

TECHNICAL MEMORANDUM ASRCE TM-62-24

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**AN INDEX TO METALS R&D PROGRAMS OF  
SEVEN AFROSPACE COMPANIES**

Prepared By

Applications Laboratory  
Directorate of Materials and Processes  
Deputy for Technology

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Aeronautical Systems Division  
Air Force Systems Command  
United States Air Force  
Wright-Patterson Air Force Base, Ohio

*AD-404487*

## NOTICES

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Aeronautical Systems Division  
Air Force Systems Command  
United States Air Force  
Wright-Patterson Air Force Base, Ohio

Technical Memorandum  
ASRCE TM-62-24

Applications Laboratory  
Directorate of Materials & Processes  
Deputy for Technology

AN INDEX TO METALS R&D PROGRAMS OF  
SEVEN AEROSPACE COMPANIES

I. PURPOSE:

To provide an aid for retrieving information about metals R&D programs being conducted by seven aerospace companies.

II. FACTUAL DATA:

1. This index (Appendix I) covers 235 annotated abstracts describing metals R&D programs being conducted by seven aircraft companies. All of the programs described are recent and many of them are still in progress. It should be noted that the index also includes a few non-metallics which only indicates that a few programs mentioned overlap into the non-metallics area.

2. The abstracts included in Appendix II were submitted by the following companies as a partial requirement of several data compilation contracts sponsored by the Information Processing Section of the Applications Laboratory:

The Boeing Company (All Divisions)  
General Dynamics (Astronautics)  
General Electric (Evendale)  
McDonnell Aircraft  
North American Aviation (All Divisions)  
The Northrop Corp (Norair)  
Solar Aircraft

The companies are generally identified on each abstract by their name or by a code number in the upper right hand corner. The North American Aviation and Norair abstracts are identified by code numbers prefixed by NA and NOR respectively. The abstracts of Astronautics are simply identified by the abbreviation "GDA" in the upper right hand corner and those of General Electric by "GE".

3. Each abstract was assigned an index number, and based on this number the abstracts are listed in sequential order. Hence the index numbers range from 1 to 235. Each index number appears in the lower "outside" corner of the abstract. Note that in some cases the same index number appears on each of two successive abstracts, but that one number is suffixed by the letter "A", e.g., 3 and 3A. This indicates that both abstracts cover the same program and that one abstract was a 6-month follow-on to the other.

4. The index itself is made up of four sets of terms, each term listed in alphabetical order. The first set of terms is strictly on materials, the second on properties, the third on processes and the fourth set consists of miscellaneous terms such as fasteners, rotors and pressure vessels. Behind each term are the index numbers to those abstracts concerned.

5. The abstracts presented in this report give some limited indication of the metals R&D programming in effect at several companies. The intent of this presentation is to allow some further exchange of information on a voluntary basis. In those cases where more information or an exchange of information is desired, contact should be made with the appropriate company giving sufficient identification to the material of interest. The company addresses are:

The Boeing Company  
Aerospace Division  
Attn: Mr. J. W. Smuin (Contract AF33(616)-7559)  
Seattle, Washington

General Dynamics Corp.  
Convair/Astronautics Div.  
P. O. Box 1128  
Attn: Mr. James E. Chafey (Contract AF33(616)-7984)  
San Diego 12, Calif.

General Electric Co.  
Flight Propulsion Div.  
Attn: Mr. H. G. Popp (Contract AF33(657)-8017)  
Cincinnati 15, Ohio

McDonnell Aircraft Corp.  
Box 516  
Attn: Mr. H. J. Siegel (Contract AF33(657)-7749)  
St. Louis 66, Missouri

North American Aviation, Inc.  
International Airport  
Attn: Mr. R. L. Schleicher (Contract AF33(616)-8009)  
Los Angeles 45, Calif.

The Northrop Corp.  
Norair Div.  
Attn: G. A. Nelson (Contract AF33(616)-8140)  
Hawthorne, Calif.

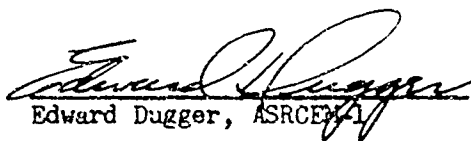
Solar Aircraft Co.  
Research Laboratories  
Attn: Mr. J. W. Welty (Contract AF33(616)-8375)  
San Diego 12, Calif.

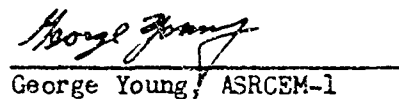
III. CONCLUSIONS: None

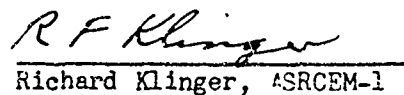
IV. RECOMMENDATIONS: That a similar index be prepared for non-metallic programs.

COORDINATION:

PREPARED BY:

  
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PUBLICATION REVIEW

This report has been reviewed and is approved.

  
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# APPENDIX I

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## Tantalum

38-48-137-202-217-232

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APPENDIX II

ANNOTATED ABSTRACTS

1. MATERIAL CLASSIFICATION: Adhesives, metallic materials and composite (metallic-non-metallic) materials
2. TITLE: Tensile Properties of Welded Aluminum Alloy, Titanium Alloy and Stainless Steel Sheet and Extrusion and Mechanical Properties of Adhesive Bonded Metal Honeycomb Sandwich.
3. OBJECTIVE:

An extensive test program was undertaken to determine design allowables to be used in preparation of the Saturn S-II Proposal. Tensile properties for the following materials were to be determined for parent, welded and notched metallic specimens:

|           |                       |
|-----------|-----------------------|
| 2024-T3   | Aluminum Sheet        |
| 2024-T351 | Aluminum Sheet        |
| 2014-T6   | Aluminum Extrusion    |
| 5Al-2.5Sn | Titanium Sheet        |
| 301XPH    | Stainless Steel Sheet |

Adhesives and composite sandwich structures were to be evaluated for shear and tensile properties. The adhesives and sandwich structures selected were:

|                                                                    |          |
|--------------------------------------------------------------------|----------|
| HT424                                                              | Adhesive |
| FM1000                                                             | Adhesive |
| Marmec 406                                                         | Adhesive |
| Sandwich Facing Sheets of 5Al-2.5Sn 0.025 in. thick Titanium Alloy |          |
| Sandwich Core of Fiberglass Exocel HRP-3/16 in.                    |          |
| UP-11, 4.0 lb density, 5/8 in. thick, filled with Polyurethane     |          |
| CPR1020-3 Foam                                                     |          |

All tests were to be run at room temperature and -300F.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Tensile and shear data determined at room temperature and -300F for the above-listed materials were determined and tabulated in Tables 1 through 20 inclusive of Lab Memo No. SMT 8-61-1.

This work was done at S&ID of NAA and was Company-Sponsored.

1. MATERIAL CLASSIFICATION: Metallic
2. TITLE: Cladding and Bonding Materials Development for Advanced Organic Moderated Reactors
3. OBJECTIVE: To evaluate cladding and diffusion barrier materials for potential use with uranium alloy and uranium-compound fuels for organic moderated reactors. This is an extensive effort.
4. ABSTRACT OF RESULTS OR CONCLUSIONS:

No discernible reaction has been observed between Mo and U or U-Mo alloy fuel materials, or aluminum cladding after 3000 hours at a temperature of 1000°F.

Increased emphasis is being placed on U - 10 Mo as the fuel material since it is presently felt that the higher fuel temperatures may require a more highly alloyed fuel for resistance to growth and swelling in a radiation field.

Major emphasis is being placed on nickel and niobium as barrier materials and aluminum and APM as cladding materials.

This work was AEC-sponsored.

Submitted by Atomics International Division

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Component and Structural Materials Development for Advanced Sodium-Cooled Reactors
3. OBJECTIVE: To establish design properties of improved Cr-Mo ferritic steels for service to 1200°F and to develop welding techniques for their fabrication. As the title of the project implies, the ultimate use of such materials is for high-temperature sodium-cooled nuclear reactors. This is an extensive effort.
4. ABSTRACT OF RESULTS OR CONCLUSIONS:

After stressed and unstressed exposure of 434 (2% Cr-1 Mo - 0.6 V) and 438 (2% Cr - 1 Mo - 0.6 V - 0.6 Cb) at 1100°F for 1000 hours; Charpy V-notch transition temperature was unchanged but the transition temperature range was narrower. Five thousand hour tests indicate the same trend.

The dynamic modulus of elasticity of 438 varies from  $28.8 \times 10^6$  psi at room temperature to  $21.9 \times 10^6$  psi at 1300°F.

Carbon loss of these two alloys in 1200°F sodium is considerably less than that for the straight 2 1/4 Cr - 1 Mo steel.

"Butter welding" techniques have been modified through the use of a lower chromium buttering alloy to prevent carbon migration. The stress rupture properties of the buttering alloys are in excess of those for the ferritic steels.

This work was AEC-sponsored.

Submitted by Atomic International Division

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Component and Structural Materials Development for Advanced Sodium-Cooled Reactors.
3. OBJECTIVE: To establish design properties of improved CR-Mo ferritic steels for service to 1200 F and to develop welding techniques for their fabrication. As the title of the project implies, the ultimate use of such materials is for high-temperature sodium-cooled nuclear reactors.
4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Short-time tensile test results for an experimental  $2\frac{1}{2}\text{Cr}-1\text{Mo}-0.6\text{V}-0.6\text{Cb}$  alloy steel are as follows:

| Test Temp.<br>F | Y.S. (0.2% offset)<br>( $10^3$ psi) | U.T.S.<br>( $10^3$ psi) | Elong. at<br>Fracture (%) | % R.A. |
|-----------------|-------------------------------------|-------------------------|---------------------------|--------|
| Room            | 30.5                                | 69.6                    | 34.5                      | 84.7   |
| 400             | 25.7                                | 56.0                    | 31.0                      | 81.0   |
| 600             | 22.9                                | 53.4                    | 27.0                      | 80.0   |
| 800             | 24.4                                | 53.6                    | 26.0                      | 79.9   |
| 1000            | 21.6                                | 42.9                    | 36.5                      | 84.5   |
| 1100            | 19.9                                | 34.4                    | 63.0                      | 89.6   |
| 1200            | 17.5                                | 28.5                    | 61.0                      | 93.2   |
| 1300            | 16.1                                | 20.9                    | 72.0                      | 95.8   |

The values reported are averages of duplicates.

This work was AEC-sponsored and performed by Atomics International Division under an extensive program.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: APM Cladding Materials Development
3. OBJECTIVE: The objective of this work is to develop information on APM cladding materials that will predict their performance under POPR (Prototype Organic Power Reactor) environmental conditions. This is an extensive effort.
4. ABSTRACT OF RESULTS OR CONCLUSIONS:

An area of particular interest was that of determining the effects of strain rate on APM materials. Information of this type is important as an aid in understanding the failure mechanisms involved, and should be considered in standardizing future testing procedures.

The data, shown in Table I, are representative of two recent lots of as-fabricated 0.100 in. thick M-257 sheet. The tests were run on a 60,000 lb Universal Testing Machine.

The following are general observations based on the somewhat limited data:

1. In most cases, the yield strengths are slightly higher with increasing strain rates.
2. A significant trend regarding effects of strain rate on ultimate tensile strength and ductility is not readily apparent. The data appear somewhat scattered.
3. The interrelationship of strain rate, temperature, and orientation of test specimen (i.e. transverse or longitudinal with respect to rolling direction) is uncertain.

Additional tests are in progress to gain basic property data that will be useful to designers in utilization of APM materials.

This work was AEC-sponsored.

Submitted by Atomics International Division.

TABLE I  
EFFECT OF STRAIN RATE ON TENSILE PROPERTIES OF M-257 SHEET  
(0.100 in. sheet, as received)

| Test Temp.<br>(°F) | Property            | STRAIN RATE ( $\text{Min}^{-1}$ ) |        |        |        |        |        |        |        |        |        |        |        |
|--------------------|---------------------|-----------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|                    |                     | 0.00025                           |        |        |        | 0.0005 |        |        |        | 0.001  |        |        |        |
|                    |                     | Lot A*                            | Lot B* | Lot A* | Lot B* | Lot A* | Lot B* | Lot A* | Lot B* | Lot A* | Lot B* | Lot A* | Lot B* |
| RT                 | YS (psi)            | 32850                             | 21100  | 35400  | 24000  | 34350  | 34500  | 36000  | 32000  | 34300  | 35050  | 34750  | 34750  |
|                    | UTS (psi)           | 39550                             | 41550  | 40350  | 42750  | 40650  | 41400  | 40750  | 41700  | 40850  | 41050  | 41600  | 41600  |
|                    | Elong.<br>(% in 2") | 8½                                | ---    | 9½     | 6      | 8½     | 7      | 8      | 6      | 8      | 7      | 6½     | 6½     |
| 600                | YS (psi)            | 7150                              | 6500   | 8050   | 8000   | 9400   | 9500   | 10400  | 9550   | 10000  | 10450  | 11700  | 11700  |
|                    | UTS (psi)           | 16350                             | 16250  | 15600  | 16700  | 15100  | 15700  | 15700  | 15750  | 16400  | 16000  | 16200  | 16200  |
|                    | Elong.<br>(% in 2") | 20                                | ---    | 23     | 15     | ---    | 20     | 22     | 17     | 16½    | 15     | 24     | 24     |
| 800                | YS (psi)            | 6800                              | ---    | 6700   | ---    | 6750   | ---    | 7500   | ---    | 7700   | ---    | ---    | ---    |
|                    | UTS (psi)           | 8750                              | ---    | 8750   | ---    | 8650   | ---    | 8750   | ---    | 8700   | ---    | ---    | ---    |
|                    | Elong.<br>(% in 2") | 7½                                | ---    | 6      | ---    | 8      | ---    | 8½     | ---    | 10     | ---    | ---    | ---    |
| 1000               | YS (psi)            | 2200**                            | 2300   | 2900   | 2500   | 3200   | 2600   | 3100   | 2900   | 3200   | 3350   | 3600   | 3600   |
|                    | UTS (psi)           | 5000                              | 4500   | 4450   | 4650   | 4500   | 4232   | 4300   | 4550   | 4700   | 4700   | 4600   | 4600   |
|                    | Elong.<br>(% in 2") | 23                                | 23     | 17     | 22     | 20     | 22     | ---    | 20     | 16     | 26     | 18     | 18     |

\* Specimen fabrication was longitudinal (L) and transverse (T) to the rolling direction of the material.

\*\* Questionable value. Test is being repeated.

NA-61-1049-1  
11-1-61

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: APM Cladding Materials Development
3. OBJECTIVE: The objective of this work is to develop information on APM cladding materials that will predict their performance under POPR (Prototype Organic Power Reactor) environmental conditions.
4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Results on the first series of subsize fuel rods consisting of UO<sub>2</sub> pellets clad with M-257 tubing showed no reaction between the two materials after 5000 hours at temperatures to 1100 F.

