/8	3.50
	3/8	6	1.5	6	yes	yes	1/2	5/8	1 1/8	3.31
	1/2	6	2.0	6	no	yes	1/2	5/8	1 1/8	2.25
	5/8	6	2	6	no	yes	3/4	3/4	1 1/2	2.41
	3/4	6	2.5	6	no	yes	3/4	3/4	1 1/2	2.00
	7/8	6	2.5	6	no	yes	1/2	3/4	1 1/4	1.71
	1	6	3	6	no	gas	-	-	-	-
P167	1/8 in.	6 in.	1.5 in.	6	no	yes	gas	3/8	3/8	3.00
	1/4	6	1.5	6	no	yes	3/8	3/8	3/4	3.00
	3/8	6	1.5	6	yes	yes	1/2	5/8	1 1/8	3.31
	1/2	6	2	6	no	yes	1/4	5/8	7/8	1.75
	5/8	6	2	6	no	yes	1 1/2	1 1/4	2 3/4	4.40
	3/4	6	2.5	6	no	yes	5/8	5/8	1 1/4	[illegible]
	7/8	6	2.5	6	no	gas		-	-	-
	1	6	3	6	no	gas	-	-	-	-
P166	1/8	6 in.	1.5 in.	7	no	yes	[illegible]	[illegible]	[illegible]	[illegible]
	1/4	6	1.5	7	no	yes	1/2	1	1 1/2	6.00
	3/8	6	1.5	7	yes	yes	3/4	3/4	1 1/2	4.00
	1/2	6	2	7	no	yes	5/8	1	1 5/8	[illegible]
	5/8	6	2	7	no	[illegible]	-	-	2	3.20
	3/4	6	2.5	7	no	[illegible]	-	-		
	7/8	6	2.5	7	no	no	-	-	1 3/4	2.00
	1	6	3	7	no	gas	-	-	-	-
P169	1/8	6 in.	1.5 in.	7	no	yes	3/8	5/8	1	[illegible]
	1/4	6	1.5	7	no	yes	3/8	3/4	1 1/8	4.50
	3/8	6	1.5	7	yes	[illegible]	1/2	1/2	1	2.67
	1/2	6	2	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	5/8	6	2	7	[illegible]	[illegible]			2	3.20
	3/4	6	2.5	7	[illegible]	[illegible]	-	-	1 3/4	[illegible]
	7/8	6	2.5	7	[illegible]	gas	-	-	-	-
	1	6	3	7	[illegible]	[illegible]			[illegible]	[illegible]

TABLE J12 (Continued)

Heat No.	PLATE Thick-ness	Dia-meter	Riser Dia.	Taper	Under Riser Shrink	Plate Shrink	Edge Sound	Sound Beyond Riser	Total Sound	T+ Total Sound Thickness
P171	1/8 in.	6 in.	1.5 in.	7	no	yes	3/8	3/4	1 1/8	9.00
	1/4	6	1.5	7	no	yes	5/8	1/2	1 1/8	4.50
	3/8	6	1.5	7	yes	yes	1/2	7/8	1 3/8	2.75
	1/2	6	2	7	no	yes	1/2	3/8	7/8	1.75
	5/8	6	2	7	yes	gas	-	-	-	-
	3/4	6	2.5	7	no	gas	-	-	-	-
	7/8	6	2.5	7	no	gas	-	-	-	-
	1	6	3	7	no	no	-	-	1 1/2	1.50
P172	1/8 in.	6 in.	1.5 in.	8	no	yes	3/8	3/4	1 1/8	9.00
	1/4	6	1.5	8	no	yes	3/8	1	1 3/8	5.50
	3/8	6	1.5	8	yes	yes	gas	1	1	2.67
	1/2	6	2	8	no	gas	-	-	-	-
	5/8	6	2	8	yes	gas	-	-	-	-
	3/4	6	2.5	8	no	gas	-	-	-	-
	7/8	6	2.5	8	no	gas	-	-	-	-
	1	6	3	8	no	gas	-	-	-	-
P173	1/8 in.	6 in.	1.5 in.	8	yes	yes	3/8	5/8	1	8.00
	1/4	6	1.5	8	no	yes	1/2	3/4	1 1/4	5.00
	3/8	6	1.5	8	yes	yes	3/8	5/8	1	2.67
	1/2	6	2	8	no	gas	-	-	-	-
	5/8	6	2	8	yes	yes	1/2	5/8	1 1/8	1.80
	3/4	6	2.5	8	no	gas	-	-	-	-
	7/8	6	2	8	no	gas	-	-	-	-
	1	6	3	8	no	gas	-	-	-	-
P174	1/8 in.	6 in.	1.5in.	8	no	yes	1/2	1/2	1	8.00
	1/4	6	1.5	8	no	yes	1/2	1/2	1	4.00
	3/8	6	1.5	8	yes	yes	5/8	7/8	1 1/4	3.30
	1/2	6	2	8	no	gas	-	-	-	-
	5/8	6	2	8	yes	gas	-	-	-	-
	3/4	6	2.5	8	no	gas	-	-	-	-
	7/8	6	2.5	8	no	gas	-	-	-	-
	1	6	3	8	no	gas	-	-	-	-
P175	1/8	6	1.5	9	no	yes	gas	1	1	8.00
	1/4	6	1.5	9	no	yes	3/4	1 1/4	2	8.00
	3/8	6	1.5	9	yes	yes	1/2	1	1 1/2	4.00
	1/2	6	2	9	no	gas	-	-	-	-
	5/8	6	2	9	yes	no	-	-	2	3.20
	3/4	6	2.5	9	no	gas	-	-	-	-
	7/8	6	2.5	9	yes	gas	-	-	-	-
	1	6	3	9	no	gas	-	-	-	-
P184	1/8 in.	6 in.	1.5 in.	9	no	yes	gas	5/8	5/8	5.00
	1/4	6	1.5	9	no	yes	1/8	7/8	1	4.00
	3/8	6	1.5	9	yes	yes	1/8	3/4	7/8	2.86
	1/2	6	2	9	no	yes	1/2	7/8	1 3/8	2.75
	5/8	6	2	9	yes	yes	1/2	7/8	1 3/8	2.20
	3/4	6	2.5	9	no	no	-	-	1 3/4	2.34
	7/8	6	2.5	9	no	no	-	-	1 3/4	2.00
	1	6	3	9	no	gas	-	-	-	-
P185	1/8 in.	6 in.	1.5 in.	9	no	yes	5/8	7/8	1 1/2	10.00
	1/4	6	1.5	9	yes	yes	1/4	7/8	1 1/8	4.50
	3/8	6	1.5	9	yes	yes	1/2	1 1/8	1 5/8	4.33
	1/2	6	2	9	no	yes	1/4	5/8	7/8	1.75
	5/8	6	2	9	yes	no	-	-	2	3.20
	3/4	6	2.5	9	no	no	-	-	1 3/4	2.34
	7/8	6	2.5	9	no	gas	-	-	-	-
	1	6	3	9	no	gas	-	-	-	-

TABLE J12 (Continued)

Heat No.	PLATE Thickness	PLATE Diameter	PLATE Riser Dia.	PLATE Taper	Under Riser Shrink	Plate Shrink	Edge Sound	Sound Beyond Riser	Total Sound	T ÷ Total Sound Thickness
P195	1/8 in.	6 in.	1.5 in.	10	no	gas	-	-	-	-
	1/4	6	1.5	10	yes	gas	-	-	-	-
	3/8	6	1.5	10	yes	gas	-	-	-	-
	1/2	6	2	10	no	gas	-	-	-	-
	5/8	6	2	10	yes	gas	-	-	-	-
	3/4	6	2.5	10	no	gas	-	-	-	-
	7/8	6	2.5	10	yes	gas	-	-	-	-
	1	6	3	10	no	gas	-	-	-	-
P196	1/8 in.	6 in.	1.5 in.	10	no	yes	1/4	1 1/4	1 1/2	10.00
	1/4	6	1.5	10	yes	yes	2/8	1	1 3/8	5.50
	3/8	6	1.5	10	yes	yes	1/2	3/4	1 1/4	3.33
	1/2	6	2	10	no	yes	3/8	1	1 3/6	2.75
	5/8	6	2	10	no	gas	-	-	-	-
	3/4	6	2.5	10	no	no	-	-	1 3/4	2.33
	7/8	6	2.5	10	no	gas	-	-	-	-
	1	6	3	10	no	no	-	-	1 1/2	1.50
P200	1/8 in.	6 in.	1.5 in.	10	no	yes	1/2	3/4	1 1/4	10.00
	1/4	6	1.5	10	yes	yes	1/4	1	1 1/4	6.0[illegible]
	3/8	6	1.5	10	yes	yes	1/2	1 1/2	2	5.34
	1/2	6	2	10	no	-	gas	1 9/8	1 5/8	3.25
	5/8	6	2	10	yes	no	-	-	2	3.20
	3/4	6	2.5	10	no	-	gas	1 1/4	1 1/4	1.67
	7/8	6	2.5	10	no	no	-	-	1 1/2	1.72
	1	6	3	10	no	no	-	-	1 1/2	1.50
P275-1	1/8 in.	6 in.	1.5 in.	11	no	yes	1/16	3/4	13/16	6.50
	1/4	6	2	11	no	yes	1/8	1/2	5/8	2.50
	3/8	6	2	11	no	no	-	-	2	5.34
	1/2	6	2	11	no	gas	-	-	-	-
P275-2	1/8 in.	6 in.	1.5 in.	11	no	yes	1/4	1/2	3/4	6.00
	1/4	6	2	11	no	yes	3/8	1 1/4	1 5/8	6.50
	3/8	6	2	11	no	no	-	-	2	5.34
	1/2	6	2	11	yes	no	-	-	2	4.00
P278	1/8 in.	6 in.	1.5 in.	11	yes	yes	1/8	7/8	1	8.00
	1/4	6	2	11	no	yes	1/4	3/4	1	4.00
	3/8	6	2	11	no	yes	3/8	1/4	1	2.66
	1/2	6	2	11	yes	gas	-	-	-	-
P279	1/8 in.	6 in.	1.5 in.	12	no	yes	1/2	1/4	3/4	6.00
	1/4	6	2	12	no	yes	3/8	1 1/4	1 5/8	6.50
	3/8	6	2	12	no	gas	-	-	-	-
	1/2	6	2.5	12	no	no	-	-	-	3.50
P2[illegible]	1/8 in.	6 in.	1.5 in.	12	no	yes	1/8	1 1/4	1 3/8	11.00
	1/4	6	2	12	no	yes	1/6	1 1/4	1 3/8	5.50
	3/8	6	2	12	no	no	-	-	-	5.34
	1/2	6	2.5	12	no	no	-	-	-	3.50
P281	1/8 in.	6 in.	1.5 in.	12	yes	yes	1/4	1	1 1/4	10.00
	1/4	6	2	12	no	gas	-	-	-	-
	3/8	6	2	12	no	no	-	-	2	5.5[illegible]
	1/2	6	2.5	12	no	[illegible]	3/4	3/4	1 1/2	3.[illegible]

TABLE J13

FEEDING DISTANCE IN HEATED MACHINED GRAPHITE MOLDS

Heat No.	PLATE Thickness	Diameter	Riser Dia.	Taper	Under Riser Shrink	Plate Shrink	Edge Sound	Sound Beyond Riser	Total Sound	T* Total Sound Thickness
P400	1/8	6	1 1/4	0	no	yes	1/16	1/16	1/8	1.00
	1/4	6	1 1/2	0	no	yes	1/8	0	1/8	0.50
	3/8	6	1 3/4	0	no	yes	1/4	0	1/4	0.66
	1/2	6	2	0	no	yes	1/4	0	1/4	0.50
	5/8	6	2	0	no	yes	1/2	1/8	5/8	1.00
	3/4	6	2 1/4	0	no	yes	1/2	1/4	3/4	1.00
	7/8	6	2 1/2	0	no	yes	1/2	1/4	3/4	0.86
	1	6	3	0	no	yes	7/8	1/2	1 3/8	1.375
P402	1/8	6	1 1/4	0	no	yes	1/16	0	1/16	0.50
	1/4	6	1 1/2	0	no	yes	1/4	0	1/4	1.00
	3/8	6	1 3/4	0	no	yes	3/8	0	3/8	1.00
	1/2	6	2	0	no	yes	1/2	1/8	5/8	1.25
	5/8	6	2	0	no	yes	1/2	0	1/2	0.80
	3/4	6	2	0	no	yes	1/2	1/4	3/4	1.00
	7/8	6	2 1/4	0	no	yes	1/2	1/8	5/8	0.71
	1	6	3	0	no	yes	3/4	1/4	1	1.00
P410	1/8	6	1 1/4	0	no	yes	1/8	0	1/8	1.00
	1/4	6	1 1/2	0	no	yes	1/4	0	1/4	1.00
	3/8	6	1 3/4	0	no	yes	3/8	1/4	5/8	1.66
	1/2	6	2	0	no	yes	1/2	0	1/2	1.00
	5/8	6	2	0	no	yes	1/2	0	1/2	0.80
	3/4	6	2	0	no	yes	5/8	1/4	7/8	1.16
	7/8	6	2 1/4	0	no	yes	1/2	1/8	5/8	0.71
	1	6	3	0	no	yes	3/4	1/4	1	1.00
P416	1/8	6	1 1/4	1	no	yes	1/8	1/16	3/16	1.50
	1/4	6	1 1/2	1	no	yes	1/4	0	1/4	1.00
	3/8	6	1 3/4	1	no	yes	3/8	0	3/8	1.00
	1/2	6	2	1	no	yes	1/2	1/2	1	2.00
	5/8	6	2	1	no	yes	1/2	1/8	5/8	1.00
	3/4	6	2 1/4	1	no	yes	1/2	0	1/2	0.66
	7/8	6	2 1/2	1	no	yes	3/4	0	3/4	0.86
	1	6	3	1	no	yes	5/8	1/8	3/4	0.75
P436	1/8	6	1 1/4	1	no	yes	0	1/8	1/8	1.00
	1/4	6	1 1/2	1	no	yes	1/8	1/8	1/4	1.00
	3/8	6	1 3/4	1	yes	yes	3/8	1/8	1/2	1.33
	1/2	6	2	1	no	yes	3/8	1/4	5/8	1.25
	5/8	6	2	1	no	yes	1/2	0	1/2	0.80
	3/4	6	2 1/4	1	no	yes	1/2	1/4	3/4	1.00
	7/8	6	2 1/2	1	no	yes	3/8	0	3/8	0.43
	1	6	3	1	no	yes	7/8	1/2	1 3/8	1.375
P445	1/8	6	1 1/4	1	no	yes	1/8	0	1/8	1.00
	1/4	6	1 1/2	1	no	yes	1/8	0	1/8	0.50
	3/8	6	1 3/4	1	no	yes	1/4	1/16	5/16	0.83
	1/2	6	2	1	no	yes	3/8	0	3/8	0.75
	5/8	6	2	1	no	yes	1/2	0	1/2	0.80
	3/4	6	2 1/4	1	no	yes	5/8	1/4	7/8	1.17
	7/8	6	2 1/2	1	no	yes	1	1/4	1 1/4	1.43
	1	6	3	1	no	no			1 1/2	1.50

TABLE J13 (Continued)

Heat No.	PLATE Thick-ness	Dia-meter	Riser Dia.	Taper	Under Riser Shrink	Plate Shrink	Edge Sound	Sound Beyond Riser	Total Sound	T* Total Sound Thickness
P477	1/8	6	1 1/4	3	no	yes	1/4	1/8	3/8	3.00
	1/4	6	1 1/2	3	no	yes	1/4	0	1/4	1.00
	3/8	6	1 1/2	3	no	yes	1/4	0	1/4	0.66
	1/2	6	2	3	no	yes	1/2	1/4	3/4	1.25
	5/8	6	2	3	yes	yes	1/2	0	1/2	0.80
	3/4	6	2 1/2	3	no	yes	1/2	1/2	1	1.33
	7/8	6	2 1/2	3	no	yes	1/2	1/2	1	1.14
	1	6	3	3	no	yes	1/2	1/2	1	1.00
P487	1/8	6	1 1/4	3	no	yes	1/8	0	1/8	1.00
	1/4	6	1 1/2	3	yes	yes	1/4	1/8	3/8	1.50
	3/8	6	1 1/2	3	yes	yes	1/4	3/8	5/8	1.66
	1/2	6	2	3	no	yes	1/8	1/4	5/8	1.25
	5/8	6	2	3	no	yes	1/2	1/4	3/4	1.20
	3/4	6	2 1/2	3	no	yes	1/2	3/8	7/8	1.16
	7/8	6	2 1/2	3	no	yes	3/4	1/4	1	1.14
	1	6	3	3	no	yes	5/8	1/2	1 1/8	1.125
P490	1/8	6	1 1/4	3	no	yes	1/8	0	1/8	1.00
	1/4	6	1 1/2	3	yes	yes	1/4	1/4	1/2	2.00
	3/8	6	1 1/2	3	yes	yes	3/8	1/8	1/2	1.33
	1/2	6	2	3	no	yes	1/2	0	1/2	1.00
	5/8	6	2	3	yes	yes	1/2	0	1/2	0.80
	3/4	6	2 1/2	3	no	yes	1/2	1/2	1	1.33
	7/8	6	2 1/2	3	no	yes	1/2	1/8	5/8	0.71
	1	6	3	3	no	yes	1	1/2	1 1/2	1.50
P502	1/8	6	1 1/4	5	no	yes	1/4	1/8	3/8	3.00
	1/4	6	1 1/2	5	no	yes	1/4	1/8	3/8	1.50
	3/8	6	1 1/2	5	no	yes	1/4	3/8	5/8	1.66
	1/2	6	2	5	no	yes	1/2	1/4	3/4	1.50
	5/8	6	2	5	yes	yes	1/2	1/8	5/8	1.00
	3/4	6	2	5	no	yes	1/8	1/4	3/8	0.50
	7/8	6	2	5	yes	yes	3/4	1/4	1	1.14
	1	6	3	5	no	yes	1	3/8	1 3/8	1.375
P504	1/8	6	1	5	no	yes	1/16	1/8	3/16	1.50
	1/4	6	1 1/4	5	no	yes	1/4	1/8	3/8	1.50
	3/8	6	1 1/2	5	no	yes	1/2	1/2	1	2.67
	1/2	6	1 3/4	5	yes	yes	1/2	1/2	1	2.00
	5/8	6	2	5	yes	yes	3/4	1/8	7/8	1.50
	3/4	6	2	5	no	yes	3/4	1/2	1 1/4	1.67
	7/8	6	2 1/2	5	yes	yes	3/4	1/4	1	1.20
	1	6	3	5	no	yes	3/4	1/2	1 1/4	1.25
[illegible]	1/8	6	1 1/4	5	no	yes	1/4	1/16	5/16	2.50
	1/4	6	1 1/2	5	no	yes	1/8	[illegible]	1/8	0.50
	3/8	6	1 1/2	5	no	yes	1/8	[illegible]	1/8	0.30
	1/2	6	2	5	no	yes	3/8	0	3/8	0.75
	5/8	6	2	5	yes	yes	1/8	[illegible]	5/8	1.00
	3/4	6	2 1/4	5	no	yes	1	1/4	1 1/4	[illegible]
	7/8	6	2 1/2	5	yes	yes	1/4	3/4	1	1.14
	1	6	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE J13 (Continued)

Heat No.	PLATE Thick-ness	Dia-meter	Riser Dia.	Taper	Under Riser Shrink	Plate Shrink	Edge Sound	Sound Beyond Riser	Total Sound	T = Total Sound / Thickness
P506	1/8	6	1¼	7	yes	yes	1/4	0	1/4	2.00
	1/4	6	1½	7	no	yes	1/4	1/2	3/4	3.00
	3/8	6	1¾	7	no	yes	1/2	3/4	1 1/4	3.00
	1/2	6	2¼	7	no	yes	1/2	1/4	3/4	1.50
	5/8	6	2½	7	no	yes	1	1/2	1 1/2	2.40
	3/4	6	2¾	7	no	yes	3/4	1/4	1	1.33
	7/8	6	3	7	no	yes	5/8	1/2	1 1/8	1.28
	1	6	3	7	no	no	--	--	1 1/2	1.50
P507	1/8	6	1	7	no	yes	1/4	1/4	1/2	4.00
	1/4	6	1¼	7	no	yes	1/4	1/4	1/2	2.00
	3/8	6	1½	7	no	yes	1/2	3/4	1 1/4	3.00
	1/2	6	2	7	no	yes	1/2	1/4	3/4	1.50
	5/8	6	2	7	no	yes	3/4	1/2	1 1/4	2.00
	3/4	6	2¼	7	no	yes	1	1/2	1 1/2	2.00
	7/8	6	2½	7	no	yes	1	1/2	1 1/2	1.73
	1	6	3	7	no	no	--	--	1 1/2	1.50
P508	1/8	6	1¼	7	no	yes	1/8	0	1/8	1.00
	1/4	6	1½	7	no	yes	1/4	1/8	3/8	1.50
	3/8	6	1½	7	yes	yes	3/8	1/4	5/8	1.67
	1/2	6	2	7	no	yes	1/2	3/4	1 1/4	2.50
	5/8	6	2	7	no	yes	1/2	1	1 1/2	2.40
	3/4	6	2¼	7	no	yes	3/4	3/8	1 1/8	1.50
	7/8	6	2½	7	no	yes	7/8	1/2	1 3/8	1.64
	1	6	3	7	no	no	--	--	1 1/2	1.50

TABLE J14

FEEDING DISTANCE IN HEATED RAMMED GRAPHITE MOLDS

Heat No.	PLATE Thick-ness	Dia-Meter	Riser Dia.	Taper	Under Riser Shrink	Plate Shrink	Edge Sound	Sound Beyond Riser	Total Sound	T* Total Sound / Thickness
P383	1/8	6	1	0	no	yes	(didn't fill)	0	0	0
	1/4	6	1	0	yes	yes	1/8	3/16	5/16	1.250
	3/8	6	1	0	yes	yes	1/4	3/16	7/16	1.165
	1/2	6	1½	0	no	yes	1/8	1/4	3/8	.750
	5/8	6	1½	0	yes	yes	3/8	3/4	1 1/8	1.80
	3/4	6	2	0	no	yes	1/2	1/2	1	1.33
	7/8	6	2	0	no	yes	5/8	1 1/8	1 3/4	2.00
	1	6	2½	0	no	yes	5/8	3/4	1 3/8	1.375
P384	1/8	6	1	0	yes	yes	1/16	1/8	3/16	1.50
	1/4	6	1	0	yes	yes	1/8	3/8	1/2	2.00
	3/8	6	1	0	yes	yes	1/4	1/4	1/2	1.33
	1/2	6	1½	0	yes	yes	1/8 gas	5/8	3/4	1.50
	5/8	6	1½	0	yes	yes	3/8	5/8	1	1.60
	3/4	6	2	0	no	yes	1/2	1/2	1	1.33
	7/8	6	2	0	yes	yes	1/2	7/8	1 3/8	1.57
	1	6	2½	0	no	no			1 3/4	1.750
P385	1/8	6	1	0	yes	yes	1/32	0	1/32	.276
	1/4	6	1	0	yes	yes	1/8	1/4	3/8	1.50
	3/8	6	1	0	yes	yes	1/4	1/4	1	2.67
	1/2	6	7½	0	no	yes	1/4	1/4	1	2.00
	5/8	6	1½	0	yes	yes	3/8	1/2	7/8	1.40
	3/4	6	1½	0	no	yes	1/2	3/4	1 1/4	1.67
	7/8	6	2	0	yes	yes	1/2	1 1/8	1 5/8	1.86
	1	6	2½	0	no	no			1 3/4	1.75
P386	1/8	6	1	1	yes	yes	0 g	0	0	0
	1/4	6	1	1	yes	yes	1/16 g	1/4	5/16	1.25
	3/8	6	1	1	yes	yes	1/4 g	3/8	5/8	1.66
	1/2	6	1½	1	yes	yes	3/8 g	1/2	7/8	1.75
	5/8	6	1½	1	yes	yes	3/8	1/2	7/8	1.40
	3/4	6	2	1	no	yes	1/2	5/8	1 1/8	1.50
	7/8	6	2	1	no	yes	1/2	1	1 1/2	1.71
	1	6	3	1	no	no			1 1/2	1.50
P387	1/8	6	1	1	yes	yes	0 gas	1/8	1/8	1.00
	1/4	6	1	1	yes	yes	1/8 g	1/8	1/4	1.00
	3/8	6	1	1	yes	yes	1/4	1/4	1	2.67
	1/2	6	1½	1	yes	yes	1/4	1/2	3/4	1.50
	5/8	6	1½	1	yes	yes	1/4	1/4	1	1.60
	3/4	6	2	1	no	yes	5/8	1/2	1 1/8	1.50
	7/8	6	2	1	yes	no	1	3/4	1 3/4	2.00
	1	6	2½	1	no	no			1 3/4	1.75

TABLE J14 (Continued)