Mechanical testing of APM finned tubing at room and elevated temperatures (600, 800, and 900 F) has revealed the following:

- (a) Strengths are comparable with those of extruded bar and sheet materials.
- (b) Burst tests show that the ultimate hoop strength values do not deviate more than 10% from the short-time ultimate tensile strengths.

This work was AEC sponsored, and was performed under an extensive program by Atomic International Division.

4-15-62

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: High Strength Cladding Alloy Development for Advanced Sodium-Cooled Nuclear Reactors
3. OBJECTIVE: To (a) develop a high strength alloy with properties suitable for use as cladding for fuel element and moderator in a sodium-cooled reactor; (b) fabricate sufficient strip, tubing and bar stock for the assembly of such core components as fuel elements and moderator cans; and (c) determine the effects of irradiation on the properties of the cladding material.
4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Flare testing of 0.810" O.D. x 0.022" wall tubing of 3Zl alloy (1.25 w/o Al, 1.0 w/o Sn, 1.0 w/o Mo, balance Zr) resulted in a 22% increase in diameter without cracking. Elevated temperature tensile tests on 6" lengths of the tubing showed the following:

| <u>Test temperature</u><br><u>(F)</u> | <u>Y.S. (0.2% offset)</u><br><u>(10<sup>3</sup> psi)</u> | <u>U.T.S.</u><br><u>(10<sup>3</sup>psi)</u> | <u>% Elong.</u><br><u>in 6"</u> |
|---------------------------------------|----------------------------------------------------------|---------------------------------------------|---------------------------------|
| 600                                   | 57.6 (55.0)                                              | 79.4 (75.0)                                 | 10.5                            |
| 1000                                  | 43.5 (45.0)                                              | 58.8 (57.0)                                 | 16.7                            |

Values in parenthesis are for 0.050" vacuum annealed strip.

This alloy has shown favorable physical, mechanical, and formability properties for use in sodium-cooled reactors operating to temperatures of 1200 F.

This work was AEC-sponsored, and was performed by Atomics International Division.

1. MATERIAL CLASSIFICATION: Metallic
2. TITLE: Advanced Nuclear Fuel and Material Development
3. OBJECTIVE: To investigate new and promising nuclear fuel materials. This is an extensive effort.
4. ABSTRACT OF RESULTS OR CONCLUSIONS: Transformation kinetics studies by x-ray diffraction have shown isothermal transformation after 20 and 16 hours at 550°C of, respectively, U - 14 and U - 16 Mo alloys gammaized at 900°C.

Analysis of AI data, as well as data from other sites, suggests that eutectoid alloys are more sluggish in transforming than are the hypo- and hypereutectoid U - Mo alloys.

The following tables list the tensile results on a quaternary U - Mo - Nb - V alloy and a ternary U - Mo - V alloy. In both cases the alloys were homogenized due to heat treating at 900°C prior to testing. The strength values shown for the quaternary alloy are approximately 10% higher than for the binary U - 10 Mo reference alloy. In the case of the U - 7.5 Mo - 2.5 V alloy, strength values are less than those for U - 10 Mo.

TABLE I  
TENSILE STRENGTH\* OF U - 7.5 Mo - 5 Nb - 2.5 V ALLOY

| Sample No. | Temperature (°C) | Ultimate T.S. (psi) | Yield Strength 0.2% Offset (psi) | Reduction of Area (%) | Elongation (%) |
|------------|------------------|---------------------|----------------------------------|-----------------------|----------------|
| 7          | R.T.             | 137,000             | 102,700                          | 4.0                   | 3.0            |
| 10         | 200              | 97,900              | 88,600                           | 7.0                   | 7.0            |
| 5          | 400              | 87,500              | 74,600                           | 18.0                  | 6.0            |
| 6          | 600              | 46,700              | 27,000                           | 31.0                  | 18.0           |
| 9          | 700              | 20,200              | 7,900                            | 57.0                  | 39.5           |
| 8          | 800              | 8,500               | 680                              | 2.7                   | —              |

\*Average results of two specimens at each temperature

TABLE II  
TENSILE STRENGTH OF U - 7.5 Mo - 2.5 V

| Sample No. | Temperature (°C) | Ultimate T.S. (psi) | Yield Strength 0.2% Offset (psi) | Reduction of Area (%) | Elongation (%) |
|------------|------------------|---------------------|----------------------------------|-----------------------|----------------|
| 2          | R.T.             | 111,500             | 45,000                           | 9.5                   | 5              |
| 4          | 200              | 81,800              | 68,000                           | 35.5                  | 17.5           |
| 5          | 400              | 161,700             | 100,500                          | 2.0                   | 2              |
| 6          | 600              | 45,500              | 20,900                           | 25.5                  | 10             |

\* Average results of two specimens at each temperature

This work was AEC-sponsored.

Submitted by Atomics International Division.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Ultrasonic Soldering to Produce High Reliability in Electrical Connection

3. OBJECTIVE:

The purpose of this study is to determine the feasibility of utilizing ultrasonic energy to create a solder wave and to produce sound and reliable solder joints.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Preliminary tests demonstrated that ultrasonic wave soldering is capable of producing improved soldered connections. The cavitation experienced in ultrasonic soldering aids in oxide removal, lowers the interfacial tension, and may allow wetting with nonactive fluxes, thereby enhancing solderability. Further efforts will be expended to evaluate pertinent parameters such as optimum frequency, transducer geometry, and power requirements.

New program: No data available. This work will be performed at Autonetics in conjunction with Air Force sponsored contracts. This program is moderate in size.

RA-61-1049-1  
11-1-61

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Residual Stress Measurement by Ultrasonics
3. OBJECTIVE:

To develop a nondestructive residual stress measurement technique which is more reliable, less expensive and more versatile than X-ray diffraction which is now the only nondestructive method. The system, if successful, will have immediate application to the study of dimensional stability in precision instrument materials but will also be widely used to solve a variety of commercial and military design and production problems.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

New Program - No data available. It is expected that this project, pending feasibility, will be funded by Autonetics and will be limited in size.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Effect of Imperfections on Solder Joint Reliability
3. OBJECTIVE:

Imperfections in the solder joints of etched circuit board assemblies may adversely effect reliability because of their susceptibility to corrosion and because of possible electrical and mechanical failure as a result of aging accelerated by vibration.

A study is being made to establish failure susceptibilities of printed (etched) circuit board assemblies with common types of solder joint imperfections both naturally occurring and artificially produced.

Board assemblies, mounted with components varying in lead material, diameter, and weight, will be soldered in a manner to induce a large number of imperfections (defects). An effort will be made to isolate different types of defects, such as voids, cold joints, depletion and poor wetting of leads and plated through-holes, observe their magnitude and obtain reliability data related to particular imperfections. The data are to be obtained by subjecting the boards to vibration, temperature extremes, aging and humidity.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

New program, no data available.

This work is being performed at Autonetics under Air Force sponsored contracts. This program is moderate in size.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Dimensional Stability Characteristics of Aluminum Alloys
3. OBJECTIVE:

Elastic limit and residual stress measurements in parts and materials were determined as functions of heat treatment variables in 2024 and A356 aluminum alloys. Similar work is being undertaken for Tens 50, Tenzalloy and X2020. This work is to determine the optimum heat treatments for these alloys and to study test methods directly related to dimensional stability (e.g., microcreep). The data are required in the design, fabrication, and reliability verification of high precision inertial instruments such as gyros, accelerometers and also optical systems where stability within one to five microinches per inch over several years is an objective. This is an extensive effort.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

The -T851 temper of 2024 alloy was determined to be optimum as was a boiling water quenched and sub-zero shock cycled version of the -T6 temper in A356. Typical values for residual stress and elastic limit in certain specific configurations of 2024 are as follows:

| <u>ALLOY</u> | <u>ELASTIC LIMIT, psi</u> | <u>RESIDUAL STRESS</u> |
|--------------|---------------------------|------------------------|
| 2024         | 30,000                    | 1,700                  |
| A356         | 10,000                    | 2,500                  |

This work has been supported by USAF in B-70 (N3B) and Minuteman Producibility Study programs, and is being conducted by Autonetics.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Resistance Strain Gage Methods for Establishing Material Dimensional Stability Parameters
3. OBJECTIVE:
  - (a) To develop a method for determining one microinch elastic limits in metallic materials.
  - (b) To obtain quick method for monitoring dimensional change as a function of materials and processes.
  - (c) To devise a technique for microcreep strain measurement.

These data are required in the design, fabrication and reliability evaluation of gyros, computer memories and other precision instruments where dimensional stability to 1-5 microinches/inch over periods of several years is an absolute essential. This is an extensive effort.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

A technique for measuring elastic limits has been developed in which the standard deviation in strain measurement error is less than  $4 \times 10^{-7}$  inch/inch. Long-time dimensional stability of materials can be monitored with an accuracy of four microinches per inch. Techniques for microcreep are still being developed. The work is being conducted at Autonetics and is supported largely by USAF Minuteman design and producibility studies.

1. MATERIAL CLASSIFICATION: Metallic Materials

2. TITLE: Evaluation of Forged "Instrument Grade" and Commercial Vacuum Hot Pressed Beryllium.

3. OBJECTIVE:

Five available types of beryllium will be evaluated extensively with respect to properties required for inertial navigation and computer components. Three of these will be commercially available vacuum hot pressed material, one will be forged and one will be a new "Instrument Grade" expected to be available soon. The parameters under study will include bulk soundness macro and microstructure, thermal expansion, precision elastic limit, and a very limited pilot survey aging phenomena.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

This is a new program; no data are available. The work will be performed at Autonetics under the sponsorship of the Air Force, Navy and Autonetics.

1. MATERIAL CLASSIFICATION: Metallic Materials

2. TITLE: Braised Corrugated Sandwich Development

3. OBJECTIVE:

1. Development of processing procedure for fabricating corrugated sandwich material using standard furnace brazing techniques.
2. Conduct a metallurgical evaluation to determine joint characteristics.
3. Conduct preliminary mechanical property tests for structural design purposes.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Furnace brazing retorts have been designed and fabricated. No sandwich panels have been fabricated to date. This work is Company-sponsored by the Columbus Division, and is being conducted under a moderate-in-size program.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Brazed Corrugated Sandwich Development
3. OBJECTIVE:
  1. Development of processing procedure for fabricating corrugated sandwich material using standard furnace brazing techniques.
  2. Conduct a metallurgical evaluation to determine joint characteristics.
  3. Conduct preliminary mechanical property tests for structural design purposes.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

This program is related to the overall effort to most effectively utilize the potentialities of various sandwich configurations. The comparatively low cost of corrugated core and use of existing furnace brazing methods makes this type of sandwich very attractive. Preliminary investigation of the feasibility of increasing the usage of brazed sandwich structures showed that corrugated core and facing sheets of PH15-7Mo stainless steel can be successfully brazed by current furnace techniques and at lower costs than panels with honeycomb core.

Retorts have been fabricated and corrugations, facing sheets and brazing foil have been assembled. The first assembly is ready for brazing.

This company-sponsored program is of moderate magnitude. Completion by 1 October 1962 is anticipated. Work is being performed by the Columbus Division.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Fracture Mechanism Study
3. OBJECTIVE:

Tensile tests will be conducted on specimens of various sizes, notch preparation and notch type, i.e. natural fatigue cracks and very sharp machined notches. E-11 steel, X-2020 and 7075 Al. alloys, B120 VCA and 4Al-3Mo-1V titanium alloys, and 17-7PH and PH15-7Mo alloys will be studied. Correlation between transition -temperature, notched/unnotched strength ratio,  $G_c$  values will be investigated.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Test specimens are being prepared. This project is Company-sponsored by the Columbus Division and is limited in magnitude.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Fracture Mechanism Study
3. OBJECTIVE:

Tensile tests will be conducted on specimens of various sizes, notch preparation and notch type, i.e. natural fatigue cracks and very sharp machined notches. H-11 steel, X-2020 and 7075 Al. alloys, B120 VCA and 4Al-3Mo-1V titanium alloys, and 17-7PH and PH15-7Mo alloys will be studied. Correlation between transition -temperature, notched/unnotched strength ratio,  $G_c$  values will be investigated.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Specimens have been finish machined from X-2020 aluminum and B120 VCA titanium alloys. Specimens remain to be machined from PH15-7Mo and 17-7PH stainless steels, 4Al-3Mo-1V titanium and 7075-T6 aluminum alloys. No testing has been completed to date. A limited number of room temperature tests should be conducted during the next quarter and a large portion of the small conventional specimens should be finish machined.

Test specimens are being prepared. This project is Company-sponsored, and is being conducted by the Columbus Division. This moderate-magnitude program is scheduled for completion in September 1962.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Residual Stresses in H-11 Steel Sheet & Their Effect on "Coralloy Y" Processing

3. OBJECTIVE:

Residual stresses will be measured by x-ray diffraction methods in H-11 steel specimens prepared by various processing methods, including straightening and plastic deformation at different points in the heat treatment cycle and stress relief treatments. Specimen with high residual tensile stresses will be Coralloy Y plated to determine the susceptibility to cracking.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Work done to date has been concerned with specimen preparation methods, calibration and experimental techniques to accomplish the program.

This project, considered to be 15% complete, is being performed under sponsorship of the Bureau of Naval Weapons by the Columbus Division and is an extensive program.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Residual Stresses in H-11 Steel Sheet and Their Effect on "Coralloy Y" Processing

3. OBJECTIVE:

Residual stresses will be measured by x-ray diffraction methods in H-11 steel specimens prepared by various processing methods, including straightening and plastic deformation at different points in the heat-treatment cycle and stress relief treatments. Specimen with high residual tensile stresses will be Coralloy Y plated to determine the susceptibility to cracking.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

This program has been discontinued. The investigation had not progressed sufficiently to obtain any reportable results. The project was being performed under Bureau of Naval Weapons sponsorship, and was to be of extensive magnitude. This was a Columbus Division program.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Effect of Section Size & Heat Treat on Notched Static & Fatigue Strength of H-11 Steel

3. OBJECTIVE:

The sharp notched static and fatigue strengths of CEVM steel heat treated to tensile strength ranges of 240-260, 260-280, 270-290 Ksi will be determined using various specimen geometries, such as flats, rounds and squares, and section sizes ranging from 0.180 to 16.0 sq. inches.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Project just starting - material has been received and specimens are being machined. This work is being performed under Bureau of Naval Weapons sponsorship by the Columbus Division. The program is extensive.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Effect of Section Size and Heat-Treat on Etched Static and Fatigue Strength of R-11 Steel
3. OBJECTIVE:

The sharp notched static and fatigue strengths of CEVM steel heat-treated to tensile strength ranges of 240-260, 260-280, 270-290 ksi will be determined using various specimen geometries, such as flats, rounds and squares, and section sizes ranging from 0.180 to 16.0 sq. inches.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

This program has been discontinued. A portion of the specimen machining work was completed but no reportable results were obtained. Program was being performed under the sponsorship of the Bureau of Naval Weapons and was to be of extensive magnitude. The program was conducted by the Columbus Division.

1. MATERIAL CLASSIFICATION: Metallic Materials

2. TITLE: Static & Fatigue Notched Strengths of H-11 Steel Sheet Weldments

3. OBJECTIVE:

To determine the notched and unnotched tensile strengths, at room and elevated temperature, of base material and welded specimens of Air Melt and CEVM H-11 steel heat treated to tensile strength levels of 240-260, 260-280, 270-290 ksi. The notched and unnotched fatigue strength under axial loading at room temperature and 650F, will be determined for similar specimens.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

None to date. Material for specimens has been received.

This work will be performed under Bureau of Naval Weapons sponsorship by the Columbus Division on an extensive scale.

NA-61-1049-2  
4-15-62

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Static and Fatigue Notched Strengths of E-11 Steel Sheet Weldments

3. OBJECTIVE:

To determine the notched and unnotched tensile strengths, at room and elevated temperature of base material and welded specimens of Air Melt and CEM E-11 steel heat-treated to tensile strength levels of 240-260, 260-280, 270-290 ksi. The notched and unnotched fatigue strength under axial loading at room temperature and 650°F. will be determined for similar specimens.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

This program has been discontinued. No reportable results were obtained. The program was to be extensive and performed under Bureau of Naval Weapons sponsorship at the Columbus Division.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Effect of Electrochem Milling on Fatigue of H-11 Steel

3. OBJECTIVE:

Repeated bending fatigue tests were conducted on mill surface and electro-chem milled specimens of H-11 steel with axis parallel to and transverse to the sheet-rolling direction. All specimens were heat treated to the 280-300 Ksi tensile strength range. S-N curves were obtained for the four conditions to evaluate the effects of electro-chem milling on the fatigue strength of the base material.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

The results obtained indicated that electro-chem milling had no significant effects on the fatigue life of H-11 steel.

This work is being performed under Bureau of Naval Weapons sponsorship and is approximately 90% completed. Program is being conducted by the Columbus Division and is moderate in size.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Effect of Electrochem Milling on Fatigue of H-11 Steel
3. OBJECTIVE:

Repeated bending fatigue tests were conducted on mill surface / electrochem milled specimens of H-11 steel with axis parallel and transverse to the sheet-rolling direction. All specimens were heat-treated to the 280-300 ksi tensile strength range. S-N curves were obtained for the four conditions to evaluate the effects of electrochem milling on the fatigue strength of the base material.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

This program has been discontinued. The raw data generated is not considered to be worth reporting. This moderate-magnitude project was being performed under Bureau of Naval Weapons sponsorship by the Columbus Division.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Determination of Mechanical Properties, Design Limits for  
240-260 Ksi H-11 Steel

3. OBJECTIVE:

To determine design allowables (tension, compression, shear and bearing) pertinent to the use of H-11 steel in the 240-260 Ksi range as an aircraft structural material.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Test specimens in preparation August 1961. This work is being performed under Bureau of Naval Weapons sponsorship. Completion is anticipated in December 1961 by the Columbus Division. The program is moderate in size.

EA-61-1049-2  
4-15-62

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Determination of Mechanical Properties, Design Limits for  
240-260 ksi E-11 Steel

3. OBJECTIVE:

To determine design allowables (tension, compression, shear and bearing) pertinent to the use of E-11 steel in the 240-260 Ksi range as an aircraft structural material.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Physical testing has been completed. Report to be prepared, with completion estimated as 1 June 1962. This moderate-magnitude program is sponsored by the Bureau of Naval Weapons at the Columbus Division.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Hastelloy R235, Determination of Design Properties
3. OBJECTIVE:

To determine elevated temperature design properties of both annealed and heat treated R235 sheet pertinent to its use as an aircraft structural material.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Heat treated R235 sheet retains its yield and ultimate strengths very well up to 1400F in addition to displaying good ductility. R235 also exhibits exceptionally high shear strength. Other design properties (compressive yield and bearing strengths) are correspondingly high.

For stability at temperatures above 1000F, R235 should be used in the aged condition, otherwise aging will occur in service.

There are no existing material specifications for R235. When minimum yield and ultimate strengths have been guaranteed by producers, the data determined by the investigation could be reduced to minimum "design allowables".

This work was performed under Company sponsorship and reported in NA61H-466 by the Columbus Division. The program was limited in magnitude.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Evaluation of 2618-T61 & 2618-F Aluminum Alloy Billet
3. OBJECTIVE:

Determine mechanical properties (including notched and unnotched tensile strength, bearing, shear, compression, stability, fatigue, and creep) of 2618 aluminum hand forged billets at room temperature, 250F, 325F and 400F. Billets include some which are purchased in the "F" condition and exceed the 4" thickness of Federal Spec. QQ-A-367. These billets will be reduced in thickness (prior to heat treatment) to a maximum thickness of 4" before the above named properties will be determined. Billet sizes to be examined include 3" x 6 $\frac{1}{2}$ "-T61, 4" x 8"-F, and 8" x 11"-F. Two suppliers' materials will be studied under this extensive program.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

No data available. This work is being performed under Bureau of Naval Weapons sponsorship. Completion is anticipated in July 1962 by the Columbus Division.

NA-61-1049-2  
4-15-62

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Evaluation of 2618-T61 and 2618-F Aluminum Alloy Billet
3. OBJECTIVE:

Determine mechanical properties (including notched and unnotched tensile strength, bearing, shear, compression, stability, fatigue, and creep) of 2618 aluminum hand-forged billets at room temperature, 250F, 325F and 400F. Billets include some which are purchased in the "F" condition and exceed the 4" thickness of Federal Spec. QQ-A-367. These billets will be reduced in thickness (prior to heat-treatment) to a maximum thickness of 4" before the above named properties will be determined. Billet sizes to be examined include 3" X 6-1/2"-T61, 4" X 8"-F, and 8" X 11"-F. Two suppliers' materials will be studied.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

This program discontinued when approximately 50% complete. Raw data were obtained, but not reduced. The program was originally planned to be of extensive magnitude, sponsored by the Bureau of Naval Weapons, and conducted by the Columbus Division.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Vacuum Melted Ultra-High Strength 25% Nickel Steel;  
Preliminary Evaluation
3. OBJECTIVE:

To determine tensile properties at Room Temperature, 600F, and 800F, room temperature notched tensile strength, and Charpy impact energy at RT and -100F.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Average tensile properties of the 25% nickel steel yielded the following:

| <u>Temp.</u> | <u>Elong.</u><br><u>%</u> | <u>Red. in Area</u><br><u>%</u> | <u>Fty</u><br><u>Ksi</u> | <u>Ftu</u><br><u>Ksi</u> | <u>Notched</u><br><u>Ftu</u><br><u>K<sub>t</sub> = 6.25</u><br><u>Ksi</u> |
|--------------|---------------------------|---------------------------------|--------------------------|--------------------------|---------------------------------------------------------------------------|
| RT           | 11.1                      | 38.1                            | 260.6                    | 272.0                    | 314.0                                                                     |
| 600F         | 12.1                      | 46.9                            | 219.0                    | 228.8                    | -                                                                         |
| 800F         | 19.6                      | 62.0                            | 166.5                    | 182.5                    | -                                                                         |

Charpy V-notch impact energy of the 25% nickel steel measured 16 ft.-lbs. at room temperature and 13.3 ft.-lbs. at -100F.

The 25% nickel steel is capable of being heat treated to ultra high strengths while maintaining good ductility. The material displayed an exceptionally high yield strength: 260 Ksi with a high Fty/Ftu ratio of 95.8%. The notched tensile strength appeared comparable to other ultra high strength steels. This alloy displayed good Charpy V-notch impact energy at room and low temperature (-100F)

This work was Company-sponsored and was performed by the Columbus Division under a limited program.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Stress-Relieving PH15-7Mo Fusion Weldments
3. OBJECTIVE:

An extensive program to develop procedures for reducing residual stresses in PH15-7Mo fusion butt weld joints is being conducted.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Various welding procedures and thermal treatments were applied in making 60" fusion butt welds in .090" PH15-7Mo CRES material. Standard techniques including weldment pre- and post-heating or "skip and back-step" had little effect on longitudinal residual stresses. Best results were obtained by heating and rapidly cooling the material adjacent to the weldment producing plastic deformation in the welds due to thermal expansion of the heated metal nearby. Another successful method applicable to PH steels involved sub-zero cooling the weld bead at -85F for three hours causing stress relief through transformation growth. This work was performed by the Los Angeles Division under U.S.A.F. sponsorship.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Molybdenum Alloy TZM Welded Structural Part Feasibility
3. OBJECTIVE:

To evaluate the problems involved in welding molybdenum alloy TZM by fabricating two simple structural parts. One, a sine wave web beam, is to be made by both the tungsten inert gas (TIG) and electron beam processes. The other part, a corrugated sandwich, is to be joined by electron beam and resistance welding processes. The program is moderate in size.
4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Welding in progress and no test data are yet available. The program is being conducted under company sponsorship by the Los Angeles Division.

1. MATERIAL CLASSIFICATION: Metallic Materials

2. TITLE: Preliminary Weldability Evaluation of Refractory Metal  
Alloys: Mo Alloy TZM, Co Alloy FS-82, Ta Alloy 90 Ta-10W

3. OBJECTIVE:

To determine weldability and preliminary weld tensile properties in molybdenum alloy TZM by the electron beam and resistance welding processes on a limited scale. Material will be tested from RT to 2400F in the "CW" condition and from RT to 3000F in the annealed condition. Preliminary weldability tests only will be performed on columbium alloy FS-82 and tantalum alloy 90 Ta-10W using tungsten inert gas, electron beam, and resistance welding processes.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Testing is in progress at this time. This work is being performed under company sponsorship by the Los Angeles Division.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: "Lack of Penetration" Defects in Assembly Fusion Welds
3. OBJECTIVE:

Development of procedures for reducing the occurrence of "lack of penetration" defects in fusion welded butt joints between honeycomb panels is being performed on a limited basis. This type of defect sometimes occurs in welds which, although penetrating completely through the joint material, has wandered away from the joint centerline on the "drop-thru" side.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Several techniques appear promising for reducing "lack of penetration" including longitudinal oscillation of the welding electrode and optimization of welding parameters. The most promising techniques will be evaluated under manufacturing conditions, i.e., long welds in honeycomb panels, inexperienced machine operators, imperfect fit-up of joint members, etc. No test data have been generated as yet. This work is being conducted by the Los Angeles Division under U.S.A.F. sponsorship.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Protection of Honeycomb Core from Erosion by Fusion (TIG) Welding Arc Plasma

3. OBJECTIVE:

Welding together of brazed honeycomb sandwich panels often brings the welding arc plasma very close to honeycomb core, resulting in core "burning". Preliminary tests indicated that a coating of alumina ( $Al_2O_3$ ) sprayed on to the core minimizes this burning. A limited program to develop and test this coating is being conducted.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Work is in progress to determine if small amounts of various organic binders can improve adhesion of the alumina to the honeycomb core. Although the adhesion presently obtained is satisfactory from the standpoint of core protection, it is desirable to reduce or eliminate spalling of the coating, which could contaminate the weld joint area. Test results are not yet available. This work is being performed by the Los Angeles Division under U.S.A.F. sponsorship.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Stud Welding Honeycomb Panel Applications; 347 Stainless Steel Pins Welded to 7015-7Mo, Braze Steel Honeycomb Panels

3. OBJECTIVE:

A limited program is being conducted to establish the process limitations for welding 1/16 and 1/8 inch diameter pins to the internal surface of honeycomb face sheets. This will provide a means of rework and/or repair of brazed honeycomb panels when access is limited to one surface.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Test results are not yet available. The work is being conducted under U.S.A.F. sponsorship by the Los Angeles Division.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Stick Welding Process Limitations and Design Allowables
3. OBJECTIVE: This previously reported program has been expanded to include the investigation of 1/16, 3/32, 1/8, 3/16, and 1/4 inch diameter pins made from 304 CRES, 321 CRES, and WPH13-7Mo materials. In addition, strength values for various pin to face sheet combinations will be determined under this now moderate-in-size program.
4. ABSTRACT OF RESULTS OR CONCLUSIONS: The test work is approximately 60% complete. The information obtained is being used to establish preliminary design allowables, process limitations and to prepare a process specification. The work is being conducted by the Los Angeles Division under U.S.A.F. sponsorship.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Establishment of Low Strength Level Arc-Spot Welds
3. OBJECTIVE:

A program to establish the minimum nugget diameters and resulting arc-spot shear strengths for PH15-7Mo material thicknesses greater than .036 inch is being conducted on a limited basis. This information will provide design information for minimum edge distance and spot spacing requirements for the arc-spot process.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Preliminary tests have determined a low strength level for arc-spots to be 50% of the published "M" strengths in material thicknesses up to and including .036 inch PH15-7Mo. Yet to be determined are the low level arc spot strengths in thicknesses greater than .036 inch PH15-7Mo. The work is being conducted by the Los Angeles Division under U.S.A.F. sponsorship.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Gage Determination for Resistance Welding Three-Sheet Sandwiches of PEL5-7Mo CRES
3. OBJECTIVE:

A limited program is being conducted to determine the minimum outer sheet gage which can be used in resistance welding three sheet sandwiches containing an .020", .063" or .090" inner sheet while maintaining an outer to inner gage ratio of 2:1. This work will provide both gage combination and edge distance information.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

No data has been determined to date. The program is being conducted by the Los Angeles Division under U.S.A.F. sponsorship.

1. MATERIAL CLASSIFICATION: Metallic Materials

2. TITLE: Room and Elevated Temperature Spot Weld Data for  
INCO 718, Nickel-Base Alloys

3. OBJECTIVE:

A determination of room and elevated temperature lap shear and cross tension strengths for spot welded INCO 718 has been conducted on a limited basis for design use.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

The results obtained have been used to establish design allowables for spot welds made in heat treated material and for spot welds made in annealed material heat treated after welding. The test work was performed by the Los Angeles Division under U.S.A.F. sponsorship.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Nickel Plated 355 CRES Weldability Test
3. OBJECTIVE:

To determine the weldability of lap joints that have been nickel plated for corrosion protection and to determine the effect of (3) three plating processes and the range of plating thickness, on the Arc-Spot and Resistance welding parameters and weld strengths.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Initial tests indicate plating thickness variations of .003 inch upset the standard welding parameters. In addition .004 inch of hard nickel has a detrimental effect upon the parent material. This moderate program is being conducted by the Los Angeles Division under U.S.A.F. sponsorship.