FEEDING DISTANCE IN HEATED RAMMED GRAPHITE MOLDS

Heat No.	PLATE Thick-ness	PLATE Dia-Meter	PLATE Riser Dia.	PLATE Taper	Under Riser Shrink	Plate Shrink	Edge Sound	Sound Beyond Riser	Total Sound	T = Total Sound Thickness
P388	1/8	6	1	1	yes	yes	0	0	0	0
	1/4	6	1	1	yes	yes	1/8 g	1/2	5/8	1.50
	3/8	6	1	1	yes	yes	1/4	1/4	1	2.67
	1/2	6	1½	1	yes	yes	1/4	1/2	3/4	1.50
	5/8	6	1½	1	yes	yes	1/2	1/2	1	1.60
	3/4	6	2	1	no	yes	1/2	1/2	1	1.33
	7/8	6	2	1	yes	yes	1/2	3/4	1 1/4	1.43
	1	6	2½	1	no	no	gas		1 3/4	1.750
P389	1/8	6	1½	3	no	yes	gas	1/4	1/4	2.00
	1/4	6	1½	3	no	yes	gas	1/8	1/8	.50
	3/8	6	1½	3	no	yes	1/4 g	1/4	1	2.67
	1/2	6	2	3	no	yes	3/8 g	3/4	1 1/8	2.25
	5/8	6	2	3	no	yes	3/8 g	1/2	7/8	1.40
	3/4	6	2½	3	no	no	gas		1 3/4	2.34
	7/8	6	2½	3	no	no	gas		1 3/4	2.00
	1	6	3	3	no	no			1 1/2	1.50
P390	1/8	6	1½	3	no	yes	gas	1/4	1/4	2.00
	1/4	6	1½	3	no	yes	1/4 g	1/4	1/4	1.00
	3/8	6	1½	3	no	yes	1/8 g	1/8	1/4	1.667
	1/2	6	2	3	no	yes	3/8	1/2	7/8	1.750
	5/8	6	2	3	no	yes	1/2	1/2	1	1.60
	3/4	6	2½	3	no	yes	5/8	1	1 5/8	2.17
	7/8	6	2½	3	no	no	gas		1 3/4	2.00
	1	6	3	3	no	no	gas		1 1/2	1.50
P391	1/8	6	1½	3	no	yes	gas	gas		0
	1/4	6	1½	3	no	yes	1/4 g	1/8	3/8	1.50
	3/8	9	1½	3	no	yes	1/4	1/4	1/2	1.33
	1/2	6	2	3	no	yes	1/4	1/2	3/4	1.50
	5/8	6	2	3	no	yes	1/2	3/4	1 1/4	2.00
	3/4	6	2½	3	no	yes	1/2	1	1 1/2	2.00
	7/8	6	2½	3	no	no	gas		1 3/4	2.00
	1	6	3	3	no	no	gas		1 1/2	1.50
P392	1/8	6	1½	5	no	yes	1/2 g	1/2	1	8.00
	1/4	6	1½	5	no	yes	1/4 g	1/4	1/2	2.00
	3/8	6	1½	5	no	yes	1/2	5/8	1 1/8	3.00
	1/2	6	2	5	no	yes	1/2	3/4	1 1/4	2.50
	5/8	6	2	5	no	yes	1/2	1/2	1	1.60
	3/4	6	2½	5	no	no	gas		1 3/4	2.80
	7/8	6	2½	5	no	no	gas		1 3/4	2.34
	1	6	3	5	no	no	gas		1 1/2	1.50

TABLE J14 (Continued)

FEEDING DISTANCE IN HEATED RAMMED GRAPHITE MOLDS

Heat No.	PLATE Thick-ness	Dia-Meter	Riser Dia.	Taper	Under Riser Shrink	Plate Shrink	Edge Sound	Sound Beyond Riser	Total Sound	T= Total Sound / Thickness
P393	1/8	6	1½	5	no	yes	0 g	1/4	1/4	4.00
	1/4	6	1½	5	no	yes	1/4 g	3/8	5/8	2.50
	3/8	6	1½	5	yes	yes	1/4 g	1/4	1/2	1.33
	1/2	6	2	5	no	yes	3/8	3/4	1 1/8	2.25
	5/8	6	2	5	no	yes	1/2	3/4	1 1/4	2.00
	3/4	6	2½	5	no	yes	1/2	1	1 1/2	2.00
	7/8	6	2½	5	no	no			1 3/4	2.00
	1	6	3	5	no	no			1 1/2	1.50
P394	1/8	6	1½	5	no	yes	gas	1/2	1/2	4.00
	1/4	6	1½	5	no	yes	1/4 g	1/2	3/4	3.00
	3/8	6	1½	5	yes	yes	1/4	1/4 g	1/2	1.37
	1/2	6	2	5	no	yes	1/2 g	3/4	1 1/4	2.50
	5/8	6	2	5	no	yes	7/8	3/4	1 5/8	2.60
	3/4	6	2½	5	no	no			1 3/4	2.34
	7/8	6	2½	5	no	no			1 3/4	2.00
	1	6	3	5	no	no			1 1/2	1.50
P395	1/8	6	1½	7	no	yes	gas	0	0	
	1/4	6	1½	7	no	yes	1/8	1 3/4	1 7/8	7.50
	3/8	6	1½	7	no	yes	1/4	3/4	1	2.67
	1/2	6	2	7	no	gas	3/16	1/4	7/16	.875
	5/8	6	2	7	yes	gas	1/8	3/4	7/8	1.40
	3/4	6	2½	7	no	gas	1/4		2	2.67
	7/8	6	2½	7	no	no			1 3/4	2.00
	1	6	3	7	no	no			1 1/2	1.50
P396	1/8	6	1½	7	no	yes	1/16	3/8	7/16	3.50
	1/4	6	1½	7	no	yes	0	1/2	1/2	2.00
	3/8	6	1½	7	yes	yes	1/8	1/2	5/8	1.67
	1/2	6	2	7	no	yes	1/2	1/4	3/4	1.50
	5/8	6	2	7	no	gas				
	3/4	6	2½	7	no	gas				
	7/8	6	2½	7	no	gas				
	1	6	3	7	no	gas				
P39/	1/8	6	1½	7	no	yes	0	1/4	1/4	2.00
	1/4	6	1½	7	no	yes	0	3/4	3/4	3.00
	3/8	6	1½	7	yes	yes	1/2	3/4	1 1/4	3.34
	1/2	6	2	7	no	gas				
	5/8	6	2	7	no	no			2	3.20
	3/4	6	2½	7	no	gas				
	7/8	6	2½	7	no	no			1 3/4	2.00
	1	6	3	7	no	no			1 1/2	1.50

TABLE J15

FEEDING DISTANCE IN CENTRIFUGED DISCS

HEAT NO.	PLATE THICKNESS	PLATE DIAMETER	RISER SIZE	EDGE SOUND	SOUND BEYOND RISER	TOTAL SOUND	T = Total Sound / Thickness	RPM/G'S
P-80	1/2	6	1	3/16	1/4	7/16	0.875	900/200
	1/2	6	1	1/4	1/4	1/2	1.000	
	1/2	6	1	3/16	1/4	7/16	0.875	
	1/2	6	1	3/16	1/8	5/16	0.630	
P-81	1/2	6	1	1/4	5/8	7/8	1.750	900/200
	1/2	6	1	3/16	1/4	7/16	0.875	
	1/2	6	1	3/16	5/16	1/2	1.000	
	1/2	6	1	3/16	1/4	7/16	0.875	
P-83	1/2	6	1	1/4	5/8	7/8	1.750	900/200
	1/2	6	1	3/16	1/4	7/16	0.875	
	1/2	6	1	3/16	1/4	7/16	0.875	
	1/2	6	1	3/16	5/8	13/16	1.625	
P-85	1/2	6	$1\frac{1}{2}$	Gas	5/8	5/8	1.250	900/200
	1/2	6	$1\frac{1}{2}$	0	1/4	1/4	0.500	
	1/2	6	$1\frac{1}{2}$	Gas	5/16	5/16	0.630	
	1/2	6	$1\frac{1}{2}$	Gas	1/2	1/2	1.000	
P-86	1/2	6	$1\frac{1}{2}$	1/4	1/4	1/2	1.000	900/200
	1/2	6	$1\frac{1}{2}$	3/16	1/4	7/16	0.875	
	1/2	6	$1\frac{1}{2}$	3/16	1/4	7/16	0.875	
	1/2	6	$1\frac{1}{2}$	1/4	1/4	1/2	1.000	
P-99	1/2	6	$1\frac{1}{2}$	3/16	1/4	7/16	0.875	1300/325
	1/2	6	$1\frac{1}{2}$	1/4	1/4	1/2	1.000	
	1/2	6	$1\frac{1}{2}$	1/4	1/4	1/2	1.000	
	1/2	6	$1\frac{1}{2}$	1/4	1/4	1/2	1.000	

TABLE J16

RESULTS OF TENSION FATIGUE TESTS TO ESTABLISH CHEMICAL REMOVAL REQUIREMENTS

SPECIMEN CONDITION	MAXIMUM STRESS, PSI	CYCLES TO FAILURE
As Cast and Abrasive Blast Cleaned	75,000	101,000
	75,000	82,000
	75,000	92,000
	75,000	151,000
	65,000	1,165,000
	60,000	1,546,000
	60,000	1,024,000
	60,000	129,000
.005" Per Surface Chemically Removed	75,000	61,000
	75,000	114,000
	75,000	33,000
	75,000	88,000
	65,000	66,000
	65,000	177,000
	65,000	205,000
	55,000	1,026,000
.010" Per Surface Chemically Removed	75,000	83,000
	75,000	74,000
	75,000	127,000
	75,000	213,000
	65,000	170,000
	65,000	182,000
	65,000	95,000
	65,000	1,072,000
.015" Per Surface Chemically Removed	85,000	724,000
	85,000	251,000
	75,000	297,000
	75,000	105,000
	75,000	744,000
	75,000	1,013,000
	65,000	1,252,000
	65,000	1,561,000

Underlined values were not failures.

$$R = \frac{\text{Minimum Stress}}{\text{Maximum Stress}} = .06$$

TABLE J17

MECHANICAL PROPERTIES OF AS-CAST Ti-6Al-4V

Heat Number	Ultimate Tensile Strength KSI	Yield Strength KSI (.2%)	Elongation in 4D Per Cent	Reduction in Area Per Cent	Notch Tensile Strength KSI	Brinell Hardness Number
P2-7	119.8	108*	4	9.2		
-7	152.3	127.1	12	22.6		
P4-8	156.1	not obtained	11	22.6		
-8	140.1	110*	10.5	15.5		
P6-5A					216.85	
-5B					210.4	
-5C					216.85	
-6	141.6	124.7	12	24		
P7-4	144.85	128.4	9	18		
	144.5	128.2	11	21		
	143.7	130.9	9.5	12		
	144.85	128.4	9	18		
	144.5	128.2	11	21		
	143.7	130.9	9.5	12		
P7-2G					213.55	
-2H					215.15	
-2I					215.2	
P9-2	145.9	131.35	9	12		
	145.55	131.4	9.5	19		
	144.9	132.5	9.5	18		
P10-2	150.6	131	10	20		
P11-2	144.5	120.5	8.5	17		
P12-1	148.65	136.15	6.5	10**		
P13-1	144.5	133.65	10	18		
P14-1	148.15	136.05	10	15		
P15-1	138.25	127.15	10	25		
P16-1	143.9	131.65	8	18		
P17-1	141.6	126.7	5	6		
P18-2	149	130.6	8	13		
P19-5	130.9	112.6	10	27 (Off analysis)		
P20-1	143.0	120	12	21		
P23-1	144.8	132.3	9	18		
P27-2B	147	135.5	9	15		
P29-2	149	Poor Curve	9	10		
P30-2	150.5	137.25	9	15		
P31-6	147.2	130.1	7	20		
P32-2	149.9	133.2	5	7		
P34-2	151.45	138.25	9.5	18		
P35-2	144.5	127.35	13	23		
P36-2	150.2	133.3	5	13		
P37-2	151	133.3	6	15		
P40-3	153.1	142	8.5	16		
P41-2	152.9	145.7	8	17		
P42-2	146.1	132.8	13	20		

*Flaw at fracture
**Broke out of gage length

TABLE J17 (Continued)

MECHANICAL PROPERTIES OF AS-CAST Ti-6Al-4V

Heat Number	Ultimate Tensile Strength KSI	Yield Strength KSI (.2%)	Elongation in 4D Per Cent	Reduction In Area Per Cent	Notch Tensile Strength KSI	Brinell Hardness Number
P43-2	151.2	140.9	6.5	13		
P45-2	145.1	130.8	11	22		
P47-2	154.7	143.5	12	20		
P48-2	154.3	141.8	12.5	18		
P50-2	150	134.95	12	18		
P51-2	152.8	137.15	12.5	18.5		334
P53-2	152.6	139.1	8	15		324
P54-2	152.9	143.2	9.5	14		324
P56-2	145.5	129.4	12	25		321
P57-3	144	128.8	10	19		321
P63-2	149.2	135.8	10	16		321
P70-2	148.9	135.7	15	23		337
P71-2	151.9	138.3	8	12		
P73-3	156.4	143.2	12	18		
P76-2	138.4	124	8	20.4		317
P78-2	156.4	138	7	16		343
P100-2	154.8	137.6	7	17		348
P101-1	137.2	121	9	15.1		345
P102-2	142.8	125.2	9	22		345
P104-2	146.8	130	9	22		348
P108-3	144	127.6	7	19.4		337
P115-3	144	127.2	9	26.5		317
P119-2	146.4	128.4	8	19.4		344
P129-2	151.6	135	8	24.1		334
P131-2	142.8	124.4	9	18.9		317
P132-2	148	143	7	18.1		338
P137-2	144	125	6	15.1		314
P142-2	156.8	135	8	17.6		344
P155-2	144	126	3	10		308
P156-2	152.4	138	8	14.2		324
P157-2	149.2	132	7	13.4		317
P158-1	141.6	124	8	17		317
P159-2	145.6	128	9	15.1		311
P186-2	134.4	118	8	9.7		302
P194-1	142	124	7	11.5		305
P197-1	132	116	7	13.1		285
P198-1	142	124	6	10.5		321
P199-2	144	125	8	15.1		311
P201-2	140	120	7	13.5		305
P206-3	138.4	121	8	15.9		299
P210-1	148	131	9	14.5		311
P211-1	142	124	9	15.1		305
P217-1	145.2	127	8	10		296
P218-1	144.2	126	7	16.7		314.3
P220-1	148	129	8	14.5		305
P221-1	136	118	4	7.6		299
P224-1	140	126	6	10.8		308.3
P225-1	150	132	7	10		331
P233-1	140	121	6	11.2		308

TABLE J17 (Continued)

MECHANICAL PROPERTIES OF AS-CAST Ti-6Al-4V

Heat Number	Ultimate Tensile Strength KSI	Yield Strength KSI (.2%)	Elongation In 4D Per Cent	Reduction In Area Per Cent	Notch Tensile Strength KSI	Brinell Hardness Number
P240-1	148	130	8	12.9		308
P241-1	142.2	125	8	13.5		299
P242-1	139.2	122	8	12.9		296
P243-1	139.2	112	5	14.5		311
P244-2	141.2	124	5	13.4		311.6
P246-1	139.6	121	8	15		311.3
P247-1	145.2	128	8	14.5		305
P248-1	144	126	8	14.5		308
P250-1	140	122	7	11.5		293.6
P260-1	146	127	6	8		296
P261-1	146	129	8	13.5		317.6
P264-1	146	130	6	4.9		321
P265-1	143.2	126	4	9.7		311
P281-1	144	126	10	15		316
P284-1	144	126	7	18.1		308
P286-1	138.4	121	7	12.7		308
P290-1	149.6	132	9	19.4		317.6
P291-1	138	120	9	17.5		311.3
P304-1	146.2	131	7	13.5		321
P305-1	148	131	7	10		324.3
P306-1	146	128	7	10		308
P307-1	146.8	130	8	15.9		305
P308-1	146.8	130	6	11.5		317.6
P309-1	152	134	7	13.5		317.6
P312-2	146.8	132	8	14.2		321
P314-1	146.4	130	8	12.9		336
P322-1	146	129	9	15.1		331
P323-1	144.8	128	9	13.4		321
P324-1	152	135	7	12.7		326
P328-1	142	124	9	12.7		311
P329-1	142	124	7	8.1		311
P330-2	148	132	9	14.5		321
P333-1	140.4	122	9	15.9		302
P336-1	144	137	8	15.1		326
P340-1	145.2	130	7	12.7		327.2
P343-1	150	135	7	16.7		324.3
P345-3	143.8	128	6	8.9		317.6
P346-2	140.2	122	7	15.1		311
P360-1	149.6	132	7	10.5		327.2
P364-1	146.8	131	7	13.5		305
P365-1	150	134	7	12.2		311
P366-1	149.6	128	8	15.1		311
P367-1	150	134	6	10.6		311
P368-1	153.6	136	6	10.6		327.6
P369-1	148.4	133	7	12.9		317.6
P370-1	150.8	134	7	12.7		314.3
P371	146.8	131	7	8.9		331
P373	151.2	132	7	12.2		324.3
P374	150.8	135	5	10.6		317.6
P379	156.0	139	7	9.2		334.3

TABLE J17 (Continued)

MECHANICAL PROPERTIES OF AS-CAST Ti-6Al-4V

Heat Number	Ultimate Tensile Strength KSI	Yield Strength KSI (.2%)	Elongation In 4D Per Cent	Reduction In Area Per Cent	Notch Tensile Strength KSI	Brinell Hardness Number
P380-1	154	137	7	8.6		331
P381-1	151.6	134	7	10		331
P382-1	152	135	7	14.5		331
P398-1	150.4	134	7	11.5		321
P399-1	140.4	123	7	12.9		302
P401-1	150	130	6	12.9		311
P403-1	150	133	5	10.5		321
P404-1	148	132	6	14.5		311.3
P405-1	154.8	137	8	12.2		327.6
P408-1	150	134	7	13.5		327.6
P411-1	147.2	129	4	10.5		324.4
P412-1	150	132	6	15.1		331
P413-1	139.6	120	8	16.7		314.3
P414 1	150	132	8	16.7		317.6
P418-1	146.8	128	8	16.7		321
P419 1	153.6	135	6	13.5		337.6
P420 1	142	122	8	21.7		321
P421-1	141.6	122	8	14.2		311
P422-1	152	133	9	18.1		324.3
P423-1	146	130	9	17.5		308
P511-1	146	131	8	12.9		311
P512-1	152	134	7	13.5		324.3
P524	153.2	137	7	13.5		331
P525	144.4	128	8	18.1		---
P526	153.6	135	7	13.5		331
P528	147.2	131	7	11.5		311.3
P529	149.2	132	8	15.1		324.3
P530	147.2	130	8	11.2		324
P531	148.2	130	7	12.2		317.6
P532	147.2	129	9	19.4		327.3
P534	150	132	7	18.9		331
P535	146.4	128	7	17.5		331
P536	152	132	8	10.6		
P538	152.8	133	9	15.1		---
P539	150	132	7	18.1		321
P540	147.2	130	6	11.5		314.4
P541-1	148.4	132	8	13.4		321
P542-1	146.8	130	7	18.1		305
P543-1	150	133	6	12.7		327.3
P546-1	143.6	126	5	12.2		306.5
P548-1	150	134	7	13.4		316
P549	165.2	145	8	13.5		311
P551	145.6	128	7	14.5		316
P552	146.2	130	8	15.9		331
P554	146.2	129	8	14.5		316
P555	148	129	10	23.7		302
P557	148.8	131	11	21.7		302
P558-1	148	129	8	17.5		292
P559	149.2	131	9	17.8		363
P562	155.2	136	9	17.5		311
P560	154	134	13	22.4		331
P561	144.8	125	11	16.7		265

TABLE J17 (Continued)

MECHANICAL PROPERTIES OF AS-CAST Ti-6Al-4V

Heat Number	Ultimate Tensile Strength KSI	Yield Strength KSI (.2%)	Elongation in 4D Per Cent	Reduction in Area Per Cent	Notch Tensile Strength KSI	Brinell Hardness Number
P564	144.8	130	9	16.4		
P566-1	152.4	136	6	10.5		
P568-1	143.6	128	8	17.0		
P575-1	150	134	7	15.9		
P570	143.2	126	7	16.4		
P571	146.8	129	8	15.9		
P572	143.6	126	8	14.2		
P573	146.4	130	6	16.4		
P574	145.2	130	5	12.2		
P576	147.2	131	7	11.2		
P577-1	142.8	122	13	27		302
P578-1	148.8	128	9	19.4		311
P580-1	146.4	128	11	21		311
P581-1	144	124	10	20.4		302
P582-1	135.6	118	10	18.1		
P584-1	146.8	124	10	19.7		302
P585-1	158	138	9	19.7		331
P586-1	146	128	8	15.8		302
P586-1	148.8	130	9	10		302
P586-1A	146.4	128	9	18.1		302
P586-2A	146.8	128	9	20.5		293
P587-1	158.8	137	7	13.5		321
P588-1	152	132	9	16.7		311
P589-1	152.4	129	9	15.9		
P590-1	160	138	10	21		
P591-1	154.8	134	8	15.1		
P592-1	168.8	146	5	10.5		
P593-1	154.8	134	11	20.8		
P595-1	156.4	136	8	15.9		
P598-1	162.4	140	8	15.1		
P599-1	156	136	10	15.9		
P604-1	150	130	8	16.7		311
P608-3	151.2	132	9	13.5		331
P609-1	152.8	136	9	18.1		
P610-1	144.8	123	9	18.1		
P611-1	150.4	130	9	21		
P612-1	150.8	132	11	24.8		
P613-1	149.2	128	9	17.5		
P614-1	151.2	128	9	18.3		
P617-1	148.8	130	11	24.6		
P618-1	[illegible]	128	11	23.7		
P619-1	142.2	120	11	24.6		
P620-1	141.8	120	11	23.7		
P621-3	151.2	129	10	20.6		
P622-3	147.2	123	13	26.1		
P623-3	147.8	125	11	21.7		
P624-3	154.8	132	5	17.5		
P625-3	150	129	12	27.2		

TABLE J18

ELEVATED TEMPERATURE PROPERTIES OF AS-CAST Ti-6Al-4V

HEAT NO.	TEST TEMPERATURE, °F	ULTIMATE TENSILE STRENGTH, KSI	YIELD STRENGTH, KSI (.2%)	ELONGATION, PER CENT	REDUCTION, OF AREA, PER CENT	MODULUS OF ELASTICITY, PSI x 10^{-6}
467	70	140.5	127.8	8	13	16.5
467	70	141.0	129.6	11	23	16.9
469	70	141.5	126.3	10	13	16.0
469	70	141.2	126.6	10	15	16.9
467	400	107.2	88.5	12	20	14.8
467	400	107.8	90.6	12	24	16.9
469	400	107.2	90.5	9	10	15.7
469	400	107.6	91.9	10	16	15.7
467	600	94.3	75.7	11	24	14.3
467	600	92.7	73.5	12	27	13.7
469	600	90.6	72.9	11	23	13.5
469	600	92.0	74.2	11	23	15.6
467	800	84.8	65.3	11	34	12.8
467	800	85.8	64.0	12	31	12.0
469	800	82.9	66.0	13	37	13.0
469	800	82.4	65.3	11	34	12.9

NOTE: The first two tests at each temperature were from heat 467.