1. MATERIAL CLASSIFICATION: Metallic Materials

2. TITLE: Post-Braze Attachments to Honeycomb Structure by  
Fusion Welding

3. OBJECTIVE:

A moderate program to establish fusion welding procedures and equipment requirements for attaching members (angles, tees, etc.) to PH15-7Mo brazed honeycomb steel sandwich structure is being conducted.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Welding procedures, design information, process data and equipment requirements were established for publishing design allowables and process specification. Such things as thickness limitation, thickness ratios, welding speed, current, voltage, shielding gas and filler metal were established in order to prevent damage to the brazed bond between core and face sheet directly under the weld bend. Sponsored by USAF, the program is being conducted at the Los Angeles Division.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Thermal Emittance Measurements of Anodized and Dyed-Anodized 2219-T81 Aluminum Alloy

3. OBJECTIVE:

Total thermal emittance measurements are being made on 2219-T81 aluminum alloy test specimens with sulfuric-acid anodized surfaces and with several different dyed-anodized surfaces. The emittance measurements are being made for temperatures between 300F and 600F to determine the temperature control afforded by these surface treatments.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

No test results have, as yet, been obtained. This limited program is being conducted under company sponsorship by the Los Angeles Division.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Investigation of Methods of Extrapolation of Short Time Creep Data for Ti 3Al-4V and AM350 CRES
3. OBJECTIVE:

A limited program is currently being conducted to establish a method of extrapolating short time creep data to long time. Three techniques most extensively used are being investigated: Manson-Haeferd, Larson-Miller and Dorn.

4. ABSTRACTS OF RESULTS OR CONCLUSIONS:

Data are being generated at test temperatures from 600F to 1000F and test durations from one to 500 hours. Values for 0.1, 0.2, 0.5 and 1.0% creep deformation are being plotted on master curves using all three aforementioned techniques in order to permit extrapolation. Master curve plots for the titanium alloy is nearly complete; however, difficulty due to some undetermined metallurgical change has been experienced with the AM350 alloy. The program is being conducted by the Los Angeles Division under company sponsorship.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Transverse Ductility and Notch Sensitivity of  
440A and 420 Steel Bar
3. OBJECTIVE:

A limited test program was conducted on smooth and notched specimens of 440A and 420 steels. Tests were conducted to determine if these alloys have adequate ductility and notch strength in the transverse direction for use as rod seals in hydraulic actuator cylinders.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

The test results are listed below. Specimens were heat treated to a hardness of 50 to 55 Rc.

|                                     | <u>UTS</u><br><u>ksi</u> | <u>TYS</u><br><u>ksi</u><br><u>Smooth</u> | <u>% Elong.</u> | <u>RA %</u> |
|-------------------------------------|--------------------------|-------------------------------------------|-----------------|-------------|
| 420 Steel                           | 241.6                    | 211.0                                     | 8               | 15          |
| 440A Steel                          | 176.1                    | -                                         | <1              | <1          |
| <u>Notched, K<sub>t</sub> = 2.5</u> |                          |                                           |                 |             |
| 420 Steel                           | 321.7                    | -                                         | -               | -           |
| 440A Steel                          | 148.7                    | -                                         | -               | -           |

The above values are the average of three specimens. The results show that 440A is very brittle in the short transverse direction, and, therefore, would not be usable for rod seal application. The ductility and notch strength of 420 is adequate for the aforementioned application. The work was conducted under U.S.A.F. sponsorship by the Los Angeles Division.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Short Transverse Properties of 15-7AMV Steel Alloy
3. OBJECTIVE:

Mechanical properties testing is being conducted under a limited program to verify supplier data published for a new PH steel. Short transverse mechanical properties are also being investigated.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Macro and microexamination of a cross-section have been completed. There is evidence of many long stringers of retained austenite and heavy carbide networks. Tensile testing has not yet begun. This work is being performed under company sponsorship by the Los Angeles Division.

NA-61-1049-2  
4-15-62

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Short Transverse Properties of 15-7AMV Steel Alloy
3. OBJECTIVE:

Mechanical properties testing is being conducted under a limited program to verify supplier data published for a new PH steel. Short transverse mechanical properties are also being investigated.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Macro and microexamination of a cross-section have been completed. There is evidence of many long stringers of retained austenite and heavy carbide networks. Transverse tensile properties were very poor as compared to those determined for the longitudinal direction, and stress corrosion tests performed at applied stress levels of 80% tensile yield strength produced failures in less than 8 hours in a 20% salt spray environment. This work was completed under company sponsorship by the Los Angeles Division.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Effects of High Temperatures on Mechanical Properties of Refractory Metals
3. OBJECTIVE:

This program is investigating the deteriorating effects of high temperatures on mechanical properties of refractory metals. Uncoated specimens of molybdenum alloy TZM, columbium alloys FS-82 and F-48, and unalloyed tantalum are being exposed to temperatures up to about 3000F to determine recrystallization and grain growth behavior. Tension and simple riveted joint specimens of TZM and FS-82, with oxidation protective coatings, are being heated up to about 3000F for varying times and then tested for mechanical strength in comparison with unheated specimens. Creep strength, and static strength after exposure to creep conditions, are being determined. Specimens subjected to the various test conditions are being examined for progressive diffusion of the coatings into the base metals.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

This extensive program is being performed under company sponsorship by the Los Angeles Division. Results on all phases of the program are incomplete. Molybdenum alloy TZM was found to begin recrystallization at about 2400F, and columbium alloy FS-82 at about 2000F. Preliminary data have indicated that the room temperature tensile properties of FS-82, protected with a NAA-developed coating, are not degraded after exposure to static air for 3 hours at 2600F.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Design Allowables for PH13-8Mo Steel Bar
3. OBJECTIVE:

Notched and unnotched static strength in longitudinal, long transverse and short transverse for standard and braze cycle heat treatments are being determined at room temperature and at 600F. Other determinations include:

1. Fatigue ( $R=+0.1$ ), notched and unnotched at room temperature and at 500F.
2. Stress corrosion at 80% tensile yield strength.
3. Tensile creep 650F, 800F, 900F for 10,000 and 1000 hours at 0.2%, 1% and 2% permanent deformation.
4. Growth characteristics by dilatometry.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

The alloy to date has not met short transverse ductility requirements established for sizes. This extensive work is being performed under U.S.A.F. sponsorship by the Los Angeles Division.

1. MATERIAL CLASSIFICATION: Metallic Material
2. TITLE: Design Allowables for PHL3-8Mo Steel Bar
3. OBJECTIVE:

Notched and unnotched static strength in longitudinal, long transverse and short transverse for standard and braze cycle heat treatments are being determined at room temperature and at 600 F. Other determinations include:

1. Fatigue ( $R=40.1$ ), notched and unnotched at room temperature and at 500 F.
  2. Stress corrosion at 80% tensile yield strength.
  3. Tensile creep 650 F, 800 F, 900 F for 10,000 and 1000 hours at 0.2%, 1% and 2% permanent deformation.
4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Erratic short transverse properties in 3" x 4" cross-sections have eliminated this material from further consideration. Extensive heat treatment studies failed to consistently improve short transverse properties through the center of bar material studied, although mid-radius and edge locations exhibited good mechanical properties. This work has been performed under U.S.A.F. sponsorship by the Los Angeles Division.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: 350 CRT CRKS Aging Evaluation
3. OBJECTIVE:

Static strength, burst strength, impulse fatigue, bending fatigue, stress corrosion, and metallurgical tests are being conducted. Residual stress measurements are being made and a technique for residual stress control is being evaluated.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Glass bead peening of the tube O.D. surface only using .014 arc intensity has been effective in reducing residual stresses from as high as 116,000 psi to 6,000 - 14,000 psi. This moderately sized program is being conducted under U.S.A.F. sponsorship by the Los Angeles Division.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Investigation of the Effects of Oronite 8200 Hydraulic Fluid on Bare H-11 Alloy Steel Under Environmental Conditions
3. OBJECTIVE:

Internal H-11 alloy steel components of hydraulic cylinders and valve bodies that will be exposed to Oronite 8200 hydraulic fluid will be used without protective coatings. The corrosive action, if any, of Oronite 8200 hydraulic fluid and its redissolved combustion products on H-11 alloy steel are unknown. The following tests, simulating environmental conditions will be made to determine if Oronite 8200 causes detrimental effects on bare H-11 alloy steel; (all test coupons heat treated 260,000 to 280,000 psi) (a) sustained load tests at 2/3 of F<sub>tu</sub> for 500 hours at 620 F, specimens immersed in Oronite 8200 hydraulic fluid, (b) sustained load tests at 2/3 F<sub>tu</sub> for 500 hours at 620 F, specimens suspended in air while periodically coated with Oronite 8200 hydraulic fluid (burned off fluid remaining on specimen redissolved with each application of fresh fluid), and (c) static tensile strength of test specimens exposed to (a) and (b) conditions above.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

No data are as yet available. The moderately sized program is being conducted under U.S.A.F. sponsorship by the Los Angeles Division.

NA-61-1049-1  
11-1-61

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Effects of Temperature and Stress on the Mechanical Properties of Metals
3. OBJECTIVE:

A limited program is in progress to determine the room temperature tensile properties of AM350 and Ti-6Al-4V alloys after exposure to temperatures of 650 and 750 F and to stresses which will produce approximately 1 percent creep in 10,000 to 25,000 hours.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

No data have been recorded to date. The program is being conducted under company sponsorship by the Los Angeles Division.

NA-61-1049-1  
11-1-61

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Effects of Oxidation on PH15-7Mo Steel Braze Panels
3. OBJECTIVE:

Braze panels (10" x 10" x 1") are to be placed in circulating air at elevated temperatures. One series of panels are to be subjected to 500 F and 630 F for 300 and 1500 hrs. Another series of panels will be coated around the edges with RTV 60 silicone compound and subjected to the same environmental conditions. After environmental conditioning, flatwise tensile specimens will be taken from each section and compared to a set of control samples. The program is moderate in size.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

No data have as yet been determined from this work. The program is being conducted by the Los Angeles Division under U.S.A.F. sponsorship.

1. MATERIAL CLASSIFICATION:    Metallic Materials
2. TITLE:    Repair of Brazed Honeycomb Sandwich Panels by Electro-Deposit.
3. OBJECTIVE:    Previous investigations have indicated the feasibility of utilizing electro-deposited nickel as a means of repairing brazed honeycomb face sheets damaged by indentions or creases. The purpose of this investigation is to establish process requirements for applying electro-deposited fillers and to evaluate the strength of such fillers and the possibility of attaching doublers by spot brazing to the fillers.
4. ABSTRACT OF RESULTS OR CONCLUSIONS:

A process has been developed for the electro-deposition of sulfamate nickel to fill dents or creases as a repair process for brazed honeycomb structural panels.

Tensile properties at room temperature and 630 F have been determined for the deposited nickel.

To date attempts to spot braze doublers to the deposited nickel with the hand-gun used to repair honeycomb panels have been unsuccessful.

A satisfactory test of adhesion has not been developed at this time. This moderately sized program is being conducted under U.S.A.F. sponsorship by the Los Angeles Division.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Brazing Characteristics and Shear Strength of 80-20 LTCM with Pd replaced by Ni.
3. OBJECTIVE:

A moderate-in-size determination of the optimum brazing thermal cycle to produce 100% node flow and minimum alloy damage is being experimentally made. Using this braze cycle the following are being established:

- (a) Fillet size obtained with 3-10 core
- (b) Drainage characteristics
- (c) Shear strength of brazed joints at room and elevated temperatures.

Removal of Pd from this alloy without changing its brazing characteristics will lower the cost of this alloy from \$2.00/troy to \$1.50/tr oz.

4. ABSTRACT OF RESULTS AND CONCLUSIONS:

- a. The brazing temperature for the alloy was lowered 50 F by removing Pd.
- b. The fillet size, depth of diffusion into PH15-7Mo steel, drainage characteristics, joint strengths up to 1000 F, and thermal conductance of the alloy were unaffected by removal of Pd.
- c. The lower brazing temperature is not compatible with the process currently used for brazing PH15-7Mo H/C sandwich.
- d. Since only the braze temperature was affected by removing Pd, the balance of the Cu and Ag can be adjusted to raise the brazing temperature to the desired 1725 F. This work is being performed by the Los Angeles Division under U.S.A.F. sponsorship.

1. MATERIAL CLASSIFICATION:    Metallic Materials
2. TITLE:    Elevated Temperature Properties of Lap Joints Brazed  
                  with AMS 4769 Alloy

3. OBJECTIVE:

A limited program is being conducted to determine the lap shear strengths of joints brazed with AMS 4769 alloy at RT, 300 F, 500 F, and 700 F, and develop the 1 hr, 10 hr, 100 hr, and 1000 hr stress rupture curves between RT and 650 F. AMS 4769 alloy has been selected for use in post braze attachment, necessitating development of the elevated temperature characteristics, which will be used for determination of design allowables.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

No data have been generated to date. Work is being performed by the Los Angeles Division under U.S.A.F. sponsorship

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Elevated Temperature Properties of Lap Joints Brazed with AMS 4769 Alloy
3. OBJECTIVE:

A limited program is being conducted to determine the lap shear strengths of joints brazed with AMS 4769 alloy at RT, 300 F, 500 F, and 700 F, and develop the 1 hr., 10 hr., 100 hr., and 1000 hr stress rupture curves between RT and 650 F. AMS 4769 alloy has been selected for use in post braze attachment, necessitating development of the elevated temperature characteristics, which will be used for determination of design allowables.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Average lap shear strengths for a 0.500" overlap length between room and various elevated temperatures are tabulated below:

| <u>Temperature</u> | <u>Lap Shear Strength</u> |
|--------------------|---------------------------|
| Room               | 12,000 psi                |
| 300 F              | 7,600 psi                 |
| 500 F              | 3,900 psi                 |
| 700 F              | 2,700 psi                 |

Stress-rupture tests were performed for 10 hr, 100 hr, and 1000 hr durations. Representative 1000 hr data are presented:

| <u>Temperature</u> | <u>1000 hr. stress<br/>Rupture Strength</u> |
|--------------------|---------------------------------------------|
| 300 F              | 4,100 psi                                   |
| 400 F              | 2,600 psi                                   |
| 500 F              | 1,400 psi                                   |
| 600 F              | 650 psi                                     |
| 700 F              | 400 psi                                     |

This work was completed by the Los Angeles Division under U.S.A.F. sponsorship.