TABLE J19

MECHANICAL PROPERTIES OF HEAT TREATED CAST Ti-6Al-4V

Heat No.	Heat Treatment	Yield Strength KSI (.2%)	Ultimate Tensile Strength KSI	Elongation In 4D Per Cent	Reduction In Area Per Cent	Notch Tensile KSI	Brinell Hardness Number
P7	As Cast	145.1	124.1	8	19.0		
"	1900F-1/2HR-WQ +1750-1/2HR-WQ+1000F-4HR-AC	168.1	156.7	3	5.0		
P10	1900F-1/2HR-WQ +1750F-1/2HR-WQ " " "	174.1	162.6	2	5.0		
"	1750F-1/2HR-WQ " " "	173.2	162.7	4	1.0		
"	As Cast	156.8	140.6	7	19.0		
P11	As Cast	146.8	127.2	6	14.0		
"	1900F-1/2HR-WQ+1750F-1/2HR-WQ +1750-1/2HR-WQ+1000F-4HR-AC	164.6	151.4	4	9.0		
"	1750F-1/2HR-WQ+1000F-4HR-AC	162.7	150.6	4	6.0		
P41	" 2HR " " 8HR "	179.1	174.3	0	0.6		
"	" 16HR " " 24HR "	176.9	175.9	0	0.9		
"	As Cast	152.9	145.7	8	17.0		
"	1650F-2HR-WQ+1000F-24HR-AC	177.3	171.3	1	4.4		
"	" 16HR " " 8HR "	182.9	173.6	1	3.7		
P42	As Cast	146.1	132.8	13	2.0		
"	1750F-2HR-WQ+1000F-24HR-AC	171.5	161.7	3	7.6		
"	" 16HR " " 8HR "	172.0	161.9	3	6.7		
"	1650F-2HR " " " "	168.3	158.6	2	8.7		
"	" 16HR " " 24HR "	166.4	159.5	2	4.2		
"	1500F-2HR-FCE Cool to 1000F-AC	144.5	135.8	7	13.6		
P41	" " " " " " "	152.7	152.3	7	13.0		
"	1600F-2HR-WQ+ 900F-2HR-AC	174.0	163.4	3	3.6		
P63	" " " " 4HR "	171		0	1.0		
"	" " " " 8HR "	178.5	---	0	1.4		
P40	As Cast	153.1	142	8.5	6.0		
"	1600F-2HR-WQ+1000F-2HR-AC	168	---	2	4.0		
P57	As Cast	144	128.8	10	19.0		
"	1600F-2HR-WQ+1000F-4HR-AC	159.7	---	4	5.7		
"	" " " " 2HR "	157.6	149.4	5	8.1		
P71	As Cast	151.9	138.3	8	12		
"	1600F-2HR-WQ+1100F-4HR-AC	149.4	143.7	2	1.8		
P42	1500F-2HR-WQ+ 900F-2HR "	163.6	149.1	3	5.5		
P40	1550F-2HR-WQ+ 900F-8HR-AC	174.7	162.0	3	6.7		
"	" " " 1000F-2HR "	168.7	162.5	3	3.9		
P57	" " " " 4HR "	157.9	149.4	5	8.0		
P71	" " " 1100F-2HR "	165.6	162.8	5	9.5		
"	" " " " 4HR "	164.5	161.2	3	7.0		
47	As Cast	144	154.7	12	20		338
"	1100F-8HR-AC	150	158.0	6.0	13.5	206.8	331
"	1550F-2HR WQ+1000F 4HR "	150	162.8	6	12.9		341
"	1100F-8HR-AC+1550F 2HR-WQ +1000F-4HR-AC	146	146.0	1	6.3		363
48	As Cast	142	154.3	12.5	16		338
"	1100F-8HR-AC	140	154.0	9	16.4	217.6	321
"	1550F-2HR-WQ+1000F-4HR "	151	160	3	7.6	233.2	341
"	1100F-8HR-AC+1550F 2HR WQ +1000F-4HR AC	152	164.8	4	10.6	226.8	352

TABLE J19 (Continued)

MECHANICAL PROPERTIES OF HEAT TREATED CAST Ti-6Al-4V

Heat No.	Heat Treatment	Yield Strength KSI (.2%)	Ultimate Tensile Strength KSI	Elongation In 4D Per Cent	Reduction In Area Per Cent	Notch Tensile KSI	Brinell Hardness Number
45	As Cast	131	145	11	22.0		
"	1100F-8HR-AC	137	152	9	25.9	223	
"	1550F-2HR-WQ +1000F-4HR-AC	143	156	6	12.2	220	
"	1100F-8HR-AC+1550F-2HR-WQ +1000F-4HR-AC	145	158	6	11.5	226	
47	As Cast	144	155	12	20		
"	1100F-8HR-AC	150	158	6	13.5	207	
"	1550F-2HR-WQ +1000F-4HR-AC	150	163	6	12.9		
"	1100F-8HR-AC+1550F-2HR-WQ +1000F-4HR-AC	148	149	1	6.3		
48	As Cast	142	154	12	18		
"	1100F-8HR-AC	140	154	9	16.4	218	
"	1550F-2HR-WQ +1000F-4HR-AC	151	160	3	7.6	233	
"	1100F-8HR-AC+1550F-2HR-WQ +1000F-4HR-AC	152	165	4	10.6	227	
50	As Cast	135	150	12	18.0		
"	1100F-8HR-AC	132	147	7	18.9	216.8	
"	1550F-2HR-WQ +1000F-4HR-AC	137	152	5	12.6	218.0	
"	1100F-8HR-AC+1550F-2HR-WQ +1000F-4HR-AC	140	155	5	9.2	217.6	
70	As Cast	136	149	15	23		
"	1100F-8HR-AC	138	153	10	24.6	228	
"	1550F-2HR-WQ +1000F-4HR-AC	154	168	4	11.5	232	
"	1100F-8HR-AC+1550F-2HR-WQ +1000F-4HR-AC	158	172	3	8.6	228	
50	As Cast	135	150	12	18		324
"	1100F-8HR-AC	132	146.8	7	18.9	216.8	311
"	1550F-2HR-WQ+1000F-4HR-AC					218.0	341
"	1100F-8HR-AC+1550F-2HR-WQ +1000F-4HR-AC					217.6	341
70	As Cast	136	146.9	15	23		337
"	1100F-8HR-AC	138	153.2	10	24.6	228	321
"	1550F-2HR-WQ+1000F-4HR-AC	154	168	4	.5	321.6	341
"	1100F-8HR-AC+1550F-2HR-WQ +1000F-4HR-AC	158	172	3	8.6	228	352
115	As Cast	132	143	8	13.2	211	
"	1150F-2HR-AC	136	142	9	18.6	212	
191	As Cast	125	134	8	8.8	203	
	1150F-4HR-AC	127	133	9	20.3	205	
194	As Cast	126	136	6	13.8	201	
	1100F-2HR-AC	127	137	8	14.1	195	
201	As Cast	124	135	7	10.2	203	
"	[illegible]	[illegible]	[illegible]	7	10	196	
206	As Cast	[illegible]	[illegible]	7	13.5	201	
"	[illegible]	[illegible]	[illegible]	7	15.1	206	
209	As Cast	[illegible]	[illegible]	7	[illegible]	204	
	[illegible]	131	[illegible]	7	[illegible]	[illegible]	
[illegible]	As Cast	[illegible]	[illegible]	7	[illegible]	[illegible]	
"	[illegible]	[illegible]	[illegible]	9	[illegible]	[illegible]	
[illegible]	As Cast	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	211	
307	As Cast	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

TABLE J19 (Continued)

MECHANICAL PROPERTIES OF HEAT TREATED CAST TI-6Al-4V

Heat No.	Heat Treatment	Yield Strength KSI (.2%)	Ultimate Tensile Strength KSI	Elongation In 4D Per Cent	Reduction In Area Per Cent	Notch Tensile KSI	Brinell Hardness Number
308	As Cast	134	144	7	9.8	211	
"	1150F-4HR-AC	136	145	8	12.1	217	
309	As Cast	134	145	6	6.5	205	
"	1150F-8HR-AC	135	145	8	12.1	214	
P211-1	As Cast	142	124	9	15.1		305
"	1550F-2HR-WQ+1000F-4HR AC	136	146.8	6	11.2		321
	" " " 1100F-2HR "	136	145.6	5	10.5		321
	" " " 1100F-2HR AC	134	144.0	7	9.7		321
	" " " 1000F-4HR AC	135	146.0	7	12.9		321
P245	1600F-2HR-WQ+1000F-2HR-AC	119	138.2	7	17.5		302
"	" " " " 4HR "	119	138.2	6	14.5		302
"	" " " 1100F-2HR "	117	132.2	5	10.5		321
"	" " " " 4HR "	116	133.2	7	14.2		311
"	" 1HR " 1000F-2HR "	120	136.0	5	10.0		302
"	" " " " 4HR "	119	135.6	3	8.64		302
"	" " " 1100F-2HR "	116	130.8	4	13.5		311
"	" " " " 4HR "	116	131.6	6	10.5		293
356	1550F-2HR-WQ+1000F-2HR-AC	134	144.8	4	11.2		321
"	" " " " 4HR "	135	144.0	3	5.2		331
"	" " " 1100F-2HR "	132	143.2	4	10.0		311
"	" " " " 4HR "	132	141.6	5	18.1		321
45	As Cast	131	145.1	11.0	22.0		334
"	1100F-8HR-AC	137	151.6	9.0	25.9	222.8	293
"	1550F-2HR WQ+1000F-4HR "					220.0	331
"	1100F 8HR-AC+1550F-2HR-WQ +1000F-4HR-AC					226.4	341

TABLE J.0

MECHANICAL PROPERTIES OF AS CAST EXPERIMENTAL ALLOYS

Alloy No.	Alloy Type	Heat No.	Yield Strength, KSI	Ultimate Strength, KSI	Elong. In 4D, Per Cent	Reduction In Area, Per Cent	Notch Tensile, KSI	Brinell Hardness Number	Carbon, Per Cent	Oxygen, Per Cent	Nitrogen, Per Cent
5	Ti 6Al-4V	P51-2	137.15	152.8	12.5	18.5			.084	.181	.028
5	Ti 6Al-4V	P54-2	143.2	152.9	9.5	14 0			.080	.200	.031
5	Ti 6Al-4V	F73-3	143.2	155.4	12.0	18.0			.094	.19	.036
6	Ti5Al-2 1/2Sn	P26-28	127.15	136.7	9.0	16.0			.067	.230	.014
			129.0	136.7	11.0	20.0					
			128.2	137.4	11.0	20,0					
6	Ti5Al-2 1/2Sn	P26-2C									
		A					205.65				
		B					206.5				
		C					207.3				
6	Ti5Al-2 1/2Sn	P33-2A							.070	.256	.015
		A	132.1	139.5	11.0	22.0					
		B	132.25	139.6	11.5	22.0					
		C	133.0	139.8	11.0	22.0					
6	Ti5Al-2 1/2Sn	P33-2B									
		A					203.3				
		B					196.45				
		C					204.2				
9	Ti 6Al-4V	P47-2	143.5	154.7	12.0	20.0			.087	.240	.027
9	Ti 6Al-4V	P50-2	134.95	150.0	12.0	18.0			.054	.158	.022
10	Ti 13V-11Cr	P62-2A	120.5	122.4	16.0	27.0			.028	.146	.027
		B	120.75	123.8	16.0	25.0					
		C	121.0	123.9	16.0	26.0					
10	Ti13V-11Cr	P62-3A					174.9				
		B					182.9				
		C					192.1				
10	Ti13V-11Cr	P66-2A	124.6	125.5	9.5	16.0			.023	.19	.028
		B	124.5	123.5	6.5	13.0					
		C	124.6	125.1	6.0	9.0					
10	Ti13V-11Cr	P66-3					174.7				
							180.7				
							178.5				
11	Ti13V-11Cr-1 1/2Al	P55-1A	125.9	126.75	13.5	23.0			.028	.153	.022
		B	125.25	126.5	18.5	24.0					
		C	125.25	126.1	15.0	23.0					
11	Ti13V-11Cr-1 1/2Al	P55-2A					187.3				
		B					184.8				
		C					174.7				
11	Ti13V-11Cr-1 1/2Al	P61-1A	126.4	127.8	10.5	17.0			.032	.1575	027
		B	128.4	129.6	12.5	21.0					
		C	127.7	131.0	12.0	18.0					
11	Ti13V-11Cr-1 1/2Al	P61-2A					163.1				
		B					175.5				
		C					179.0				
11	Ti13V-11Cr-1 1/2Al	435	120	130.8	7.0	11.5	179.2	277	.051	.12	.022
			119	129.6	7 0	9.7					
12	Ti13V-11Cr-	P3G-7A	123.9	124.5	11.5	22.0			.020	.1438	.017
		B	121.95	124.7	9.5	22.0					
		C	121.0u	128.4	10.0	23.0					

TABLE J20 (Continued)

MECHANICAL PROPERTIES OF AS CAST EXPERIMENTAL ALLOYS

Alloy No.	Alloy Type	Heat No.	Yield Strength, KSI	Ultimate Strength, KSI	Elong. In 4D, Per Cent	Reduction in Area, Per Cent	Notch Tensile, KSI	Brinell Hardness Number	Carbon, Per Cent	Oxygen, Per Cent	Nitrogen, Per Cent
12	Ti13V-11Cr-2 1/2Al	P38-2B					191.1				
							176.8				
							180.65				
12		P44-2A	128.55	130.7	10.5	20.0			.030	.143	.020
		B	129.45	133.1	8.5	18.0					
		C	129.8	131.4	3.5	9.0					
12		P44-3A					165.6				
		B					170.2				
		C					162.25				
13	Ti13V-11Cr-4Al	P46-2A	131.4	133.1	9.0	21.0			.019	.143	.018
		B	134.65	136.15	9.0	21.0					
		C	133.6	135.8	8.5	18.0					
13		P46-3A					177.6				
		B					178.1				
		C					169.3				
13		P52-1A	133.3	133.1	9.0	21.0			.024	.153	.018
		B	135.2	136.15	9.0	21.0					
		C	134.3	135.8	8.5	18.0					
13		P52-2A					185.7				
		B					174.3				
		C					173.7				
14	8V-5Fe	P139-2A	None	182.4	0	0	102.8	438	.022	.101	
		B	None	180.0	0	0	104.0				
		C	None	186.0	0	0	126.0				
15	8V-5Fe-1Al	P140-2A	169.0	174.0	4	11.9	203.0	363	.030	.096	.014
		B	169.0	174.0	4	10.0	206.8				
		C	162.0	171.6	5	16.4	170.0				
15	8V-5Fe-1Al	358	150	178.8	2	4.0	178.4	355.2	.028	.11	.015
			150	180.0	2	5.3					
			150	180.0	2	5.0	178.0				
		140	167	174.0	4	13.0	193.0		.030	.096	.014
		521	---	181.0	2.0	4.9			.017	.060	.011
16	5 1/2Al-31/2V 0.45Fe-2Sn-0.25Cu	P65-2A	125.4	142.0	10.5	15.0	210.0	311	.019	.10	.010
		B	126.7	142.4	10.0	16.0	206.8				
		C	125.9	142.0	10.0	15.0					
		P65-3A					217.5				
		B					216.0				
		C					215.1				
17		P151-2A	96.0	106.0	12	31.9	172.8	262	.024	.11	.0061
		B	96.0	106.2	10	36.5	173.2				
		C	98.0	108.2	1[illegible]	29.2	172.0				
19	Ti7Al-3Mo	P64-2	112.3	128.4	8.0	18.0			.020	.131	.0083
			118.0	130.7	5.0	12.0					
			113.05	128.4	7.0	16.0					
19		P64-3					190.7				
							189.7				
							186.95				
19		P68-2	117.0	132.55	5.0	15.0			.024	.10	.010
			115.8	129.95	3.0	7.0					
			112.1	127.3	7.0	15.0					

TABLE J20 (Continued)

MECHANICAL PROPERTIES OF AS CAST EXPERIMENTAL ALLOYS

Alloy No.	Alloy Type	Heat No.	Yield Strength, KSI	Ultimate Strength, KSI	Elong. In 4D, Per Cent	Reduction In Area, Per Cent	Notch Tensile, KSI	Brinell Hardness Number	Carbon, Per Cent	Oxygen, Per Cent	Nitrogen, Per Cent
20		P150 2A	128.0	136.0	10	25.7	190.0	277	.036	.13	.018
		B	128.2	137.2	10	24.6	204.2				
		C	128.0	136.0	11	27.2	190.0				
21		P152-1A	104.0	124.2	9	26.5	196.0	277	.036	.11	.0076
		B	105.0	126.0	9	18.1	194.0				
		C	106.7	127.6	10	25.2	190.0				
24	7Al-4Mo	P148-2A	112.0	132.0	5	15.1	194.0	305	.022	.072	.0046
		B	112.0	130.0	5	12.2	193.2				
		C	110.0	128.0	7	12.9	195.6				
25		P165-1A	90.0	114.0	10	18.9	172.0	250	.029	.089	.0069
		B	91.0	114.0	11	23.9	173.6				
		C	90.0	114.0	12	25.2	176.0				
26		P166-1A	107.0	121.0	9	25.2	190.0	287.6	.022	.11	.0067
		B	107.0	119.6	9	26.5	186.0				
		C	106.6	120.8	10	26.5	190.8				
27	4Al-3Mo-1V	P147-2A	91.0	110.0	15	37.0	172.0	254	.032	.086	.0066
		B	92.0	110.2	15	36.0	173.2				
		C	94.0	111.6	9	26.5	172.4				
28		P180-1A	134.0	140.8	1	5.3	220.8	321	.0035	.10	.012
		B	128.0	144.0	4	4.5	206.8				
		C	130.0	149.6	5	4.5	212.8				
29	6 1/2Al-3 1/2Mo-1V	P149-2A	136.0	154.8	8	14.0	216.4	331	.073	.020	.018
		B	132.0	152.0	12	21.5	224.0				
		C	135.0	154.2	10	20.4	214.4				
		359	112	150.0	9	16.7	219.2	321	.062	.19	.018
			110	148.8	6	10.6					
30		P189-1A	88.0	96.0	4	17.8	160.0	223	.044	.071	.0053
		B	91.0	98.0	11	45.5	157.2				
		C	90.0	97.2	10	37.7	158.0				
31		P190-1A	90.0	96.4	10	40.7	168.0	241	.024	.08	.0038
		B	92.0	96.4	13	34.4	166.0				
		C	90.0	98.0	12	42.0	172.0				
32		P146-2A	115.0	128.8	3	9.2	122.8	293	.032	.081	.018
		B	115.0	134.0	5	11.5	167.2				
		C	115.0	135.2	6	18.6	177.6				
33		P181-1A	149.0	165.2	1	0.6	170.0	345	.027	.115	.0041
		B	145.0	158.2	1	0.6	168.0				
		C	146.0	161.2	1	1.6	172.0				
34		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.026	.084	.0056
		B	129.0	148.0	2	3.8	173.2				
		C	134.0	141.2	2	1.6	180.4				
35		P205-3A	None	106.2	1	0	125.6	331	.033	.084	.0085
		B	None	108.2	1	0	154.8				
		C	None	118.0	1	0	122.0				
36		P204-2A	Too ductile	82.8	18	34.3	122.0	190	.036	.085	.0083
		B	to draw curve	83.2	18	33.7	124.0				
		C		83.2	19	35.8	122.0				

TABLE J20 (Continued)

MECHANICAL PROPERTIES OF AS CAST EXPERIMENTAL ALLOYS

Alloy No.	Alloy Type	Heat No.	Yield Strength, KSI	Ultimate Strength, KSI	Elong. In 4D, Per Cent	Reduction In Area, Per Cent	Notch Tensile, KSI	Brinell Hardness Number	Carbon, Per Cent	Oxygen, Per Cent	Nitrogen, Per Cent
37		P203 2A	None	136.8	1	1.6	122.8	375	.029	.105	.0070
		B	None	138.2	1	.7	100.8				
		C	None	138.0	0	2.4	116.4				
38		P193-1A	Too ductile	96.4	12	27.2	148.0				
		B		92.0	18	27.2	148 0				
		C		95.6	10	19.7	140.0				
39	5Mo-6V-2Ni	P164-1A	138.0	154.0	5	13.5	204.8	314.3	.021	.095	.011
		B	137.0	152.0	4	11.0	204.0				
		C	140.0	156.2	4	10.6	204.8				
		409	140	156.0	8	13.5	217.6	314	.027	.108	.0092
			140	156.0	7	14.5					
40		P233-1A	146.0	160.0	7	13.4	226.0	331	.026	.064	.0095
		B	146.0	160.0	7	10.5	232.0				
		C	145.0	159.2	5	10.6	228.0				
41	2Cu	P202-2A	62.0	79.6	25	38.3	112.0	176	.038	.10	.032
		B	62.0	80.0	24	36.5	114.0				
		C	61.0	79.6	25	39.3	114.0				
		P202	62.0	80.0	25	38.0	114.0				
		P523	85.0	106.0	15	25.9	156.0				
		P523	88.0	104.0	16	22.4		235	.033	.20	.035
		P523	89.0	106.0	15	24.6		248			
		P523	88.0	106.0	15	23.9		241			
		P579	100.0	117.0	14	18.9	173.0	255	.045	.27	.047
		P579	100.0	118.0	13	19.7	174	255			
		P579	100.0	117	13	18.1		262			
		P579	102.0	118.0	13	17.5		262			
		P579	98.0	115.0	6.0	9.2		269			
		P579	102.0	118.0	13	22.4		248			
42		P223-1A	111.0	123.6	8	15.8	182.4	283	.025	.08	.0041
		B	110.0	122.2	9	18.9	182.8				
		C	111.0	122.4	9	15.8	182.8				
43		P267-1A	103.0	123.8	9	27.2		272	.024	.066	.0072
		B	103.0	122.8	10	21.7					
		C	102.0	122.2	12	34.4					
44	3Al-2 1/2V	P144-1A	94.0	106.8	11	28.5	168.4	253	.028	.12	.019
		B	94.0	108.0	11	29.8					
		C	94.0	108.0	12	29.9					
45		P222-1A	112.0	124.4	12	30.5	194.4	288	.019	.087	.0047
		B	113.0	125.6	14	27.2	192.0				
		C	114.0	126.4	16	25.9	196.8				
46		P182-2A	68.0	92.0	14	25.2	127.2	201	.021	.12	.012
		B	68.0	90.4	13	26.0	132.0				
		C	63.0	91.6	13	23.0	133.2				
47		P226-1A	122.0	136.8	11	27.9	206.0	290	.030	.079	.012
		B	122.0	136.8	12	24.6	206.0				
		C	121.0	136.0	13	27.9	208.6				
48		P183-2A	137.0	156.0	4	4.9	186.4		.018	.16	.013
		B	136.0	154.0	4	6.1	180.0				
		C	136.0	154.4	3	6.3	178.0				

TABLE J20 (Continued)

MECHANICAL PROPERTIES OF AS CAST EXPERIMENTAL ALLOYS

Alloy No.	Alloy Type	Heat No.	Yield Strength, KSI	Ultimate Strength, KSI	Elong. In 4D, Per Cent	Reduction In Area, Per Cent	Notch Tensile, KSI	Brinell Hardness Number	Carbon, Per Cent	Oxygen, Per Cent	Nitrogen, Per Cent
49		P234-1A	111.0	132.0	10	32.5	206.0	296	.019	.073	.024
		B	115.0	136.0	8	21.0	204.0				
		C	111.0	131.0	9	29.0	204.4				
50		P230-1A	122.0	142.0	4	5.3	196.2	305	.012	.19	.0054
		B	123.0	143.2	11	18.9	186.0				
		C	123.0	144.0	10	18.1	190.0				
51		P236-1A	None	102.8	0	0	90.0	331	.022	.15	.0054
		B	None	100.0	0	0	76.0				
		C	None	106.4	0	0	88.0				
52			Not castable		Too brittle						
53	6Al-4V-0.15S	P267-1A	114.0	133.6	8	17.5	44.8	280	.036	.12	.0078
		B	112.0	132.0	10	21.0	49.2				
		C	112.0	131.6	12	33.0	54.4				
54	6Al-4V-0.5S	[illegible]	None	76.0	0	0	62.0	282	.028		.0077
		B	None	80.0	0	0	63.2				
		C	None	90.4	0	0	78.0				
55	6Al-4V-0.5W	P297-1A	104.0	124.0	9	25.7		277	.025	.078	.0067
		B	106.0	126.0	10	25.2					
		C	104.0	124.0	12	41.4					
		313					200	243	.031	.12	.015
							197.6				
							203.2				
56	6Al-4V-0.5Ta	348	104.0	124.0	11	38.9	192.0	282.3	.024	.19	.0090
			108.0	128.0	11	24.9	190.0				
			106.0	124.0	11	33.6	196.0				
57	3Al-7Mo-0.25Be	P298-1A	114.0	134.0	6	10.6	192.0	285	.016	.106	.0047
		B	113.0	134.0	8	12.2	189.6				
		C	112.0	133.2	7	10.6	192.0				
59	4Al-4Sn-8Zr	P299-1A	112.0	123.6	10	23		262	.017	.10	.0045
		B	108.0	120.0	10	23.7					
		C	110.0	124.0	10	24.4					
		331					202.0	293	.034	.11	.020
							204.8				
							205.6				
60	4Al-4Sn-8Zr-1Fe-1Cr-1V	P300-1A	132.0	151.6	9	21.5	223.2	321	.014	.14	.0054
		B	132.0	152.0	10	22.4	218.8				
		C	136.0	154.0	10	19.7	223.2				
		P489	151.0	170.0	7	10.5			.048	.29	.063
		P489	156.0	177.0	4	7.0		352			
		P489	156.0	156.0	0	0	161.0	352			
		P489	156.0	177.0	4	5.3		352			
61	7Al-2Mo-3Cr-3Sn-2Zr-0.06N	P301-1A	156.0	168.2	1	1.6	130.0	371	.014	.12	.064
		B	156.0	172.8	2	4.0	133.2				
		C	154.0	164.0	1	0.7	137.2				
62	7Al-2Mo-3Cr-3Sn-2Zr	349	151.0	161.2			160.8	359.6	.0030	.12	.0082
			154.0	174.0	3	7.0	156.2				
			153.0	172.0	1	3.3	186.8				
63	7Al-2Mo-0.5W-0.5Ta-3Cr-3Sn-2Zr	350	155.0	172.0	1	3.3	128.0	363	.022	.11	.0073
			155.0	162.4	1	1.6	128.0				
			156.0	170.8	1	4.0	152.0				

TABLE J20 (Continued)