1. MATERIAL CLASSIFICATION:    Metallic Materials
2. TITLE:    Lap Shear Strength of Resistance Brazed Spots at Room  
                  and Elevated Temperature
3. OBJECTIVE:    Design allowables are being determined for lap  
                  shear joints of heat treated PH15-7Mo members and brazed honeycomb  
                  sandwich panels made by the indirect resistance spot brazing  
                  process. Data will be obtained for selected gage combinations  
                  and temperature relative to parent metal or braze failure.
4. ABSTRACT OF RESULTS OR CONCLUSIONS:

This moderate-in-size program has just been initiated by the  
Los Angeles Division under U.S.A.F. sponsorship and no test  
data are available yet.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Lap Shear Strength of Resistance Brazed Spots at Room and Elevated Temperature
3. OBJECTIVE: Design allowables have been determined for lap shear joints of heat treated PH15-7Mo members and brazed honeycomb sandwich panels made by the indirect resistance spot brazing process. Data were obtained for selected gage combinations and temperature relative to parent metal or braze failure for 1/4 inch diameter spot braze.
4. ABSTRACT OF RESULTS OR CONCLUSIONS:

This moderate-in-size program was initiated by the Los Angeles Division under U.S.A.F. sponsorship. Results are as follows:

SINGLE SPOT BRAZE STRENGTHS AT  
ROOM TEMPERATURE

| Face sheet<br>to doubler<br>combination | Strength<br>lb. | Percent<br>Variation | Spot<br>Dia.in. | Percent<br>Variation | Typical<br>Failure |
|-----------------------------------------|-----------------|----------------------|-----------------|----------------------|--------------------|
| .006/.006                               | 489.5           | 13.7                 | .265            | 0                    | Doubler            |
| .006/.010                               | 729.1           | 37.5                 | .286            | 17.5                 | Braze              |
| .009/.009                               | 872.0           | 13.5                 | .312            | 11.2                 | Braze              |
| .012/.012                               | 843.2           | 12.2                 | .295            | 25.4                 | Braze              |
| .012/.020                               | 808.6           | 10.3                 | .306            | 4.9                  | Braze              |
| .016/.016                               | 1166.5          | 40.1                 | .282            | 30.1                 | Braze              |
| .020/.020                               | 1265.0          | 10.9                 | .290            | 12.1                 | Braze              |
| .020/.030                               | 1492.0          | 30.9                 | .299            | 16.7                 | Braze              |
| .040/.040                               | 1442.7          | 33.8                 | .314            | 3.2                  | Braze              |

SINGLE SPOT BRAZE STRENGTHS  
AT 600 F

| Face Sheet<br>to doubler<br>combination | Strength<br>lb. | Percent<br>Variation | Spot<br>Dia.In. | Percent<br>Variation | Typical<br>Failure |
|-----------------------------------------|-----------------|----------------------|-----------------|----------------------|--------------------|
| .006/.006                               | 417.5           | 38.3                 | .205            | 0                    | Doubler            |
| .009/.009                               | 636.7           | 20.3                 | .301            | 21.6                 | Braze              |
| .016/.016                               | 821.8           | 47.7                 | .304            | 16.4                 | Braze              |

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Oxidation Protection of Refractory Metals for Advanced Vehicles
3. OBJECTIVE:

This program is investigating the feasibility of utilizing several available coatings to protect mechanically jointed sections of refractory metals from erosion and gross oxidation. Commercially available coatings for molybdenum alloy TZM, columbium alloys FS-82 and F-48, and unalloyed tantalum, and a coating developed for columbium alloys by NAA, have been screened by oxidation and erosion testing of simple coupons at temperatures up to about 3000 F. Following initial screening, simple riveted joint specimens of FS-82 and TZM have been coated and are being evaluated by erosion testing in a high temperature, high velocity air stream and by thermal cycling and stressing in high temperature static air. Finally, several complex mechanically fastened specimens of FS-82 and TZM have been designed and coated, and are being tested.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

This extensive program is being performed under company sponsorship by the Los Angeles Division. Incomplete results of the screening tests indicate that the Dursk B coating may be useful for protecting molybdenum up to about 3000 F, and that the LB-2 coating may be useful for protecting columbium up to about 2500 F. Other coatings for columbium, molybdenum, and tantalum were either found to be inferior to Dursk B or LB-2, or are still being screened.

1. MATERIAL CLASSIFICATION:    Metallic Materials
2. TITLE:    Determination of Heat Effect and Spacing on the Lap  
                Shear Strength of Indirect Resistance Spot Brazed Joints.

3. OBJECTIVE:

Lap shear strength determinations are being conducted in spot brazed joints of heat treated PH15-7Mo steel doublers and brazed honeycomb sandwich panels. Joint strengths and schedules will be established for single spot brazes and various gage combinations. Specimens will be tested and evaluated using multiple 1/4 inch diameter spots spaced 1/4, 3/8, 1/2 inch on centers. Micro hardness determinations will be made on panel face sheet and attaching members for the extent of the heat affected area.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

No test data are as yet available. This extensive program is being conducted by the Los Angeles Division under company sponsorship.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Determination of Heat Effect and Spacing on the Lap Shear Strength of Indirect Resistance Spot Brazed Joints.

3. OBJECTIVE:

Lap shear strength determinations were conducted in spot brazed joints of heat treated PH15-7Mo steel doublers and brazed honeycomb sandwich panels. Joint strengths and schedules were established for single spot brazes and various gage combinations. Specimens were tested and evaluated using multiple 1/4 inch diameter spots spaced 1/4, 3/8, 1/2 inch on center. Micro hardness determinations were made on panel face sheet and attaching members for the extent of the heat affected area.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

This extensive program was conducted by the Los Angeles Division under U.S.A.F. sponsorship. The heat-affected zone diameter was between .500 and .730 inches for face sheet to doubler combinations from .006/.006 inches to .022/.080 inches as determined by V<sub>10</sub> hardness traverse on single spot macrospecimens. The optimum spot spacing was 3/8 inch for attachments to .006 and .012 with face sheets and 1/4 inch for attachments to .022 face sheets. Additional data are tabulated as follows:

| Face Sheet<br>to Doubler<br>Combination | Spot spacing, in.   |                      |                                   |                      |                                   |                      |
|-----------------------------------------|---------------------|----------------------|-----------------------------------|----------------------|-----------------------------------|----------------------|
|                                         | 1/2                 |                      | 3/8                               |                      | 1/4                               |                      |
|                                         | Average<br>Strength | Percent<br>Variation | Average<br>Strength<br>lb/lin.in. | Percent<br>Variation | Average<br>Strength<br>lb/lin.in. | Percent<br>Variation |
| 006/006                                 | 697                 | 21.7                 | 892                               | 20.7                 | 800                               | 10.0                 |
| 006/040                                 | 1083                | 13.9                 | 1056                              | 9.4                  | 853                               | 9.4                  |
| 012/012                                 | 1666                | 9.0                  | 1938                              | 3.1                  | 1493                              | 8.0                  |
| 012/080                                 | 1608                | 4.7                  | 2020                              | 6.1                  | 1920                              | 12.5                 |
| 022/020                                 | 1683                | 3.0                  | 2154                              | 25.7                 | 2773                              | 11.5                 |
| 022/080                                 | 1633                | 3.1                  | 1969                              | 0                    | 2220                              | 24.1                 |

Ref: NA-61-1049-1, note that this program was U.S.A.F. sponsored rather than company sponsored as originally reported.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Effect of Heat Treatment Intergranular Oxidation on Mechanical Properties of Rene' 41
3. OBJECTIVE:

Tensile tests at 80 and 1400F and fatigue tests at 80F are to be conducted on Rene' 41 sheet specimens containing .0005 to .0008" of intergranular oxidation. Similar tests will also be conducted on control specimens containing no intergranular oxidation. The intergranular oxidation in the test specimens will be obtained by heat treating the specimens in air. The heat treatment of the control specimens will be conducted in argon to avoid intergranular oxidation. The program is of limited size.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

All the tensile tests have been completed and results are listed below. Each value in the table is the average of two tests. The fatigue tests still remain to be conducted.

| <u>Test Temp.</u> | <u>Gage</u> | <u>Tensile Ultimate, ksi</u> |                      | <u>Tensile Yield, ksi</u> |                | <u>% Elongation</u> |                |
|-------------------|-------------|------------------------------|----------------------|---------------------------|----------------|---------------------|----------------|
|                   |             | <u>Test Spec.</u>            | <u>Control Spec.</u> | <u>Test</u>               | <u>Control</u> | <u>Test</u>         | <u>Control</u> |
| 80F               | .014"       | 181.3                        | 196.5                | 136.8                     | 140.2          | 15.0                | 13.7           |
| 80F               | .020"       | 194.3                        | 195.8                | 150.2                     | 149.0          | 17.2                | 13.5           |
| 80F               | .040"       | 188.0                        | 193.5                | 137.0                     | 136.0          | 19.5                | 20.0           |
| 1400F             | .020"       | 132.5                        | 136.3                | 116.7                     | 115.4          | 3.0                 | 2.8            |

The tensile test results do not show any significant effects of intergranular oxidation on tensile properties. This work is being conducted by the Los Angeles Division under U.S.A.F. sponsorship.

1. MATERIAL CLASSIFICATION: Metallic Materials

2. TITLE: Mechanical Properties of Forged K-Monel at Cryogenic Temperatures.

3. OBJECTIVE:

The objective is to obtain design data for heavy K-Monel forgings in the aged condition at cryogenic temperatures. This is a moderate program.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

A 5" x 9" x 15" forging of K-Monel (QQ-N-286, Class A) was sectioned to prepare tensile, notch tensile, and Charpy V impact specimens in both longitudinal and transverse directions. Test specimens were rough machined in the as forged condition, heat treated, then finish machined. Heat treatment was as follows:

1. Stabilized at 800°F for 30 minutes, charged into furnace stabilized at 1550°F for 30 minutes and water quenched.
2. Aged at 1090  $\pm$  10°F for 16 hours, furnace cooled at 20°F/hour to 900°F, air cooled from 900°F.

Average test results are shown below:

| Temp.<br>°F | Impact Energy<br>Ft - # |        | U.T.S. - KSI |         | T.Y.S. - KSI |         | % Reduction<br>of Area |        | % Elong.<br>1" Gage |        | Notch/Unnotch<br>Ratio<br>K <sub>t</sub> = 6.4 |        |
|-------------|-------------------------|--------|--------------|---------|--------------|---------|------------------------|--------|---------------------|--------|------------------------------------------------|--------|
|             | Long.                   | Trans. | Long.        | Trans.  | Long.        | Trans.  | Long.                  | Trans. | Long.               | Trans. | Long.                                          | Trans. |
| -110        | 50                      | 47.5   | 150,100      | 151,500 | 95,900       | 95,700  | 48.0                   | 41.0   | 28                  | 27     | 1.25                                           | 1.22   |
| -110        | 49                      | 45     | 159,400      | 162,800 | 103,800      | 104,500 | 47.0                   | 41.8   | 33                  | 31     | - -                                            | - -    |
| -320        | 51                      | 42.5   | 177,700      | 179,200 | 121,400      | 119,700 | 53.5                   | 45.0   | 34                  | 37     | 1.29                                           | 1.29   |
| -423        | 52                      | 44     |              |         |              |         |                        |        |                     |        |                                                |        |

Preliminary tests show that K-Monel is not notch sensitive and does not have directional properties at cryogenic temperatures. This work, performed by Rocketdyne, was sponsored by NASA and is 80% complete.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: High and Low Temperature Tensile Properties of RA330.
3. OBJECTIVE:

Determination of tensile properties at cryogenic, room and elevated temperatures. This work is a moderate program.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

|                            | <u>Room Temperature</u> | <u>2100°F</u> |
|----------------------------|-------------------------|---------------|
| Ult. Tensile Strength, psi | 78,000                  | 3830          |
| Yield Strength 0.2% Offset | 32,000                  | 3330          |
| % Elongation in 2"         | 49                      | 89            |

This NASA sponsored work is being performed by Rocketdyne and is 25% complete.

WA-61-1049-1  
11-1-61

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: High and Low Temperature Tensile Properties of RA333.
3. OBJECTIVE:

Determination of tensile properties at cryogenic, room and elevated temperatures. This work is a moderate program.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

|                            | Temperature of |        |        |        |      |
|----------------------------|----------------|--------|--------|--------|------|
|                            | -320           | Room   | 500    | 1500   | 2100 |
| Ult. Tensile Strength psi  | 153,000        | 92,400 | 85,900 | 42,300 | 6300 |
| Yield Strength 0.2% Offset | 82,100         | 47,100 | 32,400 | 35,900 | 4000 |
| % Elongation in 2"         | 47.5           | 43.5   | 47     | 22.5   | 40   |

Work is being performed by Rocketdyne and is NASA sponsored. This work is 50% complete.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Mechanical Properties of welded Inconel 718.
3. OBJECTIVE:

To determine the mechanical properties of Inconel 718 after welding, with several sequences of thermal treatment, at temperatures between -320°F and 1500°F, in .070" and .167" material. This was an extensive program.

4. ABSTRACT OF RESULTS OF CONCLUSIONS:

The following table lists a few representative values of ultimate tensile strength across welds at various temperatures.

| TEST | WELDING SEQUENCE |           |           |                |
|------|------------------|-----------|-----------|----------------|
|      | Weld, ST, Age    | Weld, Age | Age, Weld | Age, Weld, Age |
| -320 | 214,000          | 229,500   | 180,000   | 231,600        |
| R.T. | 166,000          | 172,000   | 133,000   | 166,600        |
| 1000 | 152,600          | 147,500   | 108,500   | 165,000        |
| 1500 | 73,500           | 70,400    | 62,400    | 73,800         |

It was found that even short periods of aging improved the properties of the welded material. Cracking during welding was more of a problem with material heat treated before welding, but was not serious even here, except under conditions of severe restraint.

This work, performed by Rocketdyne, was NASA sponsored and is complete.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Effect of Brazing Temperatures on Properties of Inconel 718.
3. OBJECTIVE:

To determine whether any reduction in heat treated mechanical properties of Inconel 718 could be anticipated due to exposure of the material to temperatures in excess of optimum solution treating temperature (1725°F). This work was a limited program.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

The following table shows the results obtained:

|                    |                       | Solution Treating Temperature °F |        |        |
|--------------------|-----------------------|----------------------------------|--------|--------|
|                    |                       | 1725                             | 1950   | 2150   |
| Tested<br>at -320F | Yield Strength        | 189100                           | 161200 | 157900 |
|                    | Ultimate Tensile Str. | 243500                           | 230500 | 222300 |
|                    | % Elongation          | 27.0                             | 32.0   | 30.2   |
| Tested<br>at R.T.  | Yield Strength        | 162900                           | 133200 | 128900 |
|                    | Ultimate Tensile Str. | 190200                           | 161800 | 173300 |
|                    | % Elongation          | 22.7                             | 26.1   | 25.3   |
| Tested<br>at 1200F | Yield Strength        | 133000                           | 110700 | 106700 |
|                    | Ultimate Tensile Str. | 156000                           | 145300 | 136900 |
|                    | % Elongation          | 9.5                              | 14.0   | 12.0   |

The material is not severely affected by overheating so far as mechanical properties go, possibly 15-20%. Time and funds restricted the scope of investigation into side effects such as corrosion resistance, and these efforts could be checked prior to specification of such elevated temperature processing. Since brazing can be done at or below 1950°F, the problem is not pressing.

This work was company sponsored by Rocketdyne and is complete.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Dimensional Stability of Inconel Alloy X-750
3. OBJECTIVE:

The objective was to determine the dimensional change of Inconel alloy X-750 after thermal treatment. This work was a limited program.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

A one-inch diameter bar of Inconel alloy X-750 was cut into six 11 inch (nominal) lengths and treated to the conditions shown in Table II

TABLE I

INCONEL ALLOY X-750 TEST BAR INITIAL CONDITIONS

| Specimen Description | Condition        | Thermal Treatment                                                                         | Hardness Rc |
|----------------------|------------------|-------------------------------------------------------------------------------------------|-------------|
| A                    | Annealed         | One hour at 1950F, air cooled                                                             | 29          |
| B                    | Stress equalized | 24 hours at 1625, air cooled                                                              | 21          |
| C                    | Brazed           | F-1 braze cycle                                                                           | 25          |
| D                    | Equalized & aged | 24 hours at 1625F, air cooled, aged                                                       | 34          |
|                      |                  | 10 hours at 1300F, air cooled                                                             |             |
| E                    | "1550" condition | One hour at 1950F, air cooled<br>charged into 1550F furnace,<br>held 16 hours, air cooled | 26          |
| F                    | Hot rolled       | As-received, no treatment                                                                 | 31          |

These bars were then treated in a typical furnace braze cycle and aged 10 hours at 1300F, with measurements before and after each treatment. The results are shown in Table II.

TABLE II  
DIMENSIONAL CHANGES OF INCONEL ALLOY X-750  
AFTER THERMAL TREATMENTS

| Specimen Designation | Length before Braze Inches* | Length After Braze Inches* | Unit Change in Length Due to Brazing in/in | Length After Aging Inches* | Unit Change in Length Due to Aging in/in | Total Unit Change in Length due to Braze & Age in/in | Final Hardness Rockwell "C" |
|----------------------|-----------------------------|----------------------------|--------------------------------------------|----------------------------|------------------------------------------|------------------------------------------------------|-----------------------------|
|                      | (a)                         | (b)                        | $\frac{(a - b)}{a}$                        | (c)                        | $\frac{(b - c)}{b}$                      | $\frac{(a - c)}{a}$                                  |                             |
| A                    | 11.1741                     | 11.1642                    | .000886                                    | 11.1633                    | .0000807                                 | .000967                                              | 33                          |
| B                    | 11.2119                     | 11.2012                    | .000954                                    | 11.2002                    | .0000893                                 | .001042                                              | 31                          |
| C                    | 11.1552                     | 11.1469                    | .000744                                    | 11.1458                    | .0000987                                 | .000842                                              | 31                          |
| D                    | 11.1739                     | 11.1657                    | .000735                                    | 11.1646                    | .0000985                                 | .000833                                              | 33                          |
| E                    | 11.1638                     | 11.1532                    | .000950                                    | 11.1521                    | .0000986                                 | .001048                                              | 36                          |
| F                    | 11.0842                     | 11.0737                    | .000948                                    | 11.0724                    | .0001175                                 | .001065                                              | 31                          |

\*All length values represent the average of four measurements.

This work was performed under NASA sponsorship by Rocketdyne and is 100% complete.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Effect of Cooling Rate on Mechanical Properties of Inconel-X (X-750)
3. OBJECTIVE:

The objective was to determine the effect of the cooling rate from the solution anneal or brazing temperature on the ductility of Inconel-X. This was a limited program.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

| Condition of Inconel-X<br>(1/8 in. thick stock)                                                                                                      | Trend of "room temperature elongation<br>as ordinate, rate of cooling as<br>abscissa" curve                                                 |
|------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| Solution treated at 1950°F,<br>then cooled at rates varying<br>from 6000°F/min. to 0.6°F/min.<br>within 1700° to 1100°F range.                       | 50% elongation at 6000°/min., reaching<br>a minimum of 23% between 10 and<br>20°F/min. and increasing to 30%<br>elongation at 0.6°F/min.    |
| Solution treated at 1950°F,<br>cooled at rates from 6000°F/<br>min. to 0.6°F/min., within<br>1700 to 1100°F range, and<br>aged four hours at 1300°F. | 33% elongation at 6000°/min., reach-<br>ing a minimum of 22% between 10 and<br>20°F/min., and increasing to 25%<br>elongation at 0.6°F min. |

As a result of this investigation, three basic points have been established concerning cooling rate and hardness:

1. Within cooling rate range produced by water quenching down to rates of 200°F/min., hardness varies inversely with cooling rate.
2. Within the cooling rate range of 200°F/min. to 10°F/min., hardness is not particularly rate dependent and is a maximum for as cooled material.
3. At cooling rates less than 10°F per minute, hardness varies directly with cooling rate.

This work was done by Rocketdyne under NASA sponsorship and is complete.

11-1-61

1. MATERIAL CLASSIFICATION: Metallic Materials2. TITLE: Single Age Versus Double Age on Inconel Alloy 718:3. OBJECTIVE:

The objective is to compare the advantages of the double age as compared to the single age on Inconel 718, using stock thickness, rate of cooling from solution treatment, and testing temperature as parameters. This work is a moderate program.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

A disc forging was sectioned to yield radial and rim tangential specimens, and, after having been solution treated for two hours at 1725°F and air cooled, these were either single aged or double aged. The single age is 16 hours at 1325°F; the double age is 8 hours at 1325°F, furnace cool to 1150°F and hold until a total aging time of 16 hours elapses. Average results are shown below:

| <u>Location of Specimen</u><br><u>in Inconel 718 Forging</u> | <u>Temperature</u> | <u>Aging</u><br><u>Treatment</u> | <u>UTS</u><br><u>KSI</u> | <u>TYS</u><br><u>KSI</u> | <u>%</u><br><u>Elong.</u> | <u>Hardness</u><br><u>Rc</u> |
|--------------------------------------------------------------|--------------------|----------------------------------|--------------------------|--------------------------|---------------------------|------------------------------|
| Rim Tangential                                               | Room               | Single                           | 181                      | 149                      | 29                        | 39                           |
|                                                              |                    | Double                           | 188                      | 161                      | 29                        | 41                           |
|                                                              | 1100°F             | Single                           | 151                      | 124                      | 22                        |                              |
|                                                              |                    | Double                           | 157                      | 134                      | 26                        |                              |
| Radial                                                       | Room               | Single                           | 180                      | 142                      | 28                        | 39                           |
|                                                              |                    | Double                           | 184                      | 157                      | 28                        | 41                           |
|                                                              | 1100°F             | Single                           | 154                      | 117                      | 18                        |                              |
|                                                              |                    | Double                           | 158                      | 131                      | 22                        |                              |

Preliminary work indicates the double age increases ultimate and yield strengths without impairing ductility. This work is being performed by Rocketdyne under NASA sponsorship and is approximately 25% complete.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Mechanical Properties of Single and Double Aged Inconel 718
3. OBJECTIVE:

To determine and evaluate the tensile properties of Inconel 718 in the double aged condition as compared to those of the single aged condition. The work described herein is part of a comprehensive study intended to supplement existing information and is a moderate effort.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Ten smooth and ten notched tensile specimens were machined from one inch barstock, solution treated, and then tested in the single and double aged conditions at -423F, 80F, and 1300F. The results of the tests are shown in the attached table.

The double aging treatment resulted in an increase in the strength of Inconel 718 at the temperatures investigated. However, there is an indication of some loss in ductility at elevated temperatures.

This investigation was performed by Rocketdyne under NASA contract and is 50% complete.

MECHANICAL PROPERTIES OF INCONEL 718

| Aging Treatment | Test Temp. °F | U.T.S. KSI | Y.S. .2% Offset KSI | Elong. in 4" Dia. % | Red. of Area % | Notched Strength** KSI | Notched Strength Ratio | Hard. Rc |
|-----------------|---------------|------------|---------------------|---------------------|----------------|------------------------|------------------------|----------|
| Single          | 1300          | 148.0      | 127.0               | 41.0                | 59.7           | 227.5                  | 1.54                   | 39.      |
| Double          | 1300          | 152.7      | 130.7               | 30.5*               | 56.6           | 226.0                  | 1.48                   | 42.      |
| Single          | 80            | 202.2      | 162.6               | 24.5                | 36.6           | 265.0                  | 1.31                   | 40.      |
| Double          | 80            | 211.0      | 174.0               | 24.0                | 32.4           | 266.0                  | 1.26                   | 43.      |
| Single          | -423          | 243.2      | 203.0               | 18.0                | 20.6           | 300.0                  | 1.23                   | ---      |
| Double          | -423          | 256.7      | 234.0               | 19.5                | 19.1           | 321.0                  | 1.25                   | ---      |

\*Result of one test. Second specimen failed in gage mark.

\*\*Kt - Varied between 4.0 and 4.4

Note: All material solution treated one hour at 1750F, air cooled prior to aging.

Single Aging Treatment: 16 hours @ 1325F.

Double Aging Treatment: 8 hours @ 1325F furnace cooled to 1150F, held @ 1150F long enough to make the total aging time 16 hours, air cooled.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Properties of Oxygen Free High Conductivity Copper
3. OBJECTIVE:

The objective was to compile the physical and mechanical properties of OFHC copper at temperatures ranging from -423°F to 1900°F. This was a limited program.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Data were collected in 100°F increments on tensile strength, yield strength, elongation, thermal expansion, thermal conductivity, and specific heat. Shown below is an abstract of the results.

| Property                  | Trend of "property as ordinate, temperature as abscissa" curves                                                          |
|---------------------------|--------------------------------------------------------------------------------------------------------------------------|
| Ultimate Tensile Strength | 77,000 psi at -423°F decreasing in a concave upward type curve to around 660 psi at 1900°F                               |
| Ductility                 | Goes through a minimum of 20% elongation between 600°F and 800°F. At 1900°F, elongation is over 50%.                     |
| Thermal Conductivity      | A fairly straight line function between 400°F and 1600°F with the value decreasing from 2600 to 2300 BTU/sq.ft/in/°F/hr. |

The work was performed by Rocketdyne under company sponsorship and is complete.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Evaluation of 17-4PH Stainless Steel Sheet in Welded Pressure Vessel Applications
3. OBJECTIVE:

Since experimentally produced 17-4PH sheet was available, evaluation tests were conducted for the purpose of determining tensile properties of welded and unwelded sheet material in the H900, H950, and H1000 conditions. A pressure vessel design, previously produced in 17-7PH, was fabricated from 17-4PH and tested to destruction in the H900, H950, and H1000 conditions and the results compared to those obtained with 17-7PH. This program was completed and was of moderate size.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

The following can be concluded from the tests performed:

1. The burst pressure of the 17-4PH pressure vessels increased with the heat treat strength level to a condition H900 which was the highest strength level investigated herein.
2. The GAM-77 Ammonia Pressure Vessel constructed of 17-4PH stainless may be heat treated to 200,000 psi ultimate tensile strength (Condition H900) without evidence of brittle failure of decrease in burst pressure. The burst pressure accompanying this highest pressure as compared to 17-7PH stainless steel tanks, heat treated to the 150,000-170,000 psi range, which burst from 2500 to 3000 psi.
3. Severe forming and deep drawing should be performed in the over-aged condition (H1200) after which the 17-4PH material must be solution annealed before aging to gain maximum strength.
4. Longitudinal and transverse notched-to-unnotched tensile ratios ( $K_t-3$ ) of 17-4PH wrought sheet were greater than unity in conditions H900, H950, and H1000 (200,000 psi, 194,000 psi, and 179,000 psi average ultimate tensile strength, respectively). The elongation for the longitudinal and transverse tensile specimens in these three conditions was greater than 7%.

This work was done at S&ID of MAA and was Company-Sponsored.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Evaluation of Surface Preparation Treatments to Improve Low Temperature Braze Sealing of CRES Joints
3. OBJECTIVE: This limited program is being conducted to determine a surface preparation or treatment for CRES steel joints, such as those of PH15-7Mo or 355, which will improve the integrity of the braze seal, promote wetting, flow, and adherence of the braze alloy and/or subsequently reduce the brazing time and/or temperature.
4. ABSTRACT OF RESULTS OR CONCLUSIONS: Preliminary feasibility tests have indicated that surface treatments can affect brazing characteristics. No further data are as yet available. The work is being conducted by the Los Angeles Division under U.S.A.F. sponsorship.

NA-61-1049-2  
4-15-62

1. MATERIAL CLASSIFICATION: **Metallic Materials**
2. TITLE: Honeycomb Panel Sealing with Resistance Seam Welded Foil Doublers
3. OBJECTIVE: This limited program was conducted to establish a process for seam welding doubler material to PH15-7Mo brazed honeycomb face sheets in order to form a pressure carrying seal.
4. ABSTRACT OF RESULTS OR CONCLUSIONS: PH15-7Mo steel foil .0015" in thickness has been satisfactorily welded to honeycomb panels ranging in face sheet gages from .012 to .060". These weldments have withstood 100 cycles of 30 psi pressurization. The effort is being conducted under U.S.A.F. sponsorship by the Los Angeles Division.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Preliminary investigation of 18Ni-7Co-5Mo High Strength Steel Alloy
3. OBJECTIVE: The 18Ni-7Co-5Mo steel alloy is one of a group of new materials reported to have exceptional toughness (resistance to notch effects) at high strength levels. Limited tests will be made to determine (1) room and elevated temperature smooth round-bar tensile properties, (2) room and elevated temperature notched ( $K_t \approx 3.5$ ) round-bar tensile strength, and (3) charpy "V" notch impact strength at room temperature and -65 F.
4. ABSTRACT OF RESULTS OR CONCLUSIONS:

| Temp.<br>F | TYS<br>KSI | UTS<br>KSI | NTS<br>KSI | UTS/NTS | %EL  | %RA  | Charpy<br>Ft-lb |
|------------|------------|------------|------------|---------|------|------|-----------------|
| RT         | 248.7      | 258.7      | 414.3      | 1.60    | 9.0  | 55   | 49.2            |
| 70C        | 201.9      | 217.9      | 327.7      | 1.50    | 10.0 | 59.5 | -               |
| -65        | -          | -          | -          | -       | -    | -    | 43.0            |

This program is being conducted by the Los Angeles Division under U.S.A.F. sponsorship.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Dimensional Stability Study of Selected Magnesium Alloys
3. OBJECTIVE:
  - 1) The purpose of this work was to determine the precision elastic limits of selected magnesium alloys heat treated for optimum dimensional stability.
  - 2) To monitor dimensional change of alloys selected from the precision plastic limit results.