MECHANICAL PROPERTIES OF AS CAST EXPERIMENTAL ALLOYS

Alloy No.	Alloy Type	Heat No.	Yield Strength, KSI	Ultimate Strength, KSI	Elong. In 4D, Per Cent	Reduction In Area, Per Cent	Notch Tensile, KSI	Brinell Hardness Number	Carbon, Per Cent	Oxygen, Per Cent	Nitrogen, Per Cent
64	4Al-4Sn-8Zr-	P302-A	124.0	141.2	11	22.4	213.2	290	.010	.12	.068
	0.07N	B	126.0	142.0	10	21.5	214.0				
		C	125.0	142.8	10	23.0	214.4				
65	4Al-2Mo-2Cr-	351		183.2	1	0	150.8	405.2	.018	.15	.0099
	2V-2Fe-4Sn-			137.6	1	0	131.6				
	8Zr			190.8	0	0	130.0				
66	2Al-5Fe-2Sn-	352	131	140.0	2	3.0	154.8	285.1	.023	.18	.015
	8V-5Zr		131	140.0	22	0.7	116.0				
			130	130.0	2	1.6	118.0				
68	2Al-8V-5Fe	354	140	154.4	7	11.9	183.6	311	.026	.11	.014
			142	153.2	4	8.6	186.8				
			143	153.6	4	10.6	148.0				
69	6Al-4V-	434	129	147.6	9	15.1	204	317	.038	.12	.0063
	1Cr-1Mo	434	126	144.8	7	18.6					
		434	128	145.0	8	17.0	204				
		None-A	130	152.0	7	15.1		321			
		B	130	152.0	6	9.2					
71	6Al-4V-	355	113	128.0	7	11.5	196.0	277	.048	.06	.028
	0.048C-0.06		111	127.2	6	12.2	190.4				
	Ox-0.028N		114	128.0	6	12.9	190.8				
72	6Al-4V-	357	114	130.8	6	15.1	200.0	287.6	.028	.05	.045
	0.028C-0.050		115	133.2	7	15.1	196.8				
	Ox-0.045N		115	132.0	7	15.1	198.0				
73	6Al-4V-	356	122	136.8	8	15.1	200.4	290.3	.025	.06	.079
	0.025C-0.06		124	142.8	6	11.2	212.0				
	Ox-0.079N		121	138.8	8	16.4	206.0				
80	0.04C-0.18	341	64	82.8	15	25.9			.040	.18	.018
	Ox-0.018N		64	80.2	15	23.0					
			63	81.8	13	34.4					
84	.036C-0.28	431	48	90.8	13	21.7			.036	.28	.018
	Ox-0.018N										
84	.053C-.26	432	76	96.0	13	28.5	213.0	213	.053	.26	.021
	Ox-.021N										
90	.03 O_2, 15Al,		Not castable - too brittle								
	1V										
96		513	54	71.0	20	40.0	108		.025	.099	.016
97		514	69	84.0	20	38.7	122		.037	.077	.073
98		520	111	127.0	3	0.7	119		.053	.57	.016
99		519	117	121.0	1	1.6	90		.036	.63	.066
100		518	59	83.0	16	27.0	128		.188	.13	.013
101		517	71	94.0	11	16.7	138		.190	.14	.059
102		516		85.0	1	0.8	86		.183	.67	.013
103		515		93.0	1	2.1	68		.185	.61	.076
104		P142	135	157.0	8	17.6			.100	.196	.035
105	4Al-4Sn-8Zr-	P596	154	171.0	4	5.3	216	352	.060	.12	.038
	1.5Fe-1.5Cr-	P596	154	171.0	5	9.7		352			
	1.5V	P596	154	170.0	4	5.3		352			
106	4Al-4Sn-8Zr-	P597	132	148.0	10	22.4	219	321	.060	.11	.038
	.5Fe-.5Cr-	P597	132	149.0	11	16.7		321			
	.5V										
		P510	144	158.0	4	5.1			.055	.127	.153
		P511	131	146.0	8	12.9			.050	.151	.011
		P526	135	153.0	7	13.5			.055	.21	.025
		P531	130	148.0	7	19.4			.050	.21	.020
		P536	132	152.0	8	10.6			.050	.22	.024
		P541	132	148.0	8	13.4			.057	.23	.031
		P548	134	150.0	7	13.4			.067	.22	.055
		P554	129	146.0	8	14.5			.048	.23	.028
		P559	131	149.0	9	17.8			.026	.23	.052

TABLE J20 (Continued)

MECHANICAL PROPERTIES OF AS CAST EXPERIMENTAL ALLOYS

Alloy No.	Alloy Type	Heat No.	Yield Strength, KSI	Ultimate Strength, KSI	Elong. In 4D, Per Cent	Reduction In Area, Per Cent	Notch Tensile, KSI	Brinell Hardness Number	Carbon, Per Cent	Oxygen, Per Cent	Nitrogen, Per Cent
107	10Cr-.1Al	606		140.0	0	0					
				160.0	1	1.6					
				172.0	1	3.3					
108	8Zr-4Al-	607	130	152.4	11	21.0	208		.077	.030	.035
	4Sn-2V		130	152.8	11	20.5					
110	10Zr-4Al-	626	118	135.2	11	27.9	201		.016	.11	.014
	4Sn 2V		118	134.2	11	24.6					
111	8Zr-4Al-	627	117	140.0	12	22.4	198		.016	.12	.014
	6Sn-2V		118	141.0	10	22.4					
112	8Zr-6Al-	628	120	145.0	12	21.4			.021	.12	.013
	4Sn-2V		120	144.0	11	23.2					

TABLE J21

MECHANICAL PROPERTIES OF HEAT TREATED EXPERIMENTAL ALLOYS

Alloy No.	Alloy Type	Heat No.	Heat Treatment	Yield Strength KSI (0.2 Offset)	Ultimate Tensile Strength KSI	Elongation in 4D Per Cent	Reduction In Area Per Cent	Notch Tensile KSI	Brinell Hardness Number
6	5Al-2½Sn	P26-2a	As-Cast	127.15	136.7	9.0	16.0		
				129.0	136.7	11.0	20.0		
				125.2	137.4	11.0	20.0		
		P26-2C	As-Cast						
		A						205.65	
		B						206.5	
		C						207.3	
		P33-2A	As-Cast						
		A		132.1	139.5	11.0	22.0		
		B		132.25	139.6	11.5	22.0		
		C		133.0	139.6	11.0	22.0		
		P33-2B	As-Cast						
		A						203.3	
		B						196.95	
		C						204.2	
		P33	1600F 2HR AC+1000F-6HR AC	133.6	139.3	8.0	15.7		
		P26	1900F " " " " "	129.3	136.4	6.0	17.5		
		P33	2000F " " " " "	129.5	136.2	7.0	13.3		
10	13V-11Cr -0Al	P62	As Cast	116.157	116.555	13.0	24.7		
		"	1600F-2HR-WQ+925F-48HR-AC	142.97	150.13	4.0	5.6		
		"	" " "	174.0	179.09	12.0	20.7		
		"	1700F 2HR-WQ " " "	152.91	161.54	6.0	3.2		
		"	" " "	127.53	127.53	17.0	33.7		
		"	" " "	126.7	127.1	15.0	33.5		
		"	" " " +925F-2HR-AC	128.6	132.5	8.0	10.7		
		"	" " " 1050F- " "	122.9	125.2	6.0	7.4		
		"	" " " 925F-8HR- "	137.4	145.8	5.0	6.1		
		"	" " " 1050F " "	122.4	131.0	11.0	13.0		
		"	925F-48HR-AC	141.29	151.35	8	11.1		
		P66	1700F-2HR-WQ	130.6	131.0	11.0	14.7		
		"	" " " 925F-1HR-AC	130.9	132.0	6.0	8.7		
		"	" " " 1050F " "	126.1	129.7	4.0	5.7		
		"	" " " 925F-4HR-AC	139.0	147.6	4.0	4.9		
10	13V-11Cr -0Al	P66	1700F-2HR-WQ 1050F-4HR-AC	128.7	135.3	7.0	6.5		
		"	" " " 925F-16HR-AC	150.3	161.5	4.0	3.8		
		"	" " " 1050F " "	127.8	135.0	5.0	7.2		
11	13V-11Cr 1½Al	P55-1A	As Cast	125.9	126.75	13.5	23.0		
		B	As Cast	125.25	126.5	18.5	24.0		
		C	As Cast	125.25	126.1	15.0	23.0		
		-2A	As Cast					187.3	
		B	As Cast					184.8	
		C	As Cast					174.7	
		P61-1A	As Cast	126.4	127.8	10.5	17.0		
		B	As Cast	126.4	129.6	12.5	21.0		
		C	As Cast	127.7	131.0	12.0	18.0		
		P61-2A	As Cast					163.1	
		B	As Cast					175.5	
		C	As Cast					179.0	
		P55	1700F-2HR-WQ	125.8	125.8	17.0	36.1		
		P61	" " "+925F-1HR-AC	133.6	135.7	5.0	11.0		
			" " " 1050F " "	130.5	136.2	10.0	12.0		
		P55	" " " 925F-2HR "	126.8	131.6	11.0	18.9		
		"	" " " 1050F " "	125.3	126.5	6.0	13.3		
		P61	" " " 925F-8HR "	147.4	156.0	4.0	6.2		
		"	" " " 1050F "	156.9	163.3	6.0	10.3		
		P55	" " " 925F-8HR "	129.5	140.1	11.0	12.9		
		"	" " 1050F " "	133.[illegible]	140.6	9.0	13.6		
		P61	" " " 925F-16HR "	[illegible]	183.6	5	6.6		
			" 1050F " "	140.0	147.1	6	4.3		
				133.1	133.1	12	23.4		
		P55	As Cast	[illegible]	[illegible]	14	20.9		
		"	1600F-2HR-WQ+925F-48HR-AC	[illegible]	[illegible]	3	5.1		
		"	"	[illegible]	125.425	14	20.5		
		"	1700F-2HR-WQ 925F-8HR-AC	[illegible]	[illegible]	[illegible]	4.0		
		"	" " "	127.7	[illegible]		30.3		
		P55	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		

TABLE J21 (Continued)

MECHANICAL PROPERTIES OF HEAT TREATED EXPERIMENTAL ALLOYS

Alloy No.	Alloy Type	Heat No.	Heat Treatment	Yield Strength KSI (0.2% Offset)	Ultimate Tensile Strength KSI	Elongation In 4D Per Cent	Reduction In Area Per Cent	Notch Tensile KSI	Brinell Hardness Number
11	13V-11Cr 1¼Al	P55	1400F-2HR-WQ+925F-48HR-AC	160	176	3	5.1		
		"	" " "	125	125	14	20.5		
		"	1700F- " " 925F 48HR AC	170	180	4	4.0		
		"	" " "	127	127		30.3		
		"	" " "	126	126	17	36.1		
		P61	" " "+925F-1HR-AC	135	136	5	11.0		
		"	" " "1050 " "	130	136	10	12.0		
		P55	" " " 925F-2HR-AC	129	132	11	18.9		
		"	" " "1050F " "	125	126	6	13.3		
		P61	" " " 925 4HR- "	147	156	4	8.2		
		"	" " "1050 " "	148	163	6	10.3		
		P55	" " " 925 8HR "	140	149	11	12.9		
		"	" " "1050 " "	134	141	9	13.8		
		P61	" " " 925 16HR "	180	194	5	6.8		
		"	" " "1050 16 "	140	147	6	4.8		
		"	" " "	133	133	12	23.4		
		P55	As Cast	125	125	14	20.9		
		"	1100F-2HR-WQ-925F-12HR-AC	159	174	6	9.2		
		"	1600F-2HR-WQ+ " " "	157	174	6	10.6		
		"	1700F " " 1000F-8HR- "	143	160	8	12.9		
		"q	1600 " " " " "	143	158	8	12.7		
		P61	1600 " " 950F- " "	150	166	5	6.7		
		"	" " " " 16HR "	153	170	5	6.7		
		P55	" " " " 24HR "	153	170	5	7.6		
		"	" " " 900F- 8HR "	140	154	10	15.1		
		"	" " " " 16HR "	152	169	7	10.0		
		"	" " " " 24HR "	158	175	5	6.3		
		435	As Cast	120	130.8	7.0	11.5	179.2	277
		"	As Cast	119	129.6	7.0	9.7		
		"	1550F-2HR-WQ+950F-8HR-AC	152	163	5	7.6		
		"	" " " " 16HR "	159	175	4	6.3		
		"	" " " " 24HR "	159	174	4	5.2		
		"	" " " 900 8HR "	169	182	3	5.3		
		"	" " " " 16HR "	159	171	5	7.6		
		"	" " " " 24HR "	171	187	4	6.3		
		"	1500F " " 950F-8HR "	149	166	5	5.3		
		435	1500F-2HR-WQ-950F-16HR-AC	156	174	4	6.3		
			" " " " 24HR- "	158	176	4	5.3		
			" " " 900F- 8HR "	151	165	5	6.1		
			" " " " 16HR "	165	182	3	6.3		
			" " " " 24HR "	166	183	4	5.2		
			1600F-2Hr-WQ+1050F-2HR-AC						
		55	1700F-2HR-WQ+1050F-4HR-AC	133	146.0	7	13.5		311
		"	" " " 925F-12HR-AC	159	174.4	5.5	9.2		341
		"	1600F " " 1050F-4 HR- "	128	142.0	7.5	11.9		302
		"	" " " 925F-12HR "	157	174.4	6	10.6		341
		"	1700F " " 1000F- 8HR "	143	159.6	8	12.9		341
		"	1600F " " " " "	143	158.0	8	12.7		311
12	13V-11Cr 2½Al	P38	As Cast	125,144	125.972	11	19.1		
		"	1400F-2HR-WQ+925F-48HR-AC	172.371	174.433	1	0.0		
		"	" " "	[illegible]	[illegible]	12	20.6		
		"	1700F " " 925F-48HR-AC	180.922	194.475	2	2.7		
		"	" " "	127,108	127,316	12	25.0		
		"	925F-48HR-AC	164.251	173.037	2	2.6		
		"-7A	As Cast	123.9	124.5	11.5	22.0		
		" B	As Cast	121.95	124.7	9.5	22.0		
		" C	As Cast	121.0	125.4	10.0	23.0		
		"-2B	As Cast					191.1	
		"	As Cast					176.8	
		"	As Cast					160.55	
		P44-2A	As Cast	126.55	130.7	10.5	20.6		
		B	As Cast	[illegible]	133.1	8.5	16.0		
		C	As Cast	127.8	131.4	3.5	9.0		
		P44-3A	As Cast					165.6	
		B	As Cast					170.2	
		C	As Cast					162.25	

[illegible]BLE [illegible] (Continued)

MECHANICAL PROPERTIES OF HEAT TREATED EXPERIMENTAL ALLOYS

Alloy No.	Alloy Type	Heat No.	Heat Treatment	Yield Strength KSI (0.2% Offset)	Ultimate Tensile Strength KSI	Elongation In 4D Per Cent	Reduction In Area Per Cent	Notch Tensile KSI	Brinell Hardness Number
		P44	1700F-2HR-WQ*	133.7	133.7	18	25.6		
		"	" " " 925F-1HR-AC	135.6	135.9	4	6.2		
		"	" " " 1050F " "	137.5	139.6	6	9.2		
		"	" " " 925F-4HR "	138.3	142.6	7	10.6		
		"	" " " 1050F " "	135.6	139.8	9	10.7		
		"	" " " 925F-16HR-AC	176.1	189.0	4	4.6		
		"	" " " 1050F " "	143.4	148.9	4	6.5		
		P38	" " "	125.7	126.7	12	29.6		
		"	" " " 925F-2HR-AC	141.4	144.0	4	2.8		
		"	" " " 1050F- " "	142.2	150.2	9	14.0		
		"	" " " 925F-8HR-AC	165.5	176.5	6	9.5		
		"	" " " 1050F-8HR- "	140.0	146.7	8	10.5		
13	13V-11Cr-4Al	P46-2A	As Cast	131.4	133.1	9.0	21.0		
		B	As Cast	134.65	136.15	9.0	21.0		
		C	As Cast	133.6	135.8	8.5	18.0		
		-3A	As Cast					177.6	
		B	As Cast					178.1	
		C	As Cast					169.3	
		P52-1A	As Cast	133.3	133.1	9.0	21.0		
		B	As Cast	135.2	136.15	9.0	21.0		
		C	As Cast	134.5	135.8	8.5	18.0		
		-2A	As Cast					185.7	
		B	As Cast					174.3	
		C	As Cast					173.7	
		P46	As Cast	132.3	134.3	9	18.3		
		"	1400F-2HR-WQ+925F-48HR-AC		182.8	0	0.2		
		"	" " "	131.2	133.7	7	14.7		
		"	1700F-2HR-WQ+ " " "	205.8	206.6	0	2.0		
		"	" " "	132.918	133.956	15	31.1		
		P52	" " "	136.7	137.3	13	26.6		
		"	" " " +925F-1HR-AC	140.8	162.8	4	8.2		
		"	" " " 1050F " "	146.6	148.8	7	11.2		
		"	" " " 925F-4HR- "	157.0	163.6	3	3.9		
		"	" " " 1050F " "	160.8	170.6	4	6.5		
		"	" " " 925F-16HR-"	192.6	198.7	2	1.4		
		"	" " " 1050F " "	175.5	179.5	3	2.0		
		P46	" " "	132.5	133.8	13	32.3		
		"	" " " 925F-2HR-AC	133.7	136.8	3	2.7		
		"	" " " 1050F " "	146.6	148.4	5	8.6		
		"	" " " 925F-8HR-AC	169.0	176.3	3	4.1		
		"	" " " 1050F " "	163.6	171.7	3	2.9		
		"	925F-49HR AC		191.1	0	1.2		
								(P139-3)	
14	8V-5Fe	P139-2A	As Cast	None	182.4	0	0	102.8	438
		B	As Cast	None	180.0	0	0	104.0	
		C	As Cast	None	186.0	0	0	126.0	
		P139	1350F-2HR-WQ+1000F-1HR-AC	165.6	166.6	1	3.5		
		"	" " " " 2HR "	161.1	163.0	1	1.4		
		"	" " " " 4HR-AC	Not Taken	155.3	2	4.4		
		"	1250F " " " 1HR "	"	146.8	5	6.6		
		"	" " " " 2HR "	"	144.9	4	5.7		
		"	" " " " 4HR "	"	144.1	4	6.3		
		"	" " " " 8HR "	"	140.2	3	9.5		
		"	As Cast	"	182.8	0	0		
15	8V-5Fe-1Al	P140-2A	As Cast	169.0	174.0	4	11.9	203.0	363
		B	As Cast	169.0	176.0	4	10.0	206.8	
		C	As Cast	162.0	171.6	5	16.4	170.0	
		F358	As Cast	150	178.8	2	4.0	178.4	355.2
		"	As Cast	150	180.0	2	5.3		
		"	As Cast	157	160.0	2	5.0	178.0	
		P140	As Cast	162	174.0	4	13.0	193.0	
		P521	As Cast	XXX	181.0	2.0	4.9		
		P140	1350F-2HR-WQ+1000F-1HR-AC	Not Taken	175.4	1	3.3		
		"	" " " " 2HR "	" "	176.5	1	0.8		
		"	" " " " 4HR "	" "	169.2	2	2.2		
		"	1250F 2HR " " 1HR "	[illegible]	155.0	3	2.6		
		"	" " " 2HR	Not Taken	155.4	5	5.1		
		"	" " " " 4HR "	" "	151.7	4	4.3		
		"	" " " " [illegible]	" "	[illegible]	4	5.1		
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		331

TABLE J21 (Continued)

MECHANICAL PROPERTIES OF HEAT TREATED EXPERIMENTAL ALLOYS

Alloy No.	Alloy Type	Heat No.	Heat Treatment	Yield Strength KSI (0.2% Offset)	Ultimate Tensile Strength KSI	Elongation In 4D Per Cetn	Reduction In Area Per Cent	Notch Tensile KSI (P140-3)	Brinell Hardness Number
15		P358	1000F-48HR-AC	160	166	3	9.5	192	331
		P140	900F- 8HR "	---	201	0	0		388
		P358	" 24HR "	---	192	3	7.2		363
		"	" 48HR "	178	181	2	3.4	172	341
		P140	800F- 8HR "	---	191	2	0		401
		P358	" 24HR "	---	195	1	0.		388
		"	" 48HR "	---	194	1	0	118	375
		P140	700F- 8HR "		148	0	0		415
		P358	" 24HR "	---	121	0.5	2.1		401
		"	" 48HR "		122	0	0	85	415
		P140	600F- 8HR "						
		"	" 24HR "						
		P358	" 48HR "	---	121	0.5	1.6		388
16	5.5Al	P65	As Cast	126	142.1	10	15.3		
	5.5V-2Sn	"	1150F-16HR-AC	127.7	138.9	9	16.2		
	.5Fe-.25Cu	P69	As Cast	125.2	140.4	9	16.2		
		"	1100F- 2HR-AC	130.6	141.0	9	19.6		
		"	" 4HR "	129.4	140.6	6	13.7		
		"	" 8HR "	129	140.6	5	13.2		
		"	" 16HR "	130.8	140.8	9	13.0		
		"	1150F- 2HR "	127.5	136.6	8	14.1		
		"	" 4HR "	128.8	139.1	11	17.8		
		"	" 8HR "	128.9	140.7	8	14.8		
		"	1050F- 2HR "	129.2	141.8	7	8.8		
		"	" 4HR "	129.9	142.9	9	11.8		
		"	" 8HR "	130.5	142.3	6	12.7		
		P65-2A	As Cast	125.4	142.0	10 5	15.0	210.0	311
		B	As Cast	126.7	142.4	10.0	16.0	206.8	
		C	As Cast	125.9	142.0	10.0	15.0		
		P65-3A	As Cast					217.5	
		B	As Cast					216.0	
		C	As Cast					215.1	
		P65	As Cast	126.0	142.1	10	15.3		
		"	1650F-2HR-WQ+1000F-6HR-AC	172.0	181.2	0	0.6		
		"	" " " " 16HR	171.8	176.5	0	0.3		
		"	" " " 1100F-6HR "	161.2	172.0	0	1.0		
		"	" " " " 16HR "	158.3	168.9	2	5.0		
		"	" 16HR 1000F-6HR "	164.9	173.3	0	0.5		
		"	" " " " 16HR "	164.6	175.7	1	2.8		
		"	" " " 1100F-6HR "	161.1	168.2	1	3.6		
		"	" " " " 16HR "	156.7	165.8	1	4.8		
		P69	As Cast	125.2	140.4	9	16.2		
19	8Al-4Mo	P64-2	As Cast	112.3	128.4	8.0	18.0		
			As Cast	116.0	130.9	5	12.0		
			As Cast	113.05	128.4	7	16.0		
		P64-3	As Cast					190.7	
			As Cast					189.7	
			As Cast					186.95	
		P68-2	As Cast	117.0	132.55	5	15.0		
			As Cast	115.6	129.55	3	7.0		
			As Cast	112.1	127.3	7	15.0		
		P64	As Cast	114.3	129.3	7	15.0		
		"	1600F 2HR AC+1100F-16HR-AC	114.3	124.9	4	14.2		
		"	" " "	107.9	122.8	6	12.6		
		"	" " WQ+1100F-16HR-AC	123.5	[illegible]	3	9.2		
		"	" " "	117.3	[illegible]	[illegible]	12.2		
		"	1600F-2HR-AC+1100F-16HR-AC	[illegible]	123.0	6	15.7		
		"	" " "	[illegible]	122.0	4	12.9		
		"	" " WQ	[illegible]	[illegible]	[illegible]	[illegible]		

TABLE J21 (Continued)

MECHANICAL PROPERTIES OF HEAT TREATED EXPERIMENTAL ALLOYS

Alloy No.	Alloy Type	Heat No.	Heat Treatment	Yield Strength KSI (0.2% Offset)	Ultimate Tensile Strength KSI	Elongation In 4D Per Cent	Reduction In Area Per Cent	Notch Tensile KSI	Brinell Hardness Number
19		P68	As Cast	115.0	129.9	5	12.0		
		"	1700F-2HR-WQ+1000F-1HR-AC	130.6	142.0	3	7.6		
		"	" " " " 2HR "	133.0	148.4	3	2.7		
		"	" " " " 4HR "	138.4	148.0	2	10.7		
		"	" " " " 8HR "	132.9	148.6	2	1.8		
		"	" " " 1100F-1HR "	131.9	142.1	1	0.6		
		"	" " " " 2HR "	138.6	146.6	2	0.8		
		P64	" " " " 4HR "	131.8	138.6	2	2.1		
		"	1600F " " 1000F-4HR "	125.5	137.3	3	8.7		
		"	" " " 1100F-2HR "	127.1	138.1	3	6.9		
20	10V-13Cr 5Al	P150-2A	As Cast	128.0	136.0	10	25.7	(150-3) 190.0	277
		B	As Cast	128.2	137.2	10	24.6	204.2	
		C	As Cast	128.0	136.0	11	27.2	190.0	
		P150	As Cast	128	136	10	25.0	193	
		"	1600F-2HR-WQ+1000F-2HR-AC	151	163	3	7.0		
		"	" " " " 4HR "	179	182	1	2.1		
		"	" " " " 8HR "	---	173	0.5	0.7		
		"	" " " 1050F-2HR "	167	167	1	0.0		
		"	" " " " 4HR	---	158	1	1.5		
		"	" " " " 8HR "	---	173	1	0.0		
24	7Al-4Mo	P148-2A	As Cast	112.0	132.0	5	15.1	194.0	305
		B	As Cast	112.0	130.0	5	12.2	193.2	
		C	As Cast	110.0	128.0	7	12.9	195.6	
		P148	As Cast	111.3	130.0	6	13.4		
		"	1600F-2HR-WQ+1000F-4HR-AC	127.2	145.8	4	5.7		
		"	" " " 1100F-2HR "	129.0	140.2	2	6.7		
		"	" " " " 4HR "	129.0	142.5	3	1.4		
26	8Al-1Mo 1V	P166-1A	As Cast	107.0	121.0	9	25.2	190.0	287.6
		B	As Cast	107.0	119.6	9	26.5	186.0	
		C	As Cast	106.6	120.8	10	26.5	190.8	
		166	1600F-2HR-WQ+1000F-1HR-AC	107	122.0	4	4.9	285	
		"	" " " " 2HR "	103	119.6	9	24.1	285	
		"	" " " " 4HR "	102	116.4	8	25.9	293	
		"	" " " 900F-2HR "	104	117.2	7	21.7	285	
		"	" " " " 4HR "	106	119.6	10	22.4	293	
27	4Al-3Mo 1V	P147-2A	As Cast	91.0	110.0	15	37.0	(P147-3) 172.0	254
		B	As Cast	92.0	110.2	15	36.0	173.2	
		C	As Cast	94.0	111.6	9	26.5	172.4	
		P147	As Cast	92.3	110.6	13	33.2		
		"	1550F-2HR-WQ+1000F-4HR-AC	107.5	123.6	3	2.4		
		"	" " " 1100F-2HR "	103.4	118.6	4	8.5		
		"	" " " " 4HR "	101.6	116.4	6	11.3		
29	6½Al-3½Mo 1V	P149-2A	As Cast	136.0	154.8	8	14.0	(P149-3) 216.4	331
		B	As Cast	132.0	152.0	12	21.5	224.0	
		C	As Cast	135.0	154.2	10	20.4	214.4	
		359	As Cast	112	150.0	9	16.7	219.2	321
			As Cast	110	148.8	6	10.6		
		P149	As Cast	134.2	153.7	10	18.9		
		"	1600F-2HR-WQ+1000F-1HR-AC	165.6	171.1	2	3.3		
		"	" " " " 2HR "	168.0	173.5	1	3.0		
		"	" " " " 4HR "	170.0	175.5	2	3.2		
		"	" " " " 8HR "	---	166.1	2	0.2		
		P149	As Cast	134	154	10	18.9	218	
		"	1600F-2HR-WQ+1000F-1HR-AC	165	171	2	3.8		
		"	" " " " 2HR "	168	174	1	3.0		
		"	" " " " 4HR "	170	176	2	3.2		
		"	" " " " 8HR "	---	166	2	0.2		
		"	1550F " " " 4HR "	158	164	2	[illegible]		
		"	" " " 2HR "	159	166	2	4.0		
		"	" " " 1100F-2HR "	155	170	3	7.0		
		"	" " " " 4HR "	157	167	4	7.4		
		"	1500F " " 1000F " "	139	165	2	4.9		
		"	" " " " 8HR "	136	170	3	6.3		
		"	" 1100F 2HR	132	[illegible]	1	8.6		
		"	" " " " 4HR "	137	[illegible]	5	11.5		

TABLE J21 (Continued)

MECHANICAL PROPERTIES OF HEAT TREATED EXPERIMENTAL ALLOYS

Alloy No.	Alloy Type	Heat No.	Heat Treatment	Yield Strength KSI (0.2% Offset)	Ultimate Tensile Strength KSI	Elongation In 4D Per Cent	Reduction In Area Per Cent	Notch Tensile KSI	Brinell Hardness Number
29		P359	As Cast	111	150	7.5	14.0	219	
		"	1500F-2HR-WQ+1000F-8HR-AC	149	165	5	11.5	217	
		"	" " " 1100F-4HR "	144	158	3	6.7	226	
		"	" " " 1050F-6HR "	150	163	4	8.1	222	
		"	1450 " " 1000F-8HR "	148	163	4	10.6	214	
		"	" " " 1100F-4HR "	144	153	3	7.0	224	
		"	" " " 1050F-6HR "	146	160	5	6.7	221	
		P149	1550F-2HR-WQ+1000F-4HR-AC	158	163.6	2	4.9		363
		"	" " " " -8HR "	159	168.0	2	4.0		352
		"	" " " 1100F-2HR "	155	170.0	3	7.0		352
		"	" " " " 4HR "	152	162.4	4	7.4		352
		"	1500F " " 1000F-4HR "	134	165.0	2	4.9		352
		"	" " " " 8HR "	136	170.0	3	6.3		352
		"	" " " 1100F-2HR "	132	166.0	3	8.6		341
		"	" " " " 4HR "	132	166.0	5	11.5		352
32	15V	P146-2A	As Cast	115.0	128.8	3	9.2	(P146-3) 122.8	293
		B	As Cast	115.0	134.0	5	11.5	167.2	
		C	As Cast	115.0	135.2	6	18.6	177.6	
		P146	1350F-2HR-WQ+900F-2HR-AC	141.8	144.0	4	1.8		
		"	" " " " 4HR "	164.0	166.5	3	3.8		
		P146	" " " " 8HR "	135.3	136.7	2	3.3		
41	2Cu	P523	As Cast	85	106	15	25.9	156	
"		"	1000F-8HR-AC						
"		"	" 24HR "						
"		"	900F-72HR "	88	106	15	23.9		241
"		"	" 24 "	88	104	16	22.4		235
"		"	" 48 "	89	106	15	24.6		248
"		"	800F- 8HR "	84	104	12	20.4		299
"		"	" 24HR "	88	104	15	24.4		241
"		"	" 48HR "	88	105	16	27.2		241
"		"	700F- 8HR "	86	104	16	25.9		235
"		"	" 24HR "	86	104	17	26.5		223
"		"	" 48HR "	88	105	16	30.5		223
"		"	600F-24HR "						
"		"	" 48HR "						
"		P202	1475F-2HR-WQ+1200F-2HR-AC	55	82.8	21	41.4		170
"		"	" " " " 8HR "	58	80	19	38.1		183
"		P579	As Cast	100	117	14	18.9	173	255
"		"		100	118	13	19.7	174	255
"		"	1000F-80HR-AC	100	117	13	18.1		262
"		"	900F- 8HR- "	102	116	13	17.5		262
"		"	600F- 8HR "	98	115	6	9.2		269
"		"	" 80HR "	102	118	13	22.4		248
42	6Al-2Cu	P223-1A	As Cast	111	123.6	8	15.8	182.4	283
"		B	As Cast	110	122.2	9	14.9	182.8	
"		C	As Cast	111	122.4	9	15.0	182.8	
"		P223	1475F-2HR-WQ+1200F-2HR-AC	108	118.8	10	23.2		262
"		"	" " " " 8HR "	106	116.8	10	23.2	(P182-3)	269
44	3Al-2½V	P144-1A	As Cast	94.0	106.8	11	28.5	168.4	253
		B	As Cast	94.0	108.0	11	29.8		
		C	As Cast	94.0	108.0	12	29.9		
		P144	As Cast	94.0	107.6	11	29.6		
		"	1450F-2HR-WQ+900F-2HR-AC	101.6	113.8	9	13.2		
		"	" " " " 4HR "	105.3	113.9	5	15.3		
		"	" " " " 8HR "	105.4	112.5	9	21.2		
		"	1350F " " " 2HR "	101.4	108.6	12	30.3		
		"	" " " " 4HR "	102.0	108.6	10	21.1		
		"	" " " " 8HR "	100.2	108.5	14	30.[illegible]		
		"	" " " " 16HR "	107.2	108.0	9	21.2		
45	8Al-8Zr 1Cb-1Ta	P222-1A	As Cast	[illegible]	1[illegible].4	12	30.5	(P[illegible]-2) 194.4	[illegible]
		B	As Cast	[illegible]	1[illegible]	14	[illegible]	192	
		C	As Cast	[illegible]	1[illegible].4	1[illegible]	25.9	196.8	
		P222	1000F-4HR-AC	[illegible]	1[illegible]	[illegible]	1[illegible]		[illegible]
		"	" 8HR "	1[illegible]	1[illegible].8	5	14.[illegible]		[illegible]
		"	16HR	[illegible]	1[illegible].4	6	13.[illegible]		[illegible]

TABLE J21 (Continued)

MECHANICAL PROPERTIES OF HEAT TREATED EXPERIMENTAL ALLOYS

Alloy No.	Alloy Type	Heat No.	Heat Treatment	Yield Strength KSI (0.2% Offset)	Ultimate Tensile Strength KSI	Elongation In 4D Per Cent	Reduction In Area Per Cent	Notch Tensile KSI	Brinell Hardness Number
46	3Mo-.5Be	P182-2A	As Cast	68	92.0	14	25.2	127.2	201
"		B	As Cast	68	90.4	13	26	132	
"		C	As Cast	68	91.6	13	23	133.2	
"		P182	1500F-2HR-WQ	78	126.0	4.5	9.2		293
"		"	" " " + 900F-1HR-AC	78	106.0	3	8.6		277
"		"	" " " " 2HR "	72	108	4.5	10		248
"		"	" " " " 4HR "	72	115.6	7	11.9		248
"		"	" " " " 8HR "	60	113.2	7	11.9		241
"		"	" " " 800F-1HR "	81	122	2.5	4		285
"		"	" " " " 2HR "	78	124.8	3	6.3		293
"		"	" " " " 4HR "	76	123.6	6	7.6		293
"		"	" " " " 8HR "	76	123.2	4	7.4		285
								(P234-2)	
49	6Al-6V -2Sn	P234-1A	As Cast	111.0	132.0	10	32.5	206.0	296
		B	As Cast	115.0	136.0	8	21.0	204.0	
		C	As Cast	111.0	131.0	9	29.0	204.4	
		P234	1600F-2HR-WQ+1000F-2HR-AC	---	163.6	2	3.8		363
		"	" " " " 4HR "	150	163.6	2	3.8		352
		"	" " " 1100F-2HR "	146	158.8	2	7.0		352
		"	" " " " 4HR "	150	160.0	1	1.6		352
		"	" " " 1000F-2HR "	142	159.2	2	4.9		352
		"	" " " " 4HR "	145	157.2	1	0.3		352
		"	" " " 1100F-2HR "	141	155.2	2	7.0		341
		"	" " " " 4HR "	140	154.2	3	7.6		341
50	13Sn-2Al -10Zr	P230-1A	As Cast	122.0	142.0	4	5.3	196.2	305
		B	As Cast	123.0	143.2	11	18.9	186.0	
		C	As Cast	123.0	144.0	10	18.1	190.0	
		P230	1025F-4HR-AC	126	141.6	7	11.9		293
		"	" 16HR "	124	143.6	4	7.6		311
55	6Al-4V 0.5W	P297-1A	As Cast	104.0	124.0	9	25.7		277
		B	As Cast	106.0	126.0	10	25.2		
		C	As Cast	104.0	124.0	12	41.4		
		313						200 197.6 203.2	243
55		313	1600F-2HR-WQ+1000F-2HR-AC	121	139.6	5	11.5		321
		"	" " " " 4HR "	120	139.6	8	15.1		311
		"	" " " 1100F-2HR "	123	136.2	6	13.5		286
		"	" " " " 4HR "	119	134.0	8	16.7		293
		"	" " " 1000F-2HR "	121	138.0	7	13.5		302
		"	" " " " 4HR "	120	138.8	7	12.9		302
		"	" " " 1100F-2HR "	116	132.8	8	12.7		293
		"	" " " " 4HR "	116	133.6	9	17.5		311
56	6Al-4V -0.5Ta	348	As Cast	104	124	11	38.9	192	282.3
		"	As Cast	108	128	11	24.9	190	
		"	As Cast	106	124	11	33.6	[illegible]	
		"	1600F-2HR-WQ+ 900F-2HR-AC	117	140.4	6	10.0	[illegible]	321
		"	" " " " 8HR-AC	123	140.0	4	12.2	[illegible]	321
		"	" " " 1000F-2HR "	114	138.2	9	25.2		311
		"	" " " " 4HR "	119	136.8	9	25.0		321
		"	" " " 1100F-2HR "	117	134.0	3	14.5		302
		"	" " " " 4HR "	120	133.0	5	15.9		302
		"	" 1HR " 1000F-2HR "	120	136.0	4	12.2		311
		"	" " " " 4HR "	120	136.8	6	12.9		311
		"	" " " 1100F-2HR "	118	134.2	6	7.6		302
		"	" " " " 4HR "	116	131.2	7	14.2		311

TABLE J2 I (Continued)

MECHANICAL PROPERTIES OF HEAT TREATED EXPERIMENTAL ALLOYS

Alloy No.	Alloy Type	Heat No.	Heat Treatment	Yield Strength KSI (0.2% Offset)	Ultimate Tensile Strength KSI	Elongation In 4D Per Cent	Reduction In Area Per Cent	Notch Tensile KSI (148-3)	Brinell Hardness Number
57	3Al-7Mo	P298-1A	As Cast	114	134	6	10.6	192	285
"	-0.25Be	B	As Cast	113	134	8	12.2	189.6	
"		C	As Cast	112	133.2	7	10.6	192	
"		P298	1450F-2HR-WQ	114	132	10	18.9		269
"		"	" " " + 900F-1HR-AC	Not	148	0	0		388
"		"	" " " " 2HR "	Taken	156	0	0		375
"		"	" " " " 4HR "	"	152	0	0		388
"		"	" " " " 8HR "	"	156	0	0		375
"		"	" " " 800F-1HR "	"	156	0	0		388
"		"	" " " " 2HR "	"	157.8	0	0		388
"		"	" " " " 4 HR "	"	158.4	0	0		388
"		"	" " " " 8HR "	"	162.4	0	0		388
60	4Al-4Sn-8Zr	P300	As Cast	133	152	10	21		
"	-1Fe-1Cr-1V	"	1025F-4HR-AC	135	152	11	19.4		321
"		"	" 8HR "	136	146	3	4.9		311
"		"	" 16HR "	137	153	8	10.6		331
"		P489	1000F-8HR "	157	174	3	5.2		
"		"	" 24HR "	160	176	4	4.9		
"		"	" 48HR "	161	176	3	2.4	172	
"		"	As Cast	151	170	7	10.5		
"		"	900F-8HR "						
"		"	" 24HR "	156	177	4	7		352
"		"	" 48HR "	156	156	0	0	161	352
"		"	" 72HR "	156	177	4	5.3		352
"		"	800F-8HR "	155	173	7	11.5		
"		"	" 24HR "	157	173	2	2.4		
"		"	" 48HR "	160	182	5	7.6		
60	4Al-4Sn	P300-1A	As Cast	132.0	151.[illegible]	9	21.5	223.2	321
	8Zr-1Fe	B	As Cast	132.0	152.0	10	22.4	218.8	
	1V-1Cr	C	As Cast	136.0	154.0	10	19.7	223.2	
		P489	As Cast	151.0	170.0	7	10.5		
		300	1450F-2HR-WQ+1000F-1HR-AC	152	178.8	3	10.9		363
		"	" " " " 2HR "	153	176.8	4	10.0		363
		"	" " " " 4HR "	151	173.6	3	5.3		363
		P300	As Cast	133	152	10	21.0	221	
		P489	As Cast	151	170	7	10.5	231	
		P300	1500F-2HR-WQ-1000F-1HR-AC	---	1[illegible]1	2	2.4		
		"	" " " " 2HR "	156	180	2	3.3		
		"	1500F " " " 4HR "	154	179	2	5.3		
		"	1450F " " " 1HR "	152	179	3	10.9		
60		P300	1450F-2HR-WQ-1000F-2HR-AC	153	177	4	10.9		
		"	" " " " 4HR "	151	174	3	5.3		
		"	1500F " " " 8HR "	154	176	3	3.3		
		P489	" " " " " "	173	17[illegible]	1	0.7	168	
		P300	1500F-2HR-WQ-1000F-1HR-AC	---	180.8	2	2.4		375
		"	" " " " 2HR "	156	160.0	2	3.3		363
		"	" " " " 4HR "	154	178.8	2	5.3		375
63	7Al-2Mo-	P350	As Cast	155	172	1	3.3	128	363
"	0.5W-0.5Ta	"	As Cast	155	152.4	1	1.6	128	
"	3Cr 2Cb 2Zr	"	As Cast	150	170.3	1	4	152	
"		"	1000F 2HR-AC	Not	169.6	2	4.9		363
"		"	" 4HR "	Taken	170	2	4.2		363
"		"	1200F-2HR-AC	"	16[illegible]	1	1.6		352
"		"	" 4HR "	"	[illegible]	1	2.4		363
64	4Al-[illegible]	P302 A	As Cast	124	141.2	11	22.4	213.2	290
"		B	As Cast	124	142	10	21.5	214	
"		C	As Cast	12[illegible]	[illegible]	10	23	213.4	
"		P302	1025F-4HR-AC	12[illegible]	140.4	10	16.9		293
"		"	" [illegible] "	[illegible]	[illegible]	[illegible]	16.5		293
"		"	" 16HR "	12[illegible]	14[illegible]	8	1[illegible]		293

TABLE J21 (Continued)

MECHANICAL PROPERTIES OF HEAT TREATED EXPERIMENTAL ALLOYS

Alloy No.	Alloy Type	Heat No.	Heat Treatment	Yield Strength KSI (0.2% Offset)	Ultimate Tensile Strength KSI	Elongation In 4D Per Cent	Reduct. In Area Per Cent	Notch Tensile KSI	Brinell Hardness Number
69	6Al-4V	434	As Cast	129	147.6	9	15.1	204	317
	1Cr-1Mo	"	As Cast	126	144.8	7	18.6		
		"	As Cast	128	145.0	8	17.0	204	
		None-A	As Cast	130	152.0	7	15.1		321
		B	As Cast	130	152.0	6	9.2		
		434	1550F-2HR-WQ+1000F-4HR-AC	144	159.2	2	6.7		341
		"	1550F-2HR-WQ+1000F-8HR-AC	144	158.8	2	6.7		341
		"	1550F-2HR-QW+1100F-2HP-AC	140	154.0	4	10.5		331
		"	1550F-2HR-QW+1100F-4HR-AC	141	154.4	4	7.0		352
		"	1500F-2HR-QW+1000F-4HR-AC	145	160.0	4	7.6		341
		"	1500F-2HR-WQ+1000F-8HR-AC	141	156.8	3	7.6		331
		"	1500F-2HR-WQ+1100F-2HR-AC	139	154.4	4	9.7		321
		"	1500F-2HR-WQ+1100F-4HR-AC	136	150.0	5	11.2		311
105	8Zr-4Al-	596	As Cast	154	171	4	5.3	216	352
	4Sn-1.5Fe-	"	1500F-2HR-AC	159	175	3	6.5		363
	1.5Cr-1.5V	"	1400F-2HR-AC	154	168	8	12.9		352
		"	1300F-2HR-AC	154	168	4	6.7		352
		"	1200F-2HR-AC	158	164	2	1.6		352
		"	1400F-2HR-AC+1000F-48HR-AC		142	0	0		
		"	1400F-2HR-AC+ 900F-48HR-AC		184	0.7			
		"	1400F-2HR-AC+ 800F-48HR-AC		136	1	1.6		401
		"	1400F-2HR-AC+ 700F-48HR-AC		101	0	0		401
		"	1400F-2HR-AC+ 600F-48HR-AC		170	4	8.6		352
106	8Zr-4Al-	597	As Cast	132	148	10	20.0		321
	4Sn-.5Fe-	"	1500F-2HR-WQ+1000F-2HR-AC	146	162	4	9.2		352
	.5Cr-.5V	"	1400F-2HR-WQ+1000F-2HR-AC	144	158	5	6.3		331
		"	1000F-2HR-AC	135	149	4	14.0		311
		"	1000F-48HR-AC	138	151	5	8.6		321
		"	900F-48HR-AC	138	152	8	18.9		341
		"	800F-48HR-AC	138	154	7	13.5		331
		"	700F-48HR-AC	136	152	8	17.5		311
		"	600F-48HR-AC	133	140	10	18.9		293
		"	As Cast	132	148	10	22.4	219	321
		"	As Cast	132	149	11	16.7		321
		"	1500F-2HR-WQ+1000-2HR-AC	146	162	4	9.2		352
		"	1400F-2HR-WQ+1000-2HR-AC	144	158	5	6.3		331
107	10Cr	606	As Cast		168	1	1.6	140	
		"	As Cast		172	1	3.3		
		"	1400F-2HR-WQ		150	1	0.7		331
		"	1400F-2HR-WQ+800F-1HR-AC		107	0	0		429
		"	1400F-2HR-WQ+800F-2HR-AC		176	0	0		429
		"	1400F-2HR-WQ+800F-4HR-AC		173	0	0		
108	8Zr-4Al-	607	As Cast	130	152	11	20.0	208	331
	4Sn-2V	"	900F-48HR-AC	140	157	9	16.7		331
		"	800F-48HR-AC	139	158	10	18.9		331
		"	700F-48HR-AC	138	159	9	19.1		331
		"	600F-48HR-AC	135	158	9	23.2		331
		"	1000F-48HR-AC	140	142	1	5.3		331
		"	1500F-2HR-WQ+1000-1HR-AC	145	161	7.5	12.9		352
		"	1500F-2HR-WQ+1000-2HR-AC	145	161	7	12.9		341
		"	1500F-2HR-WQ+1000-4HR-AC	144	160	8	15.1		352
		"	1500F-2HR-WQ+1000-8HR-AC	147	164	8	17.0		352
		"	1500F-2HR-WQ+ 900-1HR-AC	144	162	6	11.2		352
		"	1500F-2HR-WQ+ 900-2HR-AC	146	162	6	12.9		352
		"	1500F-2HR-WQ+ 900-4HR-AC	146	163	9	15.1		352
		"	1500F-2HR-WQ+ 900-8HR-AC	144	161	7	14.2		352