This data is required to assist designers of inertial sensing elements to meet critical mass balance requirements for long periods of time.

4. ABSTRACT OF RESULTS:

The precision elastic limits of the Magnesium Alloys tested ranged from 2,000 psi for ZK60A-T5 to 7,500 psi for AZ31B-F bar stock. From these tests four alloys have been selected and are presently being tested for long-time stability using conventional resistance strain gages as well as semi-conductor strain gages.

An evaluation of strain gages and adhesives in the stressed condition has been conducted for use on micro creep measurement. One strain gage type and adhesive combination has remained stable under loads up to 25,000 psi to + 10 microinches/inch for a three month period. Semiconductor strain gages are presently being monitored in a positive-negative gage full bridge circuit for use on long-time stability tests. Sensitivity 0.01 microinches/inch is being realized, but room temperature variations cause fluctuations of  $\pm 1$  microinch/inch. This moderate-in-size program is being conducted by Autometrics.

MA-61-1049-2  
4-15-62

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Crushing Strength of PH 15-7 Mo Astroweld Honeycomb Core
3. OBJECTIVE: A limited program is being conducted to compare the compression or crushing strength of diffusion bonded honeycomb core with the compression strength of resistance welded honeycomb core. Tests are being performed on low density configurations of both at the brazing temperature (1740 F).
4. ABSTRACT OF RESULTS OR CONCLUSIONS: Testing is underway and early results appear to indicate the superiority of the Astroweld core (diffusion bonded at the nodes) over the normally resistance welded core on the basis of resistance to crushing at 1740 F. This program is being conducted by the Los Angeles Division under USAF sponsorship.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Effect of HT-15 Braze Alloy Diffusion on Mechanical Properties of PH 15-7 Mo Steel
3. OBJECTIVE: This limited program is being conducted to determine the diffusion characteristics of HT-15 when the alloy is used to braze PH 15-7 Mo steel and to determine whether any detrimental effects to the properties of the latter occur as a result of brazing at high temperatures for extended periods of time.
4. ABSTRACT OF RESULTS OR CONCLUSIONS: Not yet completed testing indicates some degradation of PH 15-7 Mo properties after brazing at temperatures from 1730 to 1900 F for 1/2, 2 and 6 hour durations. This program is being conducted by the Los Angeles Division under USAF sponsorship.

NA-61-1049-2  
4-15-62

1. MATERIAL SPECIFICATION: Metallic Materials
2. TITLE: Effects of N2 Content on the Fatigue Life of Fusion Butt Welded H-11 Steel
3. OBJECTIVE: Axial tension fatigue tests of hand TIG welded H-11 sheet heat treated to 280-300,000 psi are being conducted at room temperature. Welds were made in vacuum melted sheet using vacuum melted weld filler wires containing from 30 to 145 parts per million nitrogen. The information will be used in establishing weld fatigue life and determining gas content levels for welding wire procurement specifications.
4. ABSTRACT OF RESULTS OR CONCLUSIONS: No data have been generated to date. This limited program is being conducted by the Los Angeles Division under U.S.A.F. sponsorship.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Investigation of Fatigue of 260-280 KSI Consumable  
Electrode Vacuum Melted H-11 Steel at Room Temperature
3. OBJECTIVE: Project will establish room temperature axial loaded  
( $R = 0.05$ ) S-N fatigue curves for unnotched and notched ( $K_t = 3.5$ )  
consumable electrode vacuum melted H-11 alloy steel heat treated  
to 260-280 ksi. One heat of material will be tested under this  
limited program.
4. ABSTRACT OF RESULTS OR CONCLUSIONS: Fabrication of specimens has  
started: no test results to date. The project is being conducted  
by the Los Angeles Division under U.S.A.F. sponsorship.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Evaluation of Mechanical Properties of Large Forgings of Inconel 718 Alloys
3. OBJECTIVE:

To determine the relationship of the forging practice on the ductility properties of large Inconel 718 alloy forgings. This is a moderate effort.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

A large forging was made of consumable electrode vacuum melted Inconel 718 alloy into a die forging approximately 8 in thick by 22 in diameter. The initial group of forgings exhibited inadequate ductility due to residual ingotism in the forging. Subsequent forgings were produced using an improved forging practice which included more working to minimize ingotism in the final part and these possessed improved ductility with full strength properties. Representative values are tabulated.

| Sample  | Processing                   | Location    | Mechanical Properties |             |                          |
|---------|------------------------------|-------------|-----------------------|-------------|--------------------------|
|         |                              |             | U.T.S.<br>KSI         | Y.S.<br>KSI | Elongation<br>% in 4 X D |
| 1st lot | Inadequate working of metals | Center      | 162.7                 | 131.5       | 6.0                      |
|         |                              | Mid-section | 174.6                 | 147.4       | 10.5                     |
| 2nd lot | Increased working of metals  | Center      | 182.5                 | 143.0       | 15.0                     |
|         |                              | Mid-section | 179.9                 | 147.9       | 28.0                     |
| 3rd lot | Similar to 2nd lot           | Center      | 171.1                 | 133.0       | 21.0                     |
|         |                              | Mid-section | 176.4                 | 143.8       | 28.5                     |

The minimum acceptable elongation value is 10%. The results indicate the necessity for closely controlled forging procedures when there is limited mechanical working between ingot size and final part size. This work is being performed by Rocketdyne sponsored by NASA and is 75% complete.

1. MATERIAL CLASSIFICATION: Metallic Material

2. TITLE: Mechanical Properties of Hy-Tuf Steel At Cryogenic Temperatures.

3. OBJECTIVE:

The objective is to obtain design data for Hy-Tuf steel in the 220/240 ksi heat treat level at cryogenic temperatures. This is a moderate effort.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Round tensile, notch tensile, and Charpy V impact specimens were machined from 3/4" diameter rod. Test specimens were rough machined in the as received condition, heat treated to 220/240 ksi and finish ground. This was a moderate effort.

Average test results below:

| Temp.<br>°F | Charpy V<br>Impact<br>Ft - # | U.T.S. - KSI | T.Y.S. - KSI | % Elong.<br>4D | % Reduction<br>of Area | Notch/Unnotch<br>Tensile<br>Ratio<br>Kt = 6.4 |
|-------------|------------------------------|--------------|--------------|----------------|------------------------|-----------------------------------------------|
| R.T.        | 26.5                         | 231.5        | 194.0        | 14.0           | 50.0                   | 1.43                                          |
| -110        | 22.0                         | 245.0        | 220.5        | 31.8           | 51.2                   | 1.41                                          |
| -200        | 10.1                         | - - -        | - - -        | ---            | ---                    | ---                                           |
| -250        | 8.3                          | - - -        | - - -        | ---            | ---                    | ---                                           |
| -320        | 8.2                          | 281.5        | 248.1        | 16.1           | 35.5                   | 0.816                                         |
| -423        | 7.1                          | 316.0        | 292.5        | 0.5            | 1.0                    | ---                                           |

Tests show Hy-Tuf to be completely notch sensitive at -423F. Further testing is required to establish usable low temperature limits. This work performed by Rocketdyne and NASA sponsored is 75% complete.

1. MATERIAL CLASSIFICATION: Metallic Material

2. TITLE: Mechanical Properties of AISI 4340 Plate at Cryogenic Temperatures

3. OBJECTIVE:

The objective is to obtain design data for AISI 4340 plate, AMS 6359, in the 160/180 ksi heat treat level, at cryogenic temperatures. This was a moderate effort.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Flat tensile and notch tensile test specimens were machined from 1/4" thick plate in both the longitudinal and transverse directions. Test specimens were rough machined in the as received condition, heat treated to the 160/180 ksi strength level and finish ground. Average test results below.

| Temp.<br>OF | U.T.S. - KSI |        | T.Y.S. - KSI |        | % Elong.<br>2" Gage |        | Notch/Unnotch<br>Tensile Ratio<br>K <sub>t</sub> = 6.4 |        |
|-------------|--------------|--------|--------------|--------|---------------------|--------|--------------------------------------------------------|--------|
|             | Long.        | Trans. | Long.        | Trans. | Long.               | Trans. | Long.                                                  | Trans. |
| R.T.        | 161.6        | 158.8  | 154.1        | 161.6  | 12.8                | 12.5   | 1.23                                                   | 1.19   |
| -100        | 175.0        | 172.7  | 165.6        | 162.9  | 14.3                | 11.9   | 1.18                                                   | 1.15   |
| -320        | 220.1        | 218.1  | 211.2        | 208.8  | 16.3                | 14.2   | 0.97                                                   | 0.87   |
| -423        | 261.5        | 248.4  | 261.5        | 248.4  | 4.0                 | 4.1    | 0.45                                                   | 0.42   |

Tests show that AISI 4340 plate heat treated to 160/180 ksi becomes notch sensitive below -320F and should be used with caution in parts containing stress concentrations. This work, performed by Rocketdyne, was NASA sponsored and is 90% complete.

1. MATERIAL CLASSIFICATION: Metallic Material
2. TITLE: Properties of a New Nickel Base Alloy IN-102
3. OBJECTIVE:

The objective is to obtain design data for the material in the solution treated and aged condition at elevated and subzero temperatures. This is a moderate program.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Thirty flat test specimens (1/8 T) were machined per Method 211 Section 4.1.3 of the Federal Test Methods Standard No. 151, for testing tensile properties.

Fifteen specimens were tested in the annealed condition - as received.

Fifteen specimens were tested after aging for 24 hours at 1300F.

Twelve full tube sections 1/2" O.D. x 0.028" wall were heated to 2150F and furnace cooled 60F/min - simulating brazing cycle - and tested for tensile properties.

Average test results are as follows:

| Temperature<br>OF | Property            | CONDITION   |            |                                   |
|-------------------|---------------------|-------------|------------|-----------------------------------|
|                   |                     | As Received | Aged 1300F | Heated to 2150F<br>Cooled 60F/Min |
| Room              | Ult. Tens. Strength | 118,000     | 120,900    | 120,200                           |
|                   | 0.2% Yield Strength | 47,400      | 48,500     | 51,600                            |
|                   | Elong., % in 2"     | 49.5        | 51.5       | 52.6                              |
| 500               | Ult. Tens. Strength | 108,500     | 107,300    | 108,600                           |
|                   | 0.2% Yield Strength | 37,600      | 37,800     | 41,100                            |
|                   | Elong., % in 2"     | 50.7        | 48.0       | 48.8                              |
| 1000              | Ult. Tens. Strength | 100,500     | 98,700     | 110,000                           |
|                   | 0.2% Yield Strength | 34,300      | 38,400     | 37,500                            |
|                   | Elong., % in 2"     | 50.5        | 48.8       | 60.0                              |
| 1500              | Ult. Tens. Strength | 50,600      | 54,600     | 57,900                            |
|                   | 0.2% Yield Strength | 33,500      | 35,300     | 35,800                            |
|                   | Elong., % in 2"     | 50.0        | 67.0       | 37.0                              |
| -320              | Ult. Tens. Strength | 161,700     | 159,400    | 163,400                           |
|                   | 0.2% Yield Strength | 67,200      | 67,400     | 79,400                            |
|                   | Elong., % in 2"     | 50.1        | 47.6       | 57.1                              |

Preliminary tests show promising properties  
at high and low temperatures and almost constant  
yield strength within a 1000F temperature range.

The work is sponsored by Rocketdyne and is 25%  
complete.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Mechanical Properties of Rene' 41 Alloy As-Welded
3. OBJECTIVE:

To determine the tensile properties of aged Rene' 41 in the as-welded condition at various temperatures between 80 and 1700F. This work was a limited program.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Rene' 41 sheet stock 0.312" thick was solution treated at 1975F and aged at 1400F. Specimens were subsequently TIG welded using Hastelloy W filler wire and tensile tested in this condition. Weld reinforcements removed. Results are given in the following table.

| Specimen Identification | Test Temp. °F | Yield Strength KSI | Ultimate Strength KSI | Elongation - % in |      |      | Location of Fracture |
|-------------------------|---------------|--------------------|-----------------------|-------------------|------|------|----------------------|
|                         |               |                    |                       | 2"                | 1"   | 1/2" |                      |
| Parent Metal            | R.T.          | 138.0              | 177.0                 | 7.5               | ---  | ---  |                      |
| W-1                     | R.T.          | 98.0               | 134.5                 | 4.7               | 10.1 | 15.8 | Weld Metal           |
| W-2                     | R.T.          | 89.6               | 131.5                 | 6.0               | 11.0 | 19.6 | Weld Metal           |
| W-3                     | R.T.          | 99.0               | 134.5                 | 4.7               | 8.0  | 16.0 | Weld Metal           |
| Parent Metal            | 1000          | 130.3              | 172.6                 | 8.5               | ---  | ---  |                      |
| W-5                     | 1000          | 81.6               | 108.7                 | 4.5               | 10.5 | 20.0 | Weld Metal           |
| W-6                     | 1000          | 75.3               | 108.8                 | 5.2               | 11.0 | 22.0 | Weld Metal           |
| W-7                     | 1000          | 78.8               | 109.5                 | 5.7               | 11.0 | 20.8 | Weld Metal           |
| Parent Metal            | 1200          | 121.8              | 163.5                 | (1)               | ---  | ---  |                      |
| W-9                     | 1200          | 73.6               | 107.5                 | 6.0               | 14.0 | 20.0 | Weld Metal           |
| W-10                    | 1200          | 76.3               | 97.8                  | 5.0               | 9.0  | 17.0 | Weld Metal           |
| W-11                    | 1200          | 81.1               | 103.0                 | 4.0               | 11.0 | 20.0 | Weld Metal           |
| Parent Metal            | 1450          | 109.5              | 119.0                 | (2)               | ---  | ---  |                      |
| W-13                    | 1450          | (3)                | 97.0                  | 4.5               | 7.0  | 14.0 | Weld Metal           |
| W-14                    | 1450          | 71.5               | 85.6                  | 4.5               | 7.0  | 14.0 | Weld Metal           |
| W-15                    | 1450          | 71.0               | 81.6                  | 4.5               | 7.0  | 14.0 | Weld Metal           |
| Parent Metal            | 1700          | 52.7               | 61.6                  | 22.0              | ---  | ---  |                      |
| W-17                    | 1700          | 37.4               | 53.8                  | 6.0               | 11.0 | 22.0 | Weld Metal           |
| W-18                    | 1700          | 36.8               | 49.8                  | 7.5               | 15.5 | 28.0 | Weld Metal           |
| W-19                    | 1700          | 39.8               | 50.2                  | (4)               | 11.0 | 22.0 | Weld Metal           |

(1) Clevis pin sheared.

(2) Fractured outside 2 inch gage marks.

(3) Shearing action noted on clevis pin.