TABLE J22

HEAT ANALYSES

Per Cent

Heat No.	C	H	O	N	Fe	Al	V	Co	Cr	Cu	Mg	Mn	Ni	Pb	Si	Mo	Sn	BHN
P1	.004	.0033	.16	.016	.261	5.62	3.92	.002	.02	.005	.005	.004	.03	.002	.01	.015	.02	321
P2	.048	.003	.133	.017	.275	6.01	3.92	.002	.015	.005	.005	.03	.03	.002	.015	.015	.03	326
P3	.057	.0022	.175	.016	.268	5.98	3.99	.002	.03	.005	.005	.004	.04	.002	.10	.008	.004	321
P4	.025	.0021	.124	.017	.212	5.91	3.96	.002	.04	.005	.005	.01	.08	.002	.10	.10	.015	311
P5	.027	.003	.1466	.016	.147	5.98	4.13	.002	.10	.005	.005	.004	.08	.002	.10	.05	.01	305
P6	.031	.004	.1515	.016	.210	6.12	4.08	.002	.015	.005	.005	.008	.03	.002	.02	.015	.008	315
[illegible]	[illegible]	[illegible]	.1475	.019	.210	[illegible]	4.09	.002	.02	.02	.005	.004	.03	.002	.02	.02	.015	315
P8	No Analysis																	
P9	.031	.0044	.1755	.021	.220	6.07	4.09	.002	.015	.005	.005	.008	.015	.002	.01	.015	.01	316
P10	.070	.0094	.2275	.025	[illegible]	5.58	[illegible]	.002	.015	.005	.005	.004	.02	.002	.015	.02	.015	[illegible]
P11	.056	.0031	.215	.025	.270	5.82	3.98	.002	.01	.005	.005	.008	.015	.002	.01	.008	.008	315
P12	.030	.0031	.213	.024	.255	6.13	4.30	.002	.02	.005	.005	[illegible]	.03	.002	.02	.015	.01	341
P13	.036	.0026	.15	.018	.205	5.98	4.15	.002	.02	.005	.005	.004	.03	.002	.02	.015	.004	304
P14	.052	.0026	.19	.023	.215	5.85	4.15	.002	.02	.005	.005	.004	.03	.002	.02	.015	.008	341
P15	.022	.0037	.1475	.018	[illegible]	6.10	3.98	.002	.02	.01	.005	.004	.04	.002	.04	.02	.008	[illegible]
P16	.051	.0028	.2180	.022	.215	5.86	4.11	.002	.02	.005	.005	.004	.04	.002	.03	.02	.01	324
P17	.028	.0025	.305	.016	.180	6.16	4.05	.002	.02	.005	.005	.01	.04	.002	.02	.02	.003	302
P18	.042	.0032	.165	.021	.145	6.07	4.05	.002	.02	.005	.005	.008	.04	.002	.02	.03	.01	321
P19	.070	.0034	.1858	.020	.215	6.03	2.92	.002	.02	.005	.005	.002	.02	.002	.10	.02	.006	296
P20	.055	.0025	.135	.022	.195	[illegible]	3.88	.002	.02	.006	.005	.002	.02	.002	.10	.015	.004	314
P21	.050	.0036	.186	.019	.180	5.81	3.94	.002	.10	.005	.005	.015	.08	.002	.10	.015	.01	
P22	See p24 - P22 Mistun																	
P23	.042	.0043	.2698	.022	.210	5.55	3.75	.002	.02	.015	.005	.002	.03	.002	.10	.03	.004	308
P24	.030	.0024	.162	.020	.135	3.65	.02	.002	.01	.005	.005	4.18	.005	.002	.02	.002	.01	311
4Al-4Mn																		
P25	.077	.004	.22	.023	.320	5.60	3.94	.002	.02	.025	.005	.01	.03	.002	.10	.02	.004	
(P26	.067	.0024	.23	.014	.170	4.53	.50	.002	.01	.005	.005	.008	.005	.002	.01	.002	2.35	308
(5Al-2½Sn																		
P27	.054	.0027	.2575	.154	.235	5.70	3.60	.002	.02	.008	.005	.004	.03	.002	.03	.002	.01	318
P28	.060	.0023	.245	.022	.225	5.67	3.73	.002	.015	.005	.005	.01	.03	.002	.015	.015	.008	
P29	.066	.0036	.2275	.023	[illegible]	5.92	3.76	.0005	.015	.005	.005	.008	.03	.002	.02	.015	.01	321
P30	.073	.0026	.2425	.027	.240	6.04	3.92	.0005	.02	.008	.005	.008	.03	.002	.02	.015	.008	334
P31	.051	.0021	.18	.023	.300	6.11	3.92	.0005	.02	.005	.005	.008	.02	.002	.02	.015	.015	318
(P32	.075	.003	.355	.025	.240	5.93	3.86	.0005	.02	.01	.005	.008	.03	.002	.025	.015	.01	341
(5Al-2½Sn																		
P33	.070	.0032	.256	.015	.175	[illegible]	.015	.002	.03	.005	.005	.004	.005	.002	.10	.005	2.34	314
P34	.030	.0026	.1975	[illegible]	.080	5.97	3.88	.002	.02	.01	.005	.006	.02	.001	.02	.015	.015	315
P35	.053	.0022	.165	.027	.260	6.03	3.97	.002	.015	.005	.005	.015	.015	.002	.015	.015	.03	321
P36	.082	.0041	.2125	.027	.245	6.02	3.87	.002	.02	.005	.005	.004	.03	.002	.10	.02	.01	331
P37	.079	.0033	.2625	.026	.320	5.73	3.76	.002	.02	.005	.005	.004	.02	.002	.10	.015	.006	334
(13V-11Cr-2½Al																		
(P38	.020	.0046	.1438	.017	.226	2.62	12.9	.002	11.3	.005	.005	.002	.04	.002	.04	.03	.002	277
P39	.098	.0025	.2463	.029	.370	6.01	3.52	.002	.02	.005	.005	.004	.02	.002	.10	.015	.008	
P40	.092	.0042	.2512	.027	.420	5.90	4.02	.002	.10	.005	.005	.006	.02	.002	.08	.015	.01	334
P41	.096	.0032	.226	.026	[illegible]	[illegible]	[illegible]	.002	[illegible]	.005	.005	.004	.015	.002	.10	.02	.01	316
P42	[illegible]	.0034	.16	.021	.110	[illegible]	[illegible]	.002	[illegible]	.006	.005	.01	.01	.002	.10	.015	.015	299
P43	.060	.0030	.229	.026	[illegible]	[illegible]	[illegible]	.002	.02	.005	.005	[illegible]	.006	.002	[illegible]	.005	.006	331
(P44	.030	.0056	.143	.020	[illegible]	2.71	12.7	.002	[illegible]	.004	.005	.002	.015	.002	.02	.025	.004	262
(13V-11Cr-2½Al																		
P45	[illegible]	.0039	.179	[illegible]	.30	[illegible]	[illegible]	.002	.1	.50	.005	.002	.02	.002	.1	.012	.013	334
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.02	.02	.004	[illegible]
[illegible]																		
[illegible]	.067	.0037	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.015	[illegible]
[illegible]	[illegible]	.0026	.185	.021	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	.0026	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE J22 (Continued)

HEAT ANALYSES

Heat No.	C	H	O	N	Fe	Al	V	Co	Cr	Cu	Mg	Mn	Ni	Pb	Si	Mo	Sn	BHN
(13V-11Cr-4Al																		
(P52	.024	.0063	.153	.018	.21	4.05	13.5	.015	10.1	.005	.005	.003	.015	.002	.02	.02	.002	291
P53	.075	.0025	.185	.028	.34	6.03	3.93	.002	1	.005	.005	.004	.02	.002	.1	.01	.01	324
P54	.080	.0029	.	.031	.32	6.07	3.92											324
(P55	.028	.0049	.153	.022	.19	1.58	3.0	.002	10.[illegible]	.005	.005	.002	.02	.002	.015	.01	.002	283
(13V-11Cr-1½Al																		
P56	.048	.0026		.028	.[illegible]	[illegible]	3.98											321
P57	.056	.0024	.20	.024	.29	6.05	4.01	.005	.1	.005	.005	.01	.015	002	.1	.001	.012	321
P58	.081	.0032	.193	.032	.40	6.05	3.97	.002	.1	.005	.005	.01	.01	.002	.02	.01	.01	
P59	.027	.0017	.185	.017	.20	.01	.005	.002	.015	.005	.005	.002	.005	.002	.01	.002	.003	
(P60	.029	0025	.175	.014	21	01	005	.002	02	.005	005	.002	.005	.002	.01	.002	.003	
(C.P. Ti																		
(P61	.032	.0044	.158	.027	.20	1.65	13.5	.002	10.7	.005	.005	.002	.025	.002	.03	.015	.002	280
(13V-11Cr-1½Al																		
(P62	.028	.0045	.146	.027	.20		12.9	.002	10.3	.005	.005	.002	.04	.002	.02	.002	.002	260
(13V-11Cr																		
Ti6Al-4V																		
P63	.070	.0025	.18	.030	.29	5.87	4.83	.002	.1	.02	.005	.003	.01	.002	.08	.008	.015	321
Ti7Al-3Mo																		
P64	.020	.0032	.131	.0083	.12	7.32	.005	.002	.025	.005	.005	.002	.005	.002	.02	3.33	.002	308
Ti5½Al-5½V-.45Fe-2Sn-.25Cu																		
P65	.019	.0023	.10	.010	.59	5.62	5.46	.002	.02	.22	.005	.002	.01	.002	.03	.015	1.97	311
Ti13V-11Cr																		
P66	.023	.0013	.19	.028	.20	.01	12.9	.002	9.5	.005	.005	.002	.03	.002	.01	.002	.003	288
Ti6Al-4V																		
P67	.038	.0036	.16	.032	.32	6.08	3.93	.002	.1	.02	.005	.015	.02	.002	.015	.015	.02	
Ti7Al-3Mo																		
P68	.024	.0033	.10	.010	.13	7.45	.1	.002	.025	.005	.005	.002	.005	.002	.03	3.07	.002	315
Ti5½Al-5½V-.45Fe-2Sn-.25Cu																		
P69	.023	.0028	.12	.011	.59	5.59	5.41	.002	.02	.22	.005	.003	.01	.002	.02	.015	1.99	324
Ti6Al-4V																		
P70	.060	.0034	.14	.033	.30	5.99	4.32	.002	.1	.005	.005	.015	.02	.002	.015	.015	.02	337
P71	.082	.0033	.19	.033	.32	5.98	4.13	.002	.1	.005	.005	.01	.015	.002	.02	.015	.02	337
P72	.084	.0033	.13	.032	.28	6.14	4.07	002	.1	.005	.005	.01	.015	.002	.02	.015	.03	
P73	.094	.0033	.19	.036	.31	5.97	4.27	.002	.[illegible]	.005	.005	.05	.015	.002	.02	.015	.03	392
P74	.072	.0026	.17	.031	.28	6.28	4.19	.002	.1	.005	.005	.004	.015	.002	.05	.02	.02	
P75	.054	.0029	.17	.027	.19	6.14	3.95	.002	.1	.005	.005	.008	.02	.002	.025	01	.01	
P76	[illegible]	.0033	.19	.032	[illegible]	[illegible]	[illegible]	.002	.1	.005	.005	.01	.015	.002	.025	.02	.04	
P77	.079	.0029	.17	.030	.24	6.16	4.15	.002	.1	.01	.005	.008	.015	.002	.05	.02	.03	
P78	.072	.0020	.16	.032	.21	6.17	4.45	.002	.1	.1	.005	.004	.015	.002	.02	.02	.02	
P79	076	0032	20	032	[illegible]	6.34	4.17	.002	.1	.01	.005	.004	.02	.002	.1	.02	.03	
P80	.071	.0033	.23	.03[illegible]	.25	6.35	4.12	.002	.0[illegible]	.005	.005	004	.005	002	[illegible]	[illegible]	02	
P81	.105	.0026	.21	.034	.24	6.17	4.17	.002	.1	.01	.005	.004	.015	.002	.02	02	.03	
P82	.090	.0029	.19	.032	.18	6.31	4.15	.002	.1	.01	.005	.008	.015	.002	.02	03	.03	
(P83	.100	.0024	.23	.032	.27	6.24	4.15	.002	.1	.01	.005	.005	.015	.002	.02	.02	.02	
P84	.094	.0026	.24	.033	.26	6.02	3.97	.002	.1	.005	.005	.01	.01	.002	.015	.02	.02	
P85	.094	.0036	.25	.037	.28	6.09	3.90	.002	.1	.005	.005	.01	.02	.002	1	.015	.03	
P86	.092	.0026	.22	.037	.26	5.65	3.66	.002	.1	.005	.005	.01	.01	.002	.02	.02	.02	
P87	.109	.0044	.22	.031	.23	6.05	3.76	.002	.04	.01	.005	.01	.015	.002	.02	.02	.03	
P88	.091	.0026	.22	.034	.27	6.2[illegible]	[illegible]	.002	.1	.005	.005	.005	.015	.002	.02	.02	.02	
P89	.076	0033	.21	.030	[illegible]	[illegible]	[illegible]	.002	.02	[illegible]	[illegible]	[illegible]	.01	.02	[illegible]	.015	.03	
P90	.104	.0038	.22	.035	[illegible]	[illegible]	3.6[illegible]	.002	.01	.01	005	.004	.01	.002	.015	.015	.03	

TABLE J22 (Continued)

HEAT ANALYSES

Heat No.	C	H	O	N	Fe	Al	V	Co	Cr	Cu	Mg	Mn	Ni	Pb	Si	Mo	Sn	BHN
P91	No Analysis																	
P92	.094	.0041	.24	.037	.27	6.19	3.96	.002	.1	.005	.005	.002	.005	.002	.015	.004	.02	
P93	.002	.0039	.26	.037	.24	6.18	3.82	.002	.1	.005	.005	.002	.005	.002	.015	.005	.02	
P94	.041	.0031	.15	.021	.28	5.94	4.06	.002	.1	.01	.005	.003	.03	.002	.025	.015	.01	
P95	.038	.0033	.14	.017	.24	6.74	3.83	.002	.04	.015	.005	.003	.04	.002	.02	.02	.01	
P96	.066	.0026	.16	.019	.26	6.24	3.99	.002	.08	.005	.005	.003	.03	.002	.015	.015	.015	334
P97	.058	.0030	.14	.018	.25	6.06	3.92	.002	.03	.01	.005	.003	.02	.002	.015	.015	.01	
P98	.094	.0035	.26	.039	.27	6.07	4.03	.002	.1	.005	.005	.003	.015	.002	.015	.01	.015	355
P99	.088	.0017	.28	.037	.25	5.95	3.80	.002	.1	.04	.005	.004	.015	.002	.02	.015	.02	
P100	.093	.0089	.26	.034	.23	5.94	4.03	.002	.1	.01	.005	.004	.02	.002	.025	.015	.03	348
P101	.041	.0036	.14	.019	.25	5.96	3.97	.002	.06	.01	.005	.003	.03	.002	.025	.015	.015	
P102	.094	.0036	.20	.022	.25	5.96	3.87	.002	.1	.01	.005	.003	.03	.002	.03	.015	.015	345
P103	.035	.0031	.24	.015	.25	5.95	4.06	.002	.05	.02	.005	.003	.04	.002	.03	.02	.01	
P104	.072	.0031	.20	.028	.26	6.00	3.97	.002	.1	.01	.005	.01	.03	.002	.02	.015	.02	348
P105	.086	.0031	.23	.032	.26	5.90	3.99	.002	.1	.01	.005	.004	.02	.002	.015	.02	.03	
P106	.049	.0028	.16	.022	.25	5.98	4.02	.002	.1	.01	.005	.003	.03	.002	.05	.02	.01	311
P107	.092	.0039	.21	.031	.26	5.88	3.97	.002	.1	.01	.005	.01	.03	.002	.02	.02	.02	337
P108	.094	.0030	.21	.030	.27	5.69	3.85	.002	.1	.01	.005	.003	.015	.002	.02	.015	.015	337
P109	.108	.0033	.19	.032	.27	5.97	3.98	.002	.1	.01	.005	.004	.03	.002	.002	.02	.03	
P110	.048	.0031	.14	.016	.24	6.03	3.82	.002	.03	.08	.005	.004	.004	.002	.02	.03	.01	
P111	.094	.0040	.22	.028	.27	5.96	3.96	.002	.05	.03	.005	.003	.02	.002	.015	.015	.015	
P112	.070	.0034	.22	.026	.26	6.05	3.90	.002	.1	.01	.005	.003	.03	.002	.02	.02	.015	
P113	.080	.0037	.18	.030	.26	5.99	3.95	.002	.1	.01	.005	.003	.03	.002	.02	.02	.02	
P114	.080	.0028	.15	.026	.27	5.85	3.83	.002	.1	.01	.005	.003	.02	.002	.03	.02	.015	
P115	.042	.0026	.19	.025	.23	5.95	4.02	.002	.015	.015	.005	.002	.01	.002	.02	.015	.02	317
P116	.060	.0031	.21	.028	.20	5.92	3.95	.002	.015	.01	.005	.003	.02	.002	.025	.03	.03	
P117	.096	.0029	.23	.033	.26	5.88	3.76	.002	.1	.01	.005	.003	.02	.002	.02	.005	.015	
P118	.098	.0038	.26	.032	.28	5.99	3.99	.002	.1	.005	.005	.003	.04	.002	.1	.015	.005	
P119	.062	.0022	.11	.028	.27	5.90	3.78	.002	.08	.01	.005	.002	.03	.002	.02	.02	.008	334
P120	.058	.0026	.15	.022	.18	5.94	4.03	.002	.1	.008	.005	.002	.04	.002	.1	.015	.015	
P121	.100	.0036	.28	.035	.29	5.96	3.96	.002	.1	.002	.005	.002	.04	.002	.1	.015	.015	
P123	.068	.0031	.20	.029	.26	6.02	3.99	.002	.05	.005	.005	.002	.04	.002	.1	.015	.005	
P124	.048	.0029	.18	.025	.19	6.05	4.04	.002	.02	.008	.005	.002	.05	.002	.1	.015	.015	
P125	.076	.0036	.21	.032	.28	5.97	3.98	.002	.1	.01	.005	.003	.04	.002	.1	.03	.015	
P126	.078	.0036	.20	.038	.25	5.83	3.84	.002	.03	.015	.005	.002	.03	.002	.03	.02	.015	
P127	.058	.0032	.22	.030	.21	5.94	3.89	.002	.1	.04	.005	.003	.04	.002	.1	.03	.015	
P128	.074	.0038	.28	.031	.25	5.94	3.88	.002	.03	.1	.005	.002	.03	.002	.03	.02	.015	
P129	.065	.0027	.19	.035	.22	5.53	3.92	.002	.03	.04	.005	.003	.03	.005	.03	.02	.008	334
P131	.026	.0018	.15	.024	.21	6.03	3.90	.002	.015	.01	.005	.003	.015	.002	.02	.015	.002	317
P132	.059	.0028	.212	.032	.21	6.05	4.05	.002	.04	.01	.005	.003	.03	.002	.025	.02	.01	331
P133	.044	.0029	.23	.036	.19	5.82	4.09	.002	.025	.01	.005	.002	.02	.002	.03	.02	.01	
P134	.066	.0034	.226	.034	.23	6.05	4.03	.002	.03	.005	.005	.002	.01	.002	.02	.03	.01	
P135	.053	.0034	.31	.029	.18	6.00	3.84	.002	.07	.008	.005	.003	.015	.002	.02	.02	.008	321
P136	No Pour - Electrode Broke																	
P137	.030	.0035	.174	.016	.12	6.10	3.94	.002	.015	.005	.005	.003	.01	002	.02	.02	.002	311
P138	No Pour - Electrode Broke																	
(Ti8V-5Fe																		
(P139	.022	.0031	.101		5.59	.01	8.03	.002	.015	.01	.005	.002	.03	.002	.015	.002	.003	
(Ti8V-5Fe-1Al																		
(P140	.030	.0024	.096	.014	5.4	.79	6.15	.002	.02	.005	.005	.002	.03	.002	.015	.095	.002	
P141	.042	.0024	.152	.028	.29	5.85	4.05	.002	.03	.01	.005	.003	.03	.002	.08	.006	.004	
P142	.100	.0036	.196	.035	.23	6.45	4.09	.002	.04	.008	.005	.002	.02	.002	.02	.02	.01	341
P143	.026	.003	.25	.029	.23	5.96	3.96	.002	.01	.1	.005	.002	.03	.02	.02	.02	.03	330
(Ti3Al-2½V																		
(P144								.002	.01	.005	.005	.002	.005	.002	.02	.02	.02	255
P145	.065	.0040	[illegible]	.031	.28	5.90	3.93	.002	.1	.005	.005	.002	.015	.002	.03	.02	.015	341
([illegible]																		
(P146	.032	.0022	.061	.016	.058	.01	14.[illegible]	.002	.015	.005	.005	.002	.015	.002	.015	.007	.007	293

TABLE J22 (Continued)

HEAT ANALYSES

Heat No.	C	H	O	N	Fe	Al	V	[illegible]	Cr	Cu	Mg	Mn	Ni	Pb	Si	Mo	Sn	BHN
(Ti6Al-3Mo-1V																		
(P147	.032	.0027	.08	.002	.09	5.93	.98	.002	.1	.005	.005	.002	.005	.002	.02	3.00	.002	248
(Ti7Al-4Mo																		
(P148	.022	.0023	.072	.0055	.068	6.96	.01	.002	.015	.005	.005	.002	.005	.002	.02	4.10	.002	31[illegible]
P153	.23	.0033	.16	.015	.15	6.12	3.95	.002	.015	.008	.005	.002	.015	.002	.02	.04	.003	300
P154	.087	.0025	.28	.033	.19	5.85	4.11	.002	.02	.01	.005	.003	.015	.002	.02	.02	.008	309
P155	.021	.0032	.16	.017	.14	6.05	4.09	.002	.02	.008	.005	.003	.02	.002	.025	.04	.002	308
P156	.057	.0034	.31	.046	.20	5.90	4.09	.002	.025	.005	.005	.002	.015	.002	.02	.04	.003	324
P157	.056	.0031	.22	.035	.19	5.80	3.99	.002	.04	.008	.005	.002	.03	.002	.01	.01	.004	317
P158	.041	.0028	.23	.024	.16	6.00	4.09	.002	.02	.02	.002	.003	.015	.005	.02	.02	.008	317
P159	.050	.0036	.29	.025	.17	6.00	3.55	.002	.02	.02	.002	.003	.015	.005	.02	.02	.008	311
P160	.037	.0028	.21	.020	.12	5.90	4.00	.002	.01	.005	.005	.002	.005	.002	.02	.01	.42	
P161	.022	.0035	.16	.017	.14	6.00	3.96	.002	.015	.02	.005	.003	.02	.002	.03	.02	.05	306
P162	.089	.0028	.21	.040	.21	6.00	4.11	.002	.1	.008	.005	.003	.03	.002	.05	.05	.01	331
P163	.034	.0036	.14	.016	.13	5.95	3.99	.002	.015	.055	.055	.002	.005	.002	.1	.002	.015	306
P167	.015	.0045	.13	.016	.12	5.96	2.44	.002	.015	.005	.005	.003	.01	.002	.02	.015	.83	297
P168	.032	.0039	.19	.021	.14	6.05	4.04	.003	.015	.005	.005	.002	.01	.002	.02	.02	.03	311
P169	.041	.0031	.19	.019	.15	6.05	4.09	.002	.015	.005	.005	.002	.01	.002	.02	.01	.008	316
P170	No Pour - Electrode Broke																	
P171	.050	.0044	.19	.029	.17	5.95	4.00	.002	.02	.005	.005	.002	.01	.002	.02	.01	.05	331
P172	.060	.0046	.20	.029	.17	5.90	4.07	.002	.02	.005	.005	.003	.015	.002	.015	.015	.04	331
P173	.064	.0042	.29	.030	.23	5.90	4.08	.002	.025	.05	.005	.002	.02	.002	.02	.03	.02	311
P174	.093	.0041	.19	.032	.17	5.07	4.05	.002	.02	.015	.005	.002	.015	.002	.02	.015	.015	331
P175	.061	.0049	.21	.029	.17	5.87	4.07	.002	.02	.01	.005	.004	.03	.002	.02	.015	.008	326
P176	.060	.0049	.24	.030	.16	5.90	3.94	.002	.015	.005	.005	.002	.005	.002	.015	.03	.015	311
P177	.053	.0039	.25	.025	.15	6.10	4.03	.002	.015	.005	.005	.002	.009	.002	.02	.02	.04	331
P178	.074	.0041	.24	.034	.17	5.95	4.08	.002	.02	.005	.005	.002	.01	.002	.015	.02	.04	321
P179	.070	.0033	.29	.028	.16	5.95	3.93	.02	.02	.008	.005	.002	.015	.002	.02	.02	.04	336
P184	.049	.0039	.22	.027	.17	5.97	3.98	.002	.02	.005	.005	.002	.02	.002	.02	.03	.04	336
P185	.044	.0040	.29	.041	.17	6.05	3.98	.002	.02	.005	.005	.002	.015	.002	.02	.03	.04	341
P186	.044	.0045	.24	.021	.13	5.85	2.23	.002	.01	.005	.005	.002	.005	.002	.025	.01	.68	
P187	.036	.0038	.21	.026	.15	5.97	3.83	.002	.015	.005	.005	.002	.015	.002	.02	.02	.08	
P188	.030	.0041	.14	.019	.13	6.05	3.93	.002	.015	.005	.005	.004	.01	.002	.02	.05	.02	293
P191	.033	.0042	.29	.020	.14	5.18	3.14	.002	.01	.005	.005	.002	.005	.002	.015	.01	.004	
P194	.020	.0046	.24	.018	.13	6.05	4.00	.002	.01	.005	.005	.002	.005	.002	.02	.01	.002	
P195	.063	.0048	.30	.034	.16	5.75	3.83	.002	.015	.005	.005	.002	.01	.002	.02	.015	.03	336
P196	.024	.0059	.17	.017	.13	5.93	2.33	.002	.015	.005	.005	.002	.005	.002	.02	.005	.68	311
P197	.033	.0041	.14	.013	.13	5.90	3.30	.002	.01	.005	.005	.003	.005	.002	.015	.01	.1	285
P198	.013	.0042	.15	.022	.13	6.00	3.89	.002	.015	.005	.005	.003	.005	.002	.02	.02	.06	321
P199	.049	.0049	.15	.021	.13	5.87	3.97	.002	.01	.015	.005	.003	.01	.002	.02	.02	.01	
P200	.035	.0042	.25	.032	.16	5.95	3.92	.002	.02	.008	.005	.002	.015	.002	.02	.015	.05	336
P201	.049	.0041	.18	.018	.14	6.07	4.00	.002	.015	.008	.005	.002	.015	.002	.02	.02	.02	
P206	.035	.0042	.13	.015	.13	6.10	4.09	.004	.02	.01	.005	.002	.015	.002	.1	.01	.006	
P207	.025	.0052	.15	[illegible]	.14	5.82	3.40	.002	.015	.005	.005	.003	.005	.002	.02	.03	.1	306
P208	.029	.0039	.11	[illegible]	.15	6.05	4.10	.002	.015	.005	.005	.002	.005	.002	.02	.04	.01	311
P209	.045	.0032	.22	.028	.15	5.70	3.65	.002	.02	.02	.005	.003	.04	.002	.02	.03	.05	
P210	.064	.0029	.21	.029	.15	5.87	3.84	.002	.015	.005	.005	.002	.015	.002	.02	.02	.08	311
P211	.036	.0035	.13	.021	.14	5.90	3.92	.002	.02	.05	.005	.002	.015	.002	.03	.02	.015	305
P212	.042	.0033	.20	.031	.15	5.70	3.65	.002	[illegible]	[illegible]	.005	.002	.015	.002	.02	.03	.38	331
P213	.037	.0046	.17	.024	.15	5.82	3.90	.002	.015	.005	.005	.003	.01	.002	.025	.04	.05	326
P214	.035	.0029	.14	.020	.17	5.95	4.05	.002	.015	.015	.005	.003	.02	.002	.025	.02	.02	311
P215	.046	.0040	.15	.014	.13	6.05	4.03	.002	.015	.005	.005	.004	.095	.002	.015	.03	.02	311
P216	.051	.0034	.19	.045	.21	5.80	3.79	.002	.02	.03	.005	.002	.015	.002	.025	.02	.1	306
P217	.041	.0033	.21	.023	.16	6.00	4.09	.002	.015	.005	.005	.002	.01	.002	.02	.02	.05	296

TABLE J22 (Continued)

HEAT ANALYSES

Heat No.	C	H	O	N	Fe	Al	V	Co	Cr	Cu	Mg	Mn	Ni	Pb	Si	Mo	Sn	BHN
P218	.043	.0048	.22	.029	.16	5.67	3.93	.002	.015	.005	.005	.003	.015	.002	.05	.015	.06	314
P219	No Pour - Contaminated Scrap																	
P220	.032	.0051	.18	.020	.18	6.00	3.96	.002	.01	.02	.005	.002	.015	.002	.02	.02	.02	305
P221	.024	.0051	.14	.014	.14	5.82	4.08	.002	.01	.005	.005	.003	.02	.002	.03	.015	.005	299
P224	.055	.0012	.18	.025	.17	6.03	3.98	.002	.015	.02	.005	.002	.005	.002	.02	.01	.03	308
P225	.048	.0030	.16	.032	.19	6.00	3.90	.002	.02	.005	.005	.004	.015	.002	.02	.04	.08	311
P227	.048	.0036	.14	.024	.16	6.05	4.09	.002	.02	.02	.005	.002	.015	.002	.075	.02	.05	317
P228	No Pour - Electrode Broke																	
P229	.042	.0033	.20	.026	.16	5.97	3.92	.002	.02	.005	.005	.002	.005	.002	.015	.008	.03	317
P231	.040	.0043	.15	.030	.15	6.00	3.96	.002	.015	.005	.005	.004	.015	.002	.02	.03	.05	306
P232	.030	.0037	.12	.021	.14	6.05	3.98	.002	.015	.005	.005	.004	.015	.002	.02	.04	.06	311
P235	.063	.0031	.15	.024	.18	5.90	3.90	.002	.015	.015	.005	.002	.01	.002	.02	.03	.08	316
P237	No Pour - Electrode Broke																	
P238	.052	.0037	.26	.026	.22	5.80	3.96	.002	.015	.005	.005	.002	.02	.002	.02	.02	.06	324
P239	.035	.0035	.13	.019	.16	6.00	4.05	.002	.015	.005	.005	.002	.015	.002	.02	.02	.03	308
P240	.050	.0039	.21	.026	.16	5.90	3.34	.002	.015	.005	.005	.002	.01	.002	.02	.02	.03	308
P241	.041	.0049	.18	.021	.14	6.02	4.09	.002	.02	.005	.055	.002	.015	.002	.015	.02	.006	299
P242	.027	.0041	.18	.071	.14	6.03	4.00	.002	.015	.015	.005	.003	.01	.002	.02	.02	.05	296
P243	.019	.0037	.10	.013	.17	6.05	4.10	.002	.01	.005	.005	.002	.01	.002	.02	.015	.002	311
P244	.030	.0040	.14	.018	.16	6.05	4.07	.002	.01	.005	.005	.003	.03	.002	.025	.025	.015	299
P245	.028	.0014	.073	.0059	.12	5.75	4.09	.02	.02	.005	.005	.002	.03	.002	.02	.02	.008	269
P246	.022	.0031	.15	.018	.15	5.95	4.11	.002	.01	.005	.005	.0002	.01	.002	.08	.015	.015	311
P247	.040	.0031	.21	.022	.18	5.90	3.96	.002	.015	.02	.005	.002	.01	.002	.025	.02	.05	305
P248	.032	.0033	.19	.022	.15	6.02	2.98	.002	.015	.005	.005	.002	.01	.002	.02	.02	.03	308
P249	.032	.0014	.068	.0064	.13	5.70	4.09	.002	.02	.02	.005	.002	.02	.002	.02	.005	.005	274
P250	.031	.0035	.18	.024	.15	5.95	3.94	.002	.015	.005	.005	.002	.015	.002	.1	.02	.05	293
P251	.022	.0040	.11	.016	.15	6.17	4.13	.002	.01	.1	.005	.002	.015	.002	.03	.02	.002	299
P252	.035	.0016	.07	.0072	.13	5.77	4.09	.002	.02	.05	.005	.002	.01	.002	.015	.015	.004	277
P253	.040	.0038	.16	.027	.16	5.95	4.05	.004	.02	.02	.005	.003	.01	.002	.02	.02	.015	311
P254	.035	.0031	.14	.019	.14	5.95	3.90	.002	.01	.005	.005	.002	.01	.002	.015	.015	.03	
P255	.046	.0019	.07	.0073	.12	5.82	4.09	.002	.02	.008	.005	.002	.01	.002	.02	.015	.004	277
P256	.033	.0051	.20	.021	.15	6.05	3.97	.002	.01	.005	.005	.002	.005	.002	.02	.008	.03	306
P257	.050	.0032	.19	.026	.18	5.92	3.97	.002	.015	.005	.005	.002	.008	.002	.015	.008	.02	
P258	.024	.0032	.12	.016	.15	6.10	3.98	.002	.01	.005	.005	.003	.015	.002	.03	.02	.01	
P259	.049	.0020	.087	.0092	.13	5.80	4.02	.002	.02	.005	.005	.002	.02	.002	.02	.02	.008	279
P260	.045	.0050	.16	.023	.17	5.95	4.00	.002	.01	.005	.005	.002	.015	.002	.02	.02	.04	296
P261	.040	.0037	.07	.028	.15	5.92	3.90	.002	.015	.02	.005	.003	.01	.002	.015	.02	.015	311
P262	.030	.0033	.15	.021	.16	5.95	4.07	.002	.015	.005	.005	.002	.015	.002	.025	.02	.01	
P263	.051	.0029	.17	.024	.17	5.87	3.92	.002	.015	.005	.005	.002	.01	.002	.08	.01	.01	308
P264	.054	.0033	.22	.026	.18	6.00	4.17	.002	.1	.01	.005	.003	.01	.002	.015	.015	.015	326
P265	.037	.0033	.19	.025	.16	6.03	4.00	.002	.015	.008	.005	.002	.008	.002	.02	.01	.04	311
P266	.033	.0022	.15	.021	.14	6.10	4.03	.002	.01	.005	.005	.002	.005	.002	.02	.01	.015	
P267	.024	.0013	.066	.0072	.12	5.85	4.08	.002	.01	.005	.005	.003	.01	.002	.015	.02	.008	271
P268	.037	.0031	.16	.025	.16	6.03	4.00	.002	.01	.005	.005	.002	.005	.002	.02	.01	.04	311
P269	.042	.0026	.17	.026	.14	[illegible]	4.03	.002	.01	.005	.005	.002	.005	.002	.02	.02	.015	327
P270	.027	.0033	.15	.023	.16	5.95	[illegible]	.002	.015	.005	.005	.002	.005	.002	.02	.02	.02	
P271	.027	.0017	.075	.0086	.12	5.95	4.07	.002	.02	.005	.005	.002	.01	.002	.02	.015	.002	279
P272	[illegible]	[illegible]	[illegible]	.025	[illegible]	6.05	3.98	.002	.01	.005	.005	.002	.008	.002	.015	.008	.02	344
P273	.047	.0035	.17	.024	.16	6.03	4.03	.002	.015	.005	.005	.002	.005	.002	.02	.015	.02	316
P274	.042	.0033	.20	.022	.17	6.03	4.09	.002	.01	.005	.005	.002	.005	.002	.015	.005	.015	311
P275					[illegible]	[illegible]	4.00	.002	.01	.005	.005	.002	.01	.002	.02	[illegible]	.03	311
P276	.057	.0023	.20	.025	.16	5.97	3.97	.002	.015	.005	.005	.002	.005	.002	.02	.008	.03	326
P277	.044	.0026	.22	.029	.16	5.72	[illegible]	.002	.015	[illegible]	.005	.002	.01	.002	.02	.02	.05	[illegible]
P278	[illegible]	.0035	.20	.026	.20	5.35	4.11	.002	.01	.005	.005	.002	.02	.002	.02	.02	.02	326
P279	.037	.0035	.18	.025	.16	5.97	[illegible]	.002	.015	.005	.005	.002	.008	.002	[illegible]	.015	.03	311

TABLE J22 (Continued)

HEAT ANALYSES

Heat No.	C	H	O	N	Fe	Al	V	Co	Cr	Cu	Mg	Mn	Ni	Pb	Si	Mo	Sn	BHN
P280	.037	.0022	.096	.010	.12	5.80	4.03	.002	.02	.005	.005	.002	.02	.002	.02	.01	.004	282
P281	.044	.0045	.18	.026	.17	6.00	4.00	.002	.015	.04	.005	.002	.008	.002	.015	.02	.03	316
P282	.048	.0025	.20	.012	.12	5.87	4.09	.002	.015	.005	.005	.002	.008	.002	.02	.008	.002	282
P283	.042	.0024	.20	.025	.16	5.97	4.03	.002	.01	.005	.005	.002	.005	.002	.02	.003	.015	336
P284	.044	.0038	.13	.023	.14	5.95	3.98	.002	.02	.005	.005	.002	.1	.002	.1	.005	.005	308
P285A	.034	.0036	.12	.014	.15	6.03	4.09	.002	.01	.008	.005	.002	.008	.002	.015	015	.004	296
P285B	.013	.0047	.17	.015	.16	6.03	4.14	.002	.015	.005	.005	.002	.01	.002	.08	.005	.005	299
P286	.031	.0029	.17	.023	.14	6.05	4.07	.002	.015	.005	.005	.002	.005	.002	.02	.015	.015	308
P288	.050	.0036	.20	.027	.16	5.70	3.57	.002	.025	.005	.005	.002	.005	.002	.015	.005	.015	321
P289	.043	.0018	.11	.0053	.14	5.80	4.05	.002	.015	.005	.005	.002	.008	.002	.02	.008	.02	277
P290	.060	.0056	.20	.030	.16	5.75	3.92	.002	.015	.005	.005	.003	.01	.002	.02	.01	.06	317
P291	.033	.0032	.19	.022	.15	5.85	4.07	.002	.015	.005	.005	.002	.005	.002	.02	.015	.02	311
P292	.048	.0042	.20	.024	.16	5.94	3.98	.002	.015	.005	.005	.002	.008	.002	.02	.008	.015	321
P293	.048	.0030	.21	.025	.15	5.57	4.03	.002	.02	.005	.005	.002	.008	.002	.015	.005	.003	316
P294	.041	.0036	.19	.024	.17	6.00	3.93	.002	.015	.005	.005	.002	.008	.002	.015	.005	.02	321
P296	.051	.0036	.22	.026	.17	5.90	4.07	.002	.02	.005	.005	.002	.005	.002	.015	.02	.015	
P303	.052	.0019	.082	.015	.15	5.77	4.10	.002	.02	.005	.005	.002	.008	.002	.015	.01	.003	279
P304	.049	.0036	.23	.015	.17	5.30	4.03	.002	.015	.005	.005	.002	.005	002	.02	.01	.015	321
P305	.050	.0031	.22	.029	.17	5.75	3.87	.002	.02	005	.005	.002	.005	.002	.03	.01	.02	324
P306	.047	.0029	.21	.025	.16	5.35	4.05	.002	.02	.005	.005	.002	.005	.002	.03	.01	.015	308
P307	.048	.0045	.22	.026	.16	5.87	4.00	.002	.02	.005	.005	.003	.015	.002	.025	.015	.08	305
P308	.044	.0038	.19	.026	.16	5.80	4.07	.002	.02	.005	.005	.002	.008	.002	.02	.015	.03	317
P309	.063	.0033	.22	.027	.16	5.97	4.02	.002	.015	.005	.005	.003	.008	.002	.015	.015	.03	317
P310	.052	.0046	.20	.028	.17	6.04	3.95	.002	.015	.005	.005	.003	.01	.002	.02	.015	.05	316
P311	.041	.0033	.19	.023	.16	5.80	4.07	.002	.015	.005	.005	.003	.01	.002	.02	.015	.02	321
P312	.049	.0045	.18	.027	.16	5.85	4.03	.002	.015	.008	.005	.002	.008	.002	.015	.01	.015	321
P314	.053	.0026	.21	.026	.17	5.80	4.07	.002	.03	.005	.005	.003	.01	.002	.02	.02	.03	336
P315	.046	.0032	.22	.024	.18	5.97	3.98	.002	.02	.01	.005	.002	.008	.002	.02	.015	015	324
P316	.050	.0029	.16	.025	.19	5.92	4.05	.002	.015	.005	.005	.003	.008	.002	.015	.01	.02	314
P317	.044	.0031	.20	.026	.17	5.70	4.11	.002	.05	.005	.005	.002	.008	.002	.02	.02	.03	336
P318	.057	.0048	.14	.027	.18	6.10	3.90	.002	.015	.005	.005	.002	.005	.002	.015	.015	.03	316
P319	.058	.0052	.19	.025	.17	5.95	4.07	.002	.015	.005	.005	.002	.005	.002	.015	.015	.04	316
P320	.049	.0040	.19	.030	.15	5.87	3.99	.002	.015	.005	.005	.003	.005	.002	.015	.015	.04	321
P321	.052	.0035	.21	.026	.16	5.90	4.00	.002	.015	.005	.005	.002	.005	.002	.02	.01	.02	311
P322	.053	.0044	.20	.028	.16	5.92	4.00	.002	.015	.005	.005	.003	.008	.002	.02	.015	.03	331
P323	.031	.0047	.20	.021	.15	5.97	4.09	.002	.015	.005	.005	.003	.008	.002	.015	.015	.015	311
P324	.051	.0043	.21	.027	.16	5.85	3.98	.002	.02	.005	.005	.002	.01	.002	.02	.015	.04	326
P325	.051	.0057	.21	.025	.17	5.90	4.03	.002	.02	.005	.005	.002	.01	.002	.08	.004	.004	326
P326	.048	.0035	.21	.026	.16	5.92	3.98	.002	.02	.005	.005	.002	.01	.002	.08	.003	.004	316
P327	.018	.0037	.18	.023	.16	6.02	4.05	.002	.015	.005	.005	.003	.005	.002	.02	.008	.03	321
P328	.027	.0034	.15	.016	.16	5.67	4.11	.002	.015	.005	.005	.002	.008	.002	.02	.01	.004	311
P329	.027	.0033	.15	.013	.14	6.05	4.02	.002	.015	.02	.005	.002	.01	.002	.02	.01	.02	311
P330	.049	.0030	[illegible]	[illegible]	.16	5.95	4.00	.002	.015	.008	.005	.002	.008	.002	.02	.015	.05	321
P332	.037	.0016	.065	.0075	.13	5.75	4.05	.002	.025	.005	.005	.002	.02	.002	.03	.004	.002	272
P333	.026	.0039	.14	.017	.16	6.08	4.06	.002	.015	.015	.005	.003	.005	.002	.015	.002	.01	302
P334	.040	.0022	.083	.011	.13	5.60	4.03	.002	.025	.005	.005	.002	.015	.002	.08	.004	.002	290
P335	.053	.0023	.22	.027	.16	5.92	4.05	.002	.04	.005	.005	.002	.008	.002	.02	.01	.02	326
P336	.046	.0032	[illegible]	[illegible]	[illegible]	5.70	3.98	.002	.02	.005	.005	.002	.005	.002	.02	.01	.02	311
P337	.053	.0035	.20	.025	.16	6.05	4.03	.002	.02	.03	.005	.002	.005	.002	.015	.01	.02	
P340	.044	.0026	.19	.027	.16	5.85	4.02	.002	.02	.008	.005	.002	.005	.002	.02	.01	.02	327
P342	.040	.0030	.21	.026	.17	5.90	4.00	.002	.02	.008	.005	.002	.008	.002	.02	.015	.03	327
P343	.064	.0032	.24	.030	.17	5.87	4.05	.002	.015	.008	.005	.002	.005	.002	.02	.005	.02	324
P344	.055	.0045	.20	.030	.16	5.90	4.07	.002	.02	.008	.005	.002	.005	.002	.02	.01	.02	341
P345	.044	.0031	.20	.026	.16	5.95	4.00	.002	.02	.01	.005	.002	.008	.002	.02	.01	.04	317
P346	.040	.0030	.20	.022	.15	5.92	4.07	.002	.01	.005	.005	.002	.005	.002	.015	.01	.015	311

TABLE J22 (Continued)

HEAT ANALYSES

Heat No.	C	H	O	N	Fe	Al	V	Co	Cr	Cu	Mg	Mn	Ni	Pb	Si	Mo	Sn	BHN
P347	.059	.0034	.20	.029	.17	5.90	4.04	.002	.02	.005	.005	.002	.005	.002	.015	.01	.02	331
P355	.048	.0016	.06	.028	.080	5.72	4.13	.002	.01	.005	.005	.002	.008	.002	.02	.005	.002	277
P356	.025	.0022	.06	.079	.075	5.80	4.11	.002	.01	.1	.005	.002	.004	.002	.01	.002	.002	290
P357	.028	.0020	.05	.045	.075	5.87	4.13	.002	.01	.005	.005	.002	.008	.002	.02	.005	.002	287
[illegible]	[illegible]	[illegible]	.22	.027	.17	5.80	4.07	.002	.02	.005	.005	.002	.005	.002	.02	.005	.015	327
P361	.075	.0026	.21	.032	.18	5.94	3.88	.002	.015	.01	.005	.003	.005	.002	.015	.22	.015	324
P362	.041	.0029	.21	.023	.15	5.67	3.94	.002	.015	.005	.005	.002	.005	.002	.015	.02	.008	314
P363	.052	.0041	.24	.027	.15	5.97	3.97	.002	.015	.008	.005	.002	.005	.002	.02	.015	.03	317
P364	.045	.0040	.24	.025	.15	5.60	3.83	.002	.015	.01	.005	.002	.005	.002	.02	.015	.01	305
P365	.073	.0041	.24	.031	.16	6.15	3.97	.002	.02	.008	.005	.002	.005	.002	.02	.01	.02	311
P366	.051	.0031	.24	.024	.16	6.25	4.03	.002	.015	.005	.005	.003	.005	.002	.02	.005	.02	311
P367	.058	.0032	.18	.029	.16	6.00	4.05	.002	.015	.01	.005	.003	.005	.002	.02	.005	.02	346
P368	.083	.0052	.24	.030	.18	5.90	4.04	.002	.025	.01	.005	.002	.005	.002	.015	.015	.02	327
P369	.063	.0036	.23	.027	.16	5.90	4.05	.002	.02	.01	.005	.002	.005	.002	.015	.015	.02	317
P370	.073	.0033	.24	.031	.18	5.90	4.06	.002	.015	.01	.005	.003	.005	.002	.015	.02	.02	314
P371	.063	.0040	.27	.018	.18	6.06	3.98	.02	.02	.005	.005	.002	.01	.002	.1	.005	.008	331
P372	.049	.0026	.11	.012	.14	5.72	4.02	.002	.015	.008	.005	.002	.01	.002	.02	.005	.004	279
P373	.064	.0026	.24	.030	.17	5.95	4.00	.002	.015	.008	.005	.003	.005	.002	.02	.005	.02	324
P374	.064	.0028	.25	.030	.21	5.95	4.03	.002	.02	.01	.005	.002	.005	.002	.015	.002	.03	317
P375	.042	.0033	.12	.010	.13	5.80	4.05	.002	.025	.008	.005	.002	.01	.002	.025	.005	.004	287
P376	.066	.0028	.14	.016	.14	5.70	4.05	.002	.02	.008	.005	.002	.01	.002	.025	.005	.004	296
P378	.048	.0033	.26	.023	.15	6.05	3.98	.002	.025	.005	.005	.002	.01	.002	.1	.005	.008	317.6
P379	.099	.0034	.26	.038	.22	5.85	3.93	.002	.01	.008	.005	.003	.005	.002	.015	.004	.02	334.3
P380	.073	.0020	.26	.033	.20	5.90	3.98	.002	.01	.005	.005	.003	.005	.002	.015	.02	.015	331
P381	.085	.0053	.25	.030	.20	6.10	4.07	.002	.03	.005	.005	.003	.03	.002	.1	.01	.008	331
P382	.093	.0031	.27	.031	.19	6.00	4.04	.002	.02	.005	.005	.002	.02	.002	.1	.01	.008	331
P383	.066	.0027	.26	.031	.17	6.04	3.87	.002	.01	.01	.005	.002	.005	.002	.015	.004	.02	316
P384	.057	.0058	.24	.028	.18	6.03	3.91	.002	.01	.005	.005	.002	.005	.002	.015	.015	.015	326
P385	.066	.0027	.24	.032	.20	6.05	3.81	.002	.015	.008	.005	.003	.005	.002	.015	.01	.02	311
P386	.078	.0049	.23	.035	.20	5.95	4.00	.002	.01	.005	.005	.002	.005	.002	.015	.015	.015	306.5
P387	.074	.0026	.26	.033	.19	6.02	3.92	.002	.02	.008	.005	.003	.005	.002	.01	.01	.02	331
P388	.076	.0041	.25	.031	.20	5.65	3.98	.002	.01	.008	.005	.003	.005	.002	.01	.015	.015	326
P389	.080	.0041	.27	.032	.20	5.80	4.00	.002	.015	.008	.005	.002	.005	.002	.015	.01	.015	346.5
P390	.074	.0046	.28	.041	.19	5.96	3.75	.002	.015	.008	.005	.002	.005	.002	.015	.015	.02	341.5
P391	.078	.0045	.26	.032	.21	5.65	4.00	.002	.015	.01	.005	.002	.005	.002	.015	.01	.02	326
P392	.051	.0028	.24	.028	.17	6.00	4.04	.002	.04	.005	.005	.002	.02	.002	.1	.01	.01	346.5
P393	.065	.0030	.25	.030	.19	5.95	3.88	.002	.02	.008	.005	.002	.005	.002	.02	.01	.015	352
P394	.046	.0021	.22	.025	.18	6.15	4.04	.002	.03	.008	.005	.003	.01	.002	.03	.01	.01	331
P395	.053	.0027	.22	.025	.16	6.25	4.03	.002	.01	.005	.005	.003	.005	.002	.01	.01	.02	
P396	.053	.0026	.26	.026	.16	6.05	4.05	.002	.015	.005	.005	.002	.005	.002	.015	.01	.02	
P397	.057	.0026	.22	.024	.17	6.20	4.02	.002	.02	.005	.005	.003	.008	.002	.015	.01	.02	
P398	.067	.0028	.23	.029	.20	6.02	3.81	.002	.02	.01	.005	.002	.005	.002	.01	.02	.015	321
P399	.025	.0049	.32	.031	.17	6.20	4.07	.002	.015	.005	.005	.004	.015	.002	.01	.01	.02	302
P400	.056	.0034	.24	.030	.16	6.10	3.98	.002	.025	.005	.005	.002	.01	.002	.1	.005	.002	326
P401	.046	.0036	.21	.029	.16	6.11	4.00	.002	.015	.008	.005	.003	.015	.002	[illegible]	[illegible]	[illegible]	[illegible]
P402	.068	.0023	.23	.031	.16	6.05	4.05	.003	.025	.02	.005	.002	.02	.002	.1	.015	.008	326
P403	.060	.0027	.26	.033	.16	6.05	4.01	.002	.02	.005	.005	.002	.01	.002	.08	.005	.01	321
P404	.052	.0023	.22	.029	.16	6.05	4.04	.002	.03	.008	.005	.002	.01	.002	.05	.005	.05	311.3
P405	.069	.0039	.25	.030	.17	5.95	4.01	.002	.03	.005	.005	.004	.005	.002	.015	.02	.03	337.6
P408	.064	.0045	.26	.030	.16	[illegible]	4.01	.002	.04	.005	.005	.002	.01	.002	.1	.005	.008	327.6
P410	.062	.0027	.24	[illegible]	[illegible]	6.05	4.05	.002	.03	.005	.005	.002	.005	.002	.025	.01	.008	[illegible]
P411	.062	.0033	.23	.028	.16	5.95	4.07	.002	.015	.04	.005	.002	.005	.002	.025	.01	.008	324.4
P412	.054	.0026	.24	.026	.16	5.85	4.02	.002	.015	.005	.005	.002	.005	.002	.025	.005	.004	331
P413	.027	.0033	.17	.019	.15	6.10	4.09	.002	.02	.005	.005	.002	.01	.002	.1	.002	.002	314.3
P414	.066	.0032	.23	.030	.13	[illegible]	3.69	.002	.015	.01	.005	.003	.01	.002	.01	.015	.015	[illegible]

TABLE J22 (Continued)

HEAT ANALYSES

Heat No.	C	H	O	N	Fe	Al	V	Co	Cr	Cu	Mg	Mn	Ni	Pb	Si	Mo	Sn	BHN
P415	.045	.0026	.26	.025	.15	5.95	4.08	.002	.02	.005	.005	.002	.01	.002	.02	.002	.002	
P416	.058	.0021	.24	.030	.21	6.00	4.01	.002	.06	.005	.005	.002	.005	.002	.02	.03	.015	336
P417					No Pour - Hit Water													
P418	.041	.0026	.19	.019	.17	6.10	4.03	.002	.015	.01	.005	.002	.01	.002	.03	.008	.015	321
P419	.064	.0022	.26	.036	.17	6.00	4.06	.002	.02	.005	.005	.002	.005	.002	.025	.006	.015	337.[illegible]
P420	.038	.0021	.19	.015	.16	6.10	4.13	.002	.02	.006	.005	.002	.01	.002	.03	.006	.008	321
P421	.029	.0025	.17	.014	.13	6.20	4.05	.002	.02	.005	.005	.002	.01	.002	.1	.005	.002	[illegible]
P422	.066	.0030	.25	.022	.17	6.15	4.05	.002	.02	.005	.005	.003	.01	.002	.015	.015	.02	3[illegible].3
P423	.056	.0030	.21	.021	.14	6.15	4.05	.002	.025	.005	.005	.002	.005	.002	.015	.02	.02	308
P424	.043	.0026	.24	.017	.15	6.10	4.05	.002	.015	.01	.005	.004	.005	.002	.015	.015	.008	314.3
P425	.043	.0023	.21	.019	.16	6.15	4.10	.002	.02	.005	.005	.003	.015	.002	.1	.005	.004	321.6
P426	.024	.0033	.17	.015	.13	6.20	4.00	.002	.02	.005	.005	.002	.005	.002	.03	.008	.002	308
P427	.033	.0054	.16	.019	.15	6.25	4.03	.002	.002	.005	.005	.002	.01	.002	.02	.008	.002	311.3
P436	.043	.0025	.17	.014	.11	6.20	4.10	.002	.015	.005	.005	.002	.005	.002	.05	.003	.002	297.5
P437	.062	.0022	.23	.028	.17	6.00	4.04	.002	.06	.005	.005	.002	.01	.002	.03	.002	.002	
P439	.077	.0026	.12	.012	.15	5.90	4.09	.002	.01	.02	.005	.008	.005	.002	.015	.003	.003	311.3
P441	.050	.0019	.16	.023	.16	6.10	4.03	.002	.025	.005	.005	.002	.02	.002	.10	.003	.002	334.3
P442	.057	.0022	.25	.030	.17	6.10	3.97	.002	.01	.005	.005	.003	.005	.002	.01	.02	.015	334.2
P443	.039	.0021	.19	.021	.15	6.10	4.09	.002	.02	.02	.005	.002	.01	.002	.08	.005	.003	
P444	.064	.0024	.19	.028														
P445	.050	.0024	.18	.020	.16	6.15	4.05	.002	.01	.008	.005	.008	.01	.002	.015	.02	.015	316
P446	.033	.0041	.17	.017	.16	6.15	4.05	.002	.015	.015	.005	.004	.01	.002	.015	.015	.01	308
P447	.021	.0034	.17	.016	.14	6.15	4.06	.002	.02	.005	.005	.002	.02	.002	.10	.002	.002	311
P448	.032	.0031	.19	.015														
P449	.042	.0024	.18	.017	.19	5.90	3.96	.002	.025	.01	.005	.002	.015	.002	.1	.002	.002	302
P450	.050	.0025	.23	.029	.16	6.05	4.07	.002	.02	.005	.005	.002	.01	.002	.05	.002	.002	324.3
P452	.050	.0025	.21	.024	.16	6.15	4.07	.005	.015	.03	.005	.003	.005	.002	.015	.01	.015	314.3
P453	.051	.0023	.23	.025	.16	5.90	3.95	.002	.015	.01	.005	.002	.005	.002	.015	.004	.015	321
P454	.049	.0026	.17	.022	.13	6.15	4.03	.002	.015	.008	.005	[illegible]	.005	.002	.01	.004	.008	311
P455	.044	.0026	.20	.022	.15	6.00	4.05	.002	.015	.005	.005	.002	.005	.002	.04	.002	.002	317.6
P456	.073	.0022	.19	.023	.16	6.00	4.05	.002	.01	.005	.005	.002	.005	.002	.01	.002	.004	327.6
P457	.051	.0036	.19	.021	.16	6.15	4.09	.002	.015	.008	.005	.01	.01	.002	.015	.005	.006	
P458	.060	.0023	.23	.024	.15	6.10	4.04	.002	.02	.005	.005	.002	.01	.002	.08	.005	.004	331
P459	.040	.0022	.20	.020	.16	6.15	4.04	.002	.015	.008	.005	.002	.01	.002	.015	.005	.002	321
P460	.037	.0034	.20	.019	.17	6.00	4.04	.002	.02	.005	.005	.002	.01	.002	.08	.002	.002	311
P461	.062	.0033	.23	.022	.16	5.95	4.09	.002	.015	.005	.005	.003	.005	.002	.02	.002	.004	
P462	.021	.0024	.21	.024	.16	5.90	4.05	.002	.02	.005	.005	.002	.005	.002	.015	.002	.004	
P463	.050	.0034	.22	.026	.16	6.00	4.08	.002	.01	.005	.005	.002	.005	.002	.01	.002	.01	
P464	.042	.0031	.21	.022	.16	6.10	4.04	.002	.01	.005	.005	.003	.005	.002	.015	.002	.003	
P465	.023	.0028	.21	.021	.15	6.00	4.05	.002	.01	.005	.005	.002	.005	.002	.02	.002	.003	
P466	.044	.0023	.16	.026	.17	6.10	4.06	.002	.015	.005	.005	.008	.015	.002	.02	.004	.004	321
P467	.028	.0023	.20	.027	.16	5.95	4.03	.002	.01	.005	.005	.003	.005	.002	.01	.01	.008	
P468	.070	.0026	.12	.022	.18	6.00	4.04	.002	.01	.005	.005	.003	.005	.002	.01	.01	.008	
P469	.042	.0026	.15	.024	.15	5.90	4.05	.002	.015	.005	.005	.004	.005	.002	.015	.01	.01	
P470	.048	.0022	.18	.022	.18	5.90	4.04	.002	.01	.005	.005	.004	.008	.002	.015	.005	.008	
P473	.062	.0021	.24	.025	.15	5.90	4.09	.002	.015	.005	.005	.002	.005	.002	.015	.002	.01	316.3
P474	.024	.0026	.23	.025	.17	6.05	4.07	.002	.015	.015	.005	.003	.01	.002	.01	.004	.01	324.3
P475	.025	.0022	.18	.027	.15	5.95	4.07	.002	.01	.005	.005	.003	.005	.002	.01	.003	.004	408
P476	.054	.0029	.16	.024	.18	6.05	4.07	.002	.01	.005	.005	.002	.005	.002	.01	.002	.005	321
P477	.051	.0025	.22	.024	.17	5.90	4.05	.002	.01	.005	.005	.002	.005	.002	.01	.003	.008	331
P478	.045	.0015	.25	.024	.17	.01	.1	.002	.02	.005	.005	.002	.005	.002	.01	.002	.005	
P479	.035	.0039	.13	.019	.14	6.00	4.05	.002	.01	.005	.005	.002	.005	.002	.01	.01	.002	316
P481	.053	.0027	.19	.024	.16	5.90	4.01	.002	.01	.005	.005	.003	.005	.002	.01	.01	.01	3[illegible]
P482	.043	.0023	.25	.026	.17	6.00	4.04	.002	.01	.005	.005	.015	.01	.002	[illegible]	[illegible]	[illegible]	
P483	.036	[illegible]	.19	.01	[illegible]	[illegible]	4.06	[illegible]	.01	.005	.005	.002	[illegible]	[illegible]	.01	[illegible]	[illegible]	

TABLE J22 (Continued)

HEAT ANALYSES

Heat No.	C	H	[illegible]	[illegible]	Fe	Al	V	[illegible]	[illegible]	Cu	[illegible]	[illegible]	[illegible]	[illegible]	Si	[illegible]	Sn	BHN
P485	.051	.0024	.22	.028	.17	5.95	4.05	.002	.015	[illegible]	.005	.004	.01	.002	.015	.004	.008	331
P486	.056	.0023	.19	.024	.16	6.00	4.04	.002	.01	[illegible]	.005	.005	.005	.002	.01	.015	.008	[illegible]
P487	.058	.0020	.27	.027	.16	6.05	4.05	.002	.015	.008	.005	.006	.005	.002	.015	.002	.003	352
P493	.030	.0025	.21	.022	.15	6.10	4.07	.002	.015	.005	.005	.015	.005	.0021	.021	.005	.004	341
P494	.044	.0024	.15	.023	.17	6.10	4.07	.002	.015	.01	.005	.003	.006	.002	.015	.01	.01	316
P495	.057	.003	.191	.027	.17	[illegible]	4.09	.002	.015	.005	.005	.003	.005	.002	.01	.005	.01	321
P496	.041	.0029	.19	.026	.17	6.10	4.01	.002	.01	.005	.005	.007	.005	.002	.01	.003	.005	327.[illegible]
P497	.056	.0030	.22	.027	.16	6.10	4.04	.002	.01	.01	.005	.004	.01	.002	.01	.004	.015	327.6
P498	.030	.002	.188	.024	.16	6.00	4.08	.002	.01	.00	.005	.003	.005	.002	.01	.004	.006	317.6
P499	.053	.0026	.20	.023	.17	6.06	4.09	.002	.015	.01	.005	.003	.005	.002	.01	.005	.01	324.3
P500	.095	.0023	.16	.021	.16	6.00	4.05	.002	.01	.015	.005	.004	.005	.002	.01	.004	.008	324.3
P502	.076	.0021	.20	.026	.16	5.95	4.09	.002	.01	.005	.095	.004	.015	.002	.015	.02	.008	341
P503	.045	.0036	.16	.024	.18	6.05	4.05	.002	.015	.006	.005	.003	.008	.002	.021	.015	.01	311
P504	.052	.0027	.12	.023	.16	6.12	3.97	.002	.015	.005	.005	.004	.005	.003	.015	.01	.008	331
P505	.045	.0029	.20	.022	.17	6.00	[illegible]	.002	.01	.01	.005	.004	.005	.002	.01	.01	.015	326
P506	.048	.007	.216	.025	.17	6.10	4.05	.002	.015	.005	[illegible]	.003	.005	.002	.01	.008	.01	331
P507	.054	.002	.195	.022	.17	5.55	4.13	.002	.015	[illegible]	[illegible]	[illegible]	.008	.002	.01	.002	.005	326
P508	.052	.003	.177	.025	.18	6.05	4.05	.002	.015	.008	.005	.003	.002	.002	.015	.002	.003	336
P509	.055	.002	.21	.025	.17	6.10	[illegible]	.002	.015	.01	.005	.003	.005	.002	.015	.005	.006	311
P510	.055	.001	.124	.153	.14	6.05	[illegible]	.002	.01	.005	.005	.002	.005	.002	.01	.002	.003	331
P511	.050	.003	.151	.011	.16	6.00	[illegible]	.002	.01	.005	.005	.004	.006	.002	[illegible]	.002	.003	311
P512	.048	.0030	.20	.024	.15	6.15	4.03	.002	.01	.008	.005	.005	.005	.002	.015	[illegible]	.01	324.3
P524	.046	.0030	.21	.029	.16	6.10	4.05	.002	.01	.01	.005	.003	.015	.002	.01	.01	.008	331
P525	.041	.004	.161	.023	.17	6.00	4.05	.002	.015	.005	.005	.003	.005	.002	.015	.005	.01	321
P526	.055	.0035	.21	.025	.16	6.00	4.02	.002	.01	.005	.005	.005	.005	.002	.01	.005	.01	331
P528	.025	.0050	.22	.016	.16	6.00	4.12	.002	.01	.005	.005	.005	.005	.002	.01	.002	.002	311.3
P529	.048	.0030	.22	.025	.17	6.20	4.07	.002	.01	.005	.005	[illegible]	.005	.002	.01	.003	.008	321
P530	.055	.0029	[illegible]	.026	.16	6.05	4.05	.002	.01	.01	.005	.003	.002	.002	.01	.03	.006	324
P531	.050	.0030	.21	.020	.17	6.15	4.04	.002	.01	.005	.005	.002	.005	.002	.01	.003	.006	317.6
P532	.053	.0028	.23	.024	.15	6.05	4.06	.002	.015	.01	.005	.004	.01	.002	.01	.03	.008	327.3
P533	.061	.0040	.21	.027	.17	6.10	4.05	.002	.015	.08	.005	.003	.005	.002	.01	.01	.01	324.3
P534	.053	.0040	.21	.026	.14	6.05	4.07	.003	.02	.08	.005	.003	.005	.002	.01	.01	.01	331
P535	.055	.0032	.21	.024	.17	6.00	[illegible]	.002	.01	.008	.005	[illegible]	.005	.002	.01	.01	.01	331
P536	.053	.0034	.22	.024	.14	6.00	4.09	.002	.01	.005	.005	.003	.01	.002	.01	.006	.004	
P537	.050	.0029	.21	.024	.16	6.05	4.05	.002	.01	.01	.005	.004	.01	.002	.01	[illegible]	.008	
P538	.051	.0026	.21	.022	.16	6.05	4.11	.002	.01	.005	.005	.003	.01	.002	.01	.004	.008	
P539	.067	.0027	.23	.024	.15	5.90	4.05	.002	.015	.02	.005	.005	.01	.002	.01	.008	.01	321
P540	.047	.0030	.22	.025	.15	6.00	4.30	.002	.01	.005	.005	.004	.005	.002	.01	.008	.01	314.4
P541	.057	.0030	.23	.031	.16	5.95	[illegible]	.002	.01	.01	.005	.004	.006	.002	.015	.015	.015	321
P542	No Record																	335
P543	.043	.0028	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.02	[illegible]	[illegible]	.005	.01	.002	.01	[illegible]	.008	327.3
P544	.027	.0023	.16	.016	.15	[illegible]	4.07	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.015	.01	.01	
P545	.064	.0026	.16	.054	.16	5.70	[illegible]	.002	.01	[illegible]	.005	[illegible]	[illegible]	.002	.01	[illegible]	[illegible]	
P546	.050	.0024	[illegible]	.029	[illegible]	[illegible]	4.12	[illegible]	.01	.005	.005	.003	.01	.002	.01	.004	.004	[illegible]
P547	No Record																	
P548	.062	.0026	.22	.055	.16	[illegible]	[illegible]	[illegible]	.015	[illegible]	.006	.006	.01	.005	.015	.005	.005	315
P549	.055	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.002	311
P551	.048	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.01	[illegible]	.005	[illegible]
P552	.059	.0025	.23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.01	.01	[illegible]	.01	[illegible]	.01	331
P553	.052	[illegible]	[illegible]	.030	.16	[illegible]	[illegible]	[illegible]	[illegible]	.01	[illegible]	[illegible]	.01	[illegible]	[illegible]	.01	.01	
[illegible]	[illegible]	[illegible]	.23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.01	[illegible]	.008	[illegible]
P555	.063	.0027	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.01	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
P557	.061	.0025	[illegible]	[illegible]	.17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.01	[illegible]	[illegible]	

TABLE J22 (Continued)

HEAT ANALYSES

Heat No.	C	H	O	N	Fe	Al	V	[illegible]	Cr	Cu	Mg	Mn	Ni	[illegible]	Si	Mo	Sn	BHN
P559	.025	.0025	.20	.036	.13	5.95	4.11	.002	.015	.05	.005	.004	.005	.002	.015	.003	.006	303
P560	.032	.0025	.22	.039	.22	6.13	3.77	.002	.015	.008	.005	.004	.008	.002	.01	.01	.006	331
P561	.031	.0027	.14	.020	.12	5.18	4.05	.002	.02	.008	.005	.002	.01	.002	.02	.01	.005	285
P562	.026	.003	.23	.052	.14	5.90	4.00	.002	.015	.003	.005	.004	.01	.002	.02	.02	.006	311
P563	.023	.0025	.22	[illegible]	.17	5.95	4.05	.002	.015	.008	.005	.004	.005	.002	.01	.005	.008	
P564	.061	.0026	.21	.033	.17	5.95	4.05	.002	.02	.015	.005	.007	.01	.002	.015	.01	.01	321
P565	.044	.0027	.19	.035	.15	5.95	4.13	.002	.01	.01	.005	.004	.01	.002	.01	.01	.01	[illegible]
P566	.072	.0027	.37	.042	.17	6.05	4.10	.002	.01	.005	.005	.004	.015	.002	.01	.015	.008	
P567	No Record																	
P568	.051	.0028	.24	.041	.15	6.00	4.09	.002	.015	.005	.005	.004	.015	.002	.015	.015	.006	
P569	.065	.0028	.24	.037	.15	5.90	4.17	.002	.015	.005	.005	.005	.01	.002	.01	.005	.008	302
P570	.07[illegible]	.0024	.21	.041	.15	5.95	4.02	.002	.01	.005	.005	.004	.01	.002	.01	.004	.006	
P571	.077	.0021	.22	.041	.14	5.90	4.07	.002	.015	.005	.005	.004	.01	.002	.015	.004	.006	311
P572	.064	.0025	.22	.037	.14	6.02	4.04	.002	.015	.008	.005	.004	.01	.002	.0152	.08	.005	311
P573	.063	.0026	.19	.050	.16	5.95	4.04	.002	.015	.008	.005	.004	.01	.002	.01	.004	.008	311
P574	.0[illegible]8	.0024	.21	.037	.16	6.02	4.07	.002	.015	.015	.005	.004	.01	.002	.01	.004	.006	331
P575	.0[illegible]0	.0032	.26	.031	.16	5.97	4.04	.002	.015	.008	.005	.003	.008	.002	.015	.02	.008	341
P576	.0[illegible]1	.0023	.25	.033	.16	6.02	4.06	.002	.015	.008	.005	.004	.01	.002	.01	.004	.01	321
P577	.024	.0026	.17	.015	.17	6.02	4.09	.002	.015	.01	.005	.004	.01	.002	.01	.005	.008	302
P578	.072	.0033	.16	.017	.13	5.97	4.13	.002	.01	.005	.005	.003	.005	.002	.02	.03	.006	311
P579	.045	.0028	.27	.047	.11	.005	[illegible]	[illegible]	.01	2.00	.005	.002	.002	.002	.01	.002	.006	
P580	.036	.0031	.18	[illegible]	[illegible]	[illegible]	4.02	.002	.01	.005	.005	.008	.003	.002	.01	.01	.006	311
P581	.023	.0033	.18	[illegible]	.14	6.02	4.04	.002	.01	.005	.005	.003	.003	.002	.01	.01	.003	302
P582	.021	.0036	.15	.017	[illegible]	6.02	4.11	.002	.01	.005	.005	.004	.003	.002	.01	.01	.005	311
P583	No Pour																	
P584	.017	.0037	.15	.017	[illegible]	5.05	4.11	.002	.01	.005	.005	.002	.005	.002	.03	.015	.002	302
P585	.044	.0031	.23	[illegible]	[illegible]	5.98	4.10	.002	.02	.01	.005	.002	.015	.002	.1	.002	.002	331
P586	.035	.0030	.56	[illegible]	.13	5.97	4.15	.002	.015	.015	.005	.002	.008	.002	.03	.015	.002	302
P587	.029	.0026	.23	.031	[illegible]	6.12	4.04	.002	.02	.01	.005	.002	.015	.002	.1	.002	.002	321
P588	.029	.0039	.20	.026	.16	6.05	4.11	.002	.015	.005	.005	.002	.006	.002	.03	.015	.002	311
P589	.030	.0033	.19	.023	.13	6.05	[illegible]	.002	.015	.005	.005	.002	.008	.002	.025	.015	.002	331
P590	.042	.0033	.21	.033	.16	6.10	4.06	.002	[illegible]	.005	.005	.002	.005	.002	.02	.015	.003	331
P591	.065	.0030	.15	[illegible]	.13	5.98	4.06	.002	.02	.006	.005	.002	.015	.002	.02	.003	.002	331
P592	.069	.0036	.24	.046	.16	5.97	4.09		.05	.05		.05	.05		.05	.05	.05	331
P593	.070	.0025	.22	.031	.15	6.20	[illegible]		.05	.05		.05	.05		.05	.05	.05	311
P594	.050	.0020	.23	[illegible]	.14	5.60	4.09		.05	.05		.05	.05		.05	.05	.05	
P595	.042	.0027	[illegible]	.032	.14	6.16	4.05		.05	.05		.05	.05		.05	.05	.05	331
P596	.043	.0027	.23	[illegible]	.15	6.15	4.05		.05	.05		.05	.05		.05	.05	.05	331
P597	.029	.0030	.24	.002	.12	6.00	4.03		.05	.05		.05	.05		.05	.05	.05	331
P600	.043	.0027	.26	[illegible]	.16	[illegible]	[illegible]		[illegible]	[illegible]		.05	[illegible]		.05	.05	.05	
P601	.032	.0033	.17	[illegible]	.11	5.96	4.11		.05	.05		.05	[illegible]		.05	.05	.05	
P602	.060	.0030	[illegible]	[illegible]	.16	5.77	[illegible]		[illegible]	.05		.05	[illegible]		.05	.05	.05	311
P603	.014	.0033	.13	.014	.15	6.03	[illegible]		.05	[illegible]		.05	[illegible]		.05	.05	.05	311
P604	.033	.0031	.17	.019	.13	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]		.05	.05	.05	311
P605	.032	.0010	[illegible]	.017	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]		.05	.05	.05	331
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]		[illegible]	[illegible]		.05	.05	.05	331
P609	.051	.003	[illegible]	.031	.17	[illegible]	[illegible]		[illegible]	[illegible]		.05	.05		.05	.05	.05	331
P610	.021	[illegible]	[illegible]	[illegible]	.14	[illegible]	[illegible]		[illegible]	[illegible]		.05	[illegible]		.05	.05	.05	321
P611	.012	[illegible]	.10	.017	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		.05	[illegible]		.05	.05	.05	331
P612	[illegible]	[illegible]	.17	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]			[illegible]	[illegible]		.05	.05	.05	311
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]			.05	.05	.05	302
[illegible]	[illegible]	[illegible]	.17	[illegible]	[illegible]	[illegible]							[illegible]		[illegible]	[illegible]	[illegible]	331
[illegible]	.03[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]			.05	[illegible]	[illegible]	
P617	.050	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]		[illegible]	.05	[illegible]	
P618	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]		[illegible]			[illegible]	[illegible]	[illegible]	
P619	[illegible]	[illegible]	[illegible]	.01	.12	[illegible]	[illegible]					[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	
P620	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	

TABLE J23

RESULTS OF DEVELOPMENTAL BRACKET COMPARATIVE FATIGUE TESTS

Load, Pounds	Fatigue Life, Cycles: Cast Ti-6Al-4V (As-Cast)	Cast 410 Steel (180,000 psi, min.)
18,000	NT	21,000 (2)
15,000	5,010 (1)	26,700 (2)
15,000	2,542 (1)	30,380 (2)
12,000	7,552 (1)	93,180 (3)
12,000	14,710 (1)	118,450 (2)
9,000	30,000 (1)	430,330 (1)
9,000	34,149 (2)	311,000 (2)
7,000	140,051 (3)	NT
7,000	134,420 (2)	NT
5,000	448,618 (1)	NT
5,000	318,550 (2)	NT

NT - None Tested.
(1) Failure in upper flange.
(2) Failure in upper large lug, at mounting hole.
(3) Failure in small lug.

TABLE J24

RESULTS OF STATISTICAL EVALUATION OF DIMENSIONS

Dimension Type -- See Footnotes	Specified Nominal Dimension	Actual Average Dimension	Specified Range	Actual Range*
1	.200	0.205	± .015	± .011
1	.650	.674	± .015	± .015
1	3.050	3.099	± .015	± .019
1	Not Specified	9.598	± .050	± .050
2	1.520	1.533	+ .025 - .015	± .028
2	2.520	2.525	+ .025 - .015	± .028
3	Not Specified	.664	± .015	± .035
3	3.050	3.110	± .015	± .037
3	10.630	10.703	± .050	± .071

* Actual range was from conventional statistical analysis and represents plus and minus three standard deviations.

1. Simple Dimension, not across parting line.
2. Dimension across and perpendicular to parting line.
3. Dimension across but parallel to parting line (includes mismatch).

SECTION K

APPENDIX

STATISTICAL ANALYSIS TECHNIQUES

Conventional statistical analysis methods were used to establish composition limits, design allowables, and dimensional tolerances. These methods are based on the assumption that the various data being studied represent a "normal" distribution. The following symbols are used:

n = the number of individual values in a sample
X = an individual value in a sample
ΣX = the sum of the individual values in the sample
$\bar{X}$ = the arithmetic mean (average) of the individual values in the sample
σ = the standard deviation of the sample

The procedure for determining standard deviation is as follows:

1. Determine n and $\bar{X}$.

$$\bar{X} = \frac{\Sigma X}{n}$$

2. Determine the difference of each value from the average $(\bar{X} - X)$ -- n values will be obtained. Signs can be disregarded.

3. Square each of the values obtained in step 2 -- $(\bar{X} - X)^2$ -- n values will be obtained.

4. Determine the sum of the values obtained in step three and divide this sum by n.

$$\frac{\Sigma (\bar{X} - X)^2}{n}$$

5. Determine the square root of the value obtained in step 4. This will be one standard deviation.

$$\sigma = \sqrt{\frac{\Sigma (\bar{X} - X)^2}{n}}$$

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