(4) Two inch gage marks severely oxidized.

This work was performed by Rocketdyne under NASA contract and is complete.

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Weld Joint Properties of High Strength-to-Weight Ratio Materials
3. OBJECTIVE:
  - (a) To determine the weldability and mechanical properties of newly-developed high strength-to-weight and heat resisting alloys.
  - (b) To determine the most suitable welding process and techniques to yield the highest weld efficiency.
  - (c) To investigate new welding processes such as electron beam, short arc, plasma jet, etc., and compare results with known processes such as TIG and conventional MIG.
4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Cold reduced RS 140 titanium sheet has higher "as-welded" strength than RS 140 in the solution heat treated condition.

Titanium welded with the electron beam process produces welds with greater ductility than those made with the TIG process.

Spot welded doublers on RS 140 titanium tensile specimens increased the fusion weld joint strength very little over the "as-welded" strength, with a resultant loss of ductility.

Heat treatment of RS 140 and RS 8Al-10V titanium alloys after welding, increased the tensile strength with a resultant loss of ductility.

Roll planishing of both electron beam and TIG welds on 30LXFH and AM355 produced greater tensile properties than welds tested in the "as-welded" condition.

Resistance spotwelded doublers on cold reduced AM 355 and 30LXFH stainless, produced marked increase in tensile strength.

Tensile properties of electron beam welded 1/8" 2024-T3 aluminum were no higher than those made with the automatic TIG process.

Electron beam welds cannot be made on cold reduced or heat treated materials without some loss of strength.

This work was done at S&ID of NAA and was Company-Sponsored.

4-15-62

1. MATERIAL CLASSIFICATION: Metallic Materials
2. TITLE: Grain Size Related to Strength of Welds in 2014-T6 Al Alloy Forgings
3. OBJECTIVE:

An intermediate sized investigation of a problem of hot-short cracking adjacent to fusion welds in 2014-T6 aluminum alloy forgings has disclosed that a coarse grain condition in the forgings prior to welding, is the primary factor responsible for both crack sensitivity and low weld joint strength. The results of an earlier investigation indicated a relationship between radiographic grain contrast and cracking susceptibility in fusion welded 2014-T6 forgings. Further study has shown that 2014-T6 forgings can be differentiated into four classifications on the basis of radiographic grain contrast; fine, moderate, Type A and Type B coarse. Information was required regarding the mechanical properties and microstructural characteristics of 2014-T6 forgings which exhibit the aforementioned degrees of grain contrast.

The specific objectives were as follows:

1. To determine the uniaxial tensile and fatigue strengths of composite 2014-T6/2024-T3 fusion welds as a function of radiographic grain contrast in the forging.
2. To determine the relationship between radiographic grain contrast and the microstructure of 2014-T6 forgings.
3. To determine whether shot-peening prior to fusion welding will prevent hot-short cracking in coarse grained 2014-T6 forgings.
4. To determine the microstructural criteria for 2014-T6 forgings from the standpoint of optimum fusion weldability.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

The following can be concluded from the results obtained:

1. The uniaxial strength of 2014-T6/2024-T3 fusion welds diminished with increased radiographic grain contrast in the forging. Fatigue strength was not correlated with radiographic grain contrast.
2. Radiographic grain contrast in 2014-T6 forgings was found to be a qualitative measure of grain size and the degree of preferred orientation in the area to be fusion welded.
3. Hot-short cracking in coarse grained 2014-T6 forgings was prevented by shot-peening prior to welding, however tensile strength of the weldments was not satisfactory.

Page 2

4. ABSTRACT OF RESULTS OR CONCLUSIONS: (Cont'd.)

4. Forgings which exhibited optimum fusion weldability were characterized by a fine sub-grain structure with extensive fragmentation of intermetallic constituents.

This work was performed at the S&ID of NAA in connection with an Air Force Contract.

1. MATERIAL CLASSIFICATION: Metal Repair Filler
2. TITLE: Physical Properties of Nickel Plating and Plasma-Sprayed Steel Alloy as Used for Repair of Brazed Steel Honeycomb Sandwich Panels.
3. OBJECTIVE: Previous investigations have indicated the feasibility of utilizing both electrolytic sulfamate nickel plating and plasma-sprayed Metco 42C steel alloy powder for repairing indentations and wrinkles in the face sheets of brazed honeycomb-core sandwich as well as improving structural strength of those panel areas having crushed core. However, further testing is necessary to obtain certain physical properties data on the plated and plasma-sprayed metal which are required for use in structural analysis of panel repairs made by the application of deposits of these metals. Tests are being conducted on both repair metals in both the as deposited condition and after heating aging for 250 hours at 460 F (to simulate elevated temperature service conditions). The specific tests being conducted on the repair metals include:
  1. Fatigue design curves for sheets of repair metal.
  2. Fatigue design curves for repair metal laminated to PH15-7Mo CRES.
  3. Complete stress-strain curves to failure for the repair metals.
  4. The adhesion to PH15-7Mo CRES of the repair metals as determined by block-shear tests.
4. ABSTRACT OF RESULTS OR CONCLUSIONS: No test results have been obtained to date. This extensive program is being conducted by the Los Angeles Division under U.S.A.F. sponsorship.

Period 1 February 1962 to 1 August 1962

Title. Super-Titanium Alloy Evaluation

Objective. The over-all objectives of this program are

1. To select and evaluate a high strength titanium alloy for compressor wheels and blades operating at temperatures up to 1000°F in advanced air breathing engines.
2. To evaluate the potential of the newly invented Armour-WADD 1200 - 1800°F advanced titanium alloys for air breathing applications.

Results and Conclusions:

1. Three titanium alloys have been successfully forged into compressor wheels and have been fully evaluated by Wyman-Gordon and the Titanium Metals Corporation.
2. These alloys have the necessary 1000°F creep strength but the low yield strength of one alloy and the surface instability of the other two alloys has eliminated the three alloys from further consideration as compressor wheel materials.
3. At least three potential 1200 - 1800°F Armour titanium alloys are being studied by TMCA

Period. 1 February 1962 to 1 August 1962

Title Wrought Nickel Base Turbine Blade Alloy Development

Objective The over-all objective of this program is to develop a wrought nickel base alloy for air-cooled turbine blades in advanced air breathing propulsion systems with 2000 - 2400°F turbine inlet temperature. This material should have a 1900°F - 15,000 psi - 50 hour average rupture life with adequate oxidation resistance and high fatigue strength in the 1600 - 1800°F temperature range.

During 1962, the goals will be the development of the chemistry, the forging of experimental blades, and the study of commercially available oxidation resistant coatings on the selected alloy.

Results and Conclusions:

1. Six of the first seven chemistries were successfully extruded to 1 1/4" bar stock. One of these had improved rupture strength at 1900°F compared to the strongest commercial nickel base alloys, but was still short of the goal.
2. Eight new chemistries are in process.

Period: 1 February 1962 to 1 August 1962

Title: High Strength Truly Weldable Sheet Alloy Development

Objective: The aim of this program is to identify and evaluate a readily weldable high strength sheet alloy which can be utilized in advanced light weight jet engine compressor and turbine frames at temperatures up to 1400°F.

The current high strength alloys, such as Rene' 41, are not satisfactorily weldable. The readily weldable alloys do not have high strength. The objective of this program is to define a composition which will have good weldability (including resistance to strain age cracking) and substantially retain the high strength properties of Rene' 41 as follows:

|                         | <u>Required New<br/>Weldable Sheet</u> | <u>Best Present Ma-<br/>terial - Rene' 41</u> |
|-------------------------|----------------------------------------|-----------------------------------------------|
| 1400°F Tensile Strength |                                        |                                               |
| Ultimate                | 130, 000 psi                           | 143, 000 psi                                  |
| .2% Yield               | 110, 000 psi                           | 123, 000 psi                                  |
| 1400°F Rupture Strength |                                        |                                               |
| 100 Hours               | 48, 000 psi                            | 50, 000 psi                                   |

A weldable alloy meeting the strength goals is to be identified in 1962. Design data will be established, and producibility of the alloy will be demonstrated in 1963.

Results and  
Conclusions:

1. First quarter work included a survey of alloy producers to determine the status of new alloy development pertinent to this project. A number of candidate compositions were started through evaluation. Experimental compositions were melted at General Electric to evaluate the function of the hardening elements Al, Cb, and Ti on precipitation hardening rates. Additional laboratory work was started to determine the metallurgical factors which affect weldability. The purpose of this study is to provide better fundamental knowledge of welding metallurgy.
2. During the second quarter, candidate alloys submitted by alloy producers were evaluated in strength and weldability tests. None of the compositions met all of the program requirements and efforts were turned towards direct alloy development. This development, plus the study of metallurgical factors affecting welding, was stressed during the second quarter.

Period: 1 February 1962 to 1 August 1962

Title: First Stage Turbine Blades Product Improvement

Objective: This study is aimed at improving the thermal fatigue resistance of first stage turbine blades.

Results and  
Conclusions.

The evaluation of the thermal fatigue properties of various alloys on the bench test rig has continued. Alloys evaluated under three or more conditions include Cast U 500, Wrought U 500, DCM, IN-100, SEL-15, and Inco 713C. U-700, Nimonic 115, and AF 1753 are now in test.

Three types of coatings have been applied to Wrought U-500 specimens. These coatings are being quality checked to determine adherence and abrasion quality. A portion of the specimens have been returned to the coating vendor because of poor quality. Acceptable specimens are now being tested in thermal fatigue.

Long time exposure specimens are now ready for thermal fatigue testing. The effect of reheat treating after long time exposure is being evaluated for both thermal fatigue and stress rupture. It has been determined that an appreciable portion of the stress rupture life can be recovered by reheat treating. This will be correlated with thermal fatigue mechanical fatigue and tensile properties.

Period: 1 February 1962 to 1 August 1962

Title: Long Time Behavior of Turbine Materials

Objective: This program is a metallurgical and mechanical property study of power plant materials for the Supersonic Transport. Creep-rupture properties will be measured out to 10,000 hours. In addition to the actual measurement of long time properties, this program will determine the strength, ductility, and micro-structure of the materials after they have been exposed for long periods of time.

Results and  
Conclusions

Materials selected for testing are:

Inco 718  
Rene' 41  
R-27  
Astroloy

These materials are being procured as forgings. Testing has not yet started.

Period: 1 February 1962 to 1 August 1962

Title: The Effect of Oxidation and Surface Preparation on the Low Cycle Fatigue Behavior of Materials.

Objectives: The purpose of this investigation is to determine the effect of surface preparation and/or oxidation on the low cycle fatigue behavior of V-57 and A-286. The low cycle fatigue behavior of these materials has been observed to deviate from the expected levels. In order to account for this deviation, the above two phenomena are being investigated.

Results and Conclusions

Low cycle fatigue tests on specimens with various types of finishes (ground, polished, peened, coated) have indicated slight or negligible effects on the constant strain low cycle fatigue behavior of these materials in the range of about 2,000 cycles. Oxidation appears to be a very important aspect of this behavior. Incomplete data at this time indicates that little fissures of oxides at grain boundaries and/or slip planes appear to pierce the surface of the test specimens with strain cycling and cause the initiation of fatigue cracks.

This work will continue to better define this oxidation phenomena.

Period: 1 February 1962 to 1 August 1962

Title: The Low Cycle Fatigue Behavior of Turbine and Compressor Rotor Materials

Objective: The objective of this program is to generate low cycle fatigue data on jet engine rotor materials. This data is to be used in predicting the expected life of rotor parts when subjected to cyclic strain due to mechanical or thermal loading.

Results and  
Conclusions:

Since the initiation of this program, considerable amounts of data have been generated defining the low cycle fatigue behavior of A-286, V-57, M-308, B5F5 (Cr-Mo-V steel). When testing for low cycle fatigue behavior, it is necessary to control the stress or strain conditions to duplicate the condition of the application. The data from this effort is to be compared to constant strain conditions. Accordingly, equipment has been developed and used which applies a constant strain cycle to the specimen. This program has not been completed. However, considerable data has been generated. The table below indicates the temperatures and stress conditions for the data.

| <u>Material</u> | <u>Temperature,<br/>°F</u> | <u>A-Ratio</u>                                  |
|-----------------|----------------------------|-------------------------------------------------|
|                 |                            | <u>Alternating Strain</u><br><u>Mean Strain</u> |
| B5F5            | R. T , 450, 850            | .3, .8, 2.0                                     |
| V-57            | 950 and 1150               | $\pm$ 3.0                                       |
| A 286           | 950 and 1150               | $\pm$ 3.0                                       |
| M-308           | 950 and 1150               | $\pm$ 3.0                                       |

Generally, the results of the tests have indicated considerable deviation from normal expected behavior, as described by some investigators in this field. The test results have been lower than expected and it is believed that oxidation phenomenae has been the culprit in reducing the expected life times.

In test cases, where engine tests or field experience is available, excellent agreement has been noted between predicted life based on these results and engine experience.

Period: 1 February 1962 to 1 August 1962

Title: Braze Alloy Evaluation and Design Data

Objective: The objective of this program is to identify and select braze alloys for joining high temperature super alloys for the design of ultra-light weight structures needed for high thrust-to-weight ratio engines. Alloys developed by FPLD as well as by outside vendors are to be evaluated continually for application in sheet metal structures. These braze alloys are to be evaluated against the requirements listed below, and the best of the alloys will be more fully evaluated for design data.

1. Comparability. Compatible with super alloy base materials.
2. Brazing Temperature: 1950 to 2050°F
3. Minimum Heating Rate: Alloy capable of producing good joint when brazed in furnace with 25°F/Min. heating rate.
4. Oxidation Resistance: 1500°F/100 hours. No preferential oxidation; .003" max. general oxidation.
5. Strength: Shear Tensile - R. T., 35,000 psi  
1200°F, 30,000 psi  
Shear Rupture - 1250°F, 10,000 psi/100 hours  
1450°F, 4,000 psi/100 hours

Results and  
Conclusions:

Screening tests on four brazing alloys have been completed and the results compared with the requirements. Two alloys, CM-52 and R-46, approach the strength requirements; however, CM-52 results in the formation of brittle boride phases in Rene' 41 and R-46 alloy exhibits inadequate oxidation resistance. Braze test specimens for four other alloys have been brazed and are being prepared for evaluation.

Period: 1 February 1962 to 1 August 1962

Title: High Strength 2000°F Sheet Alloy Development

Objective: The objective of this program is to develop a nickel or cobalt base alloy having strength, formability, weldability, and oxidation resistance suitable for long life, high temperature combustion and afterburner liners for advanced jet engines. The property goals for such an alloy are as follows:

1. Oxidation Resistance: 90% of the basic material strength is to be retained after 1000 hours exposure at 2000°F.
2. Rupture Life: 2000°F - 2000 psi - 1000 hours  
1900°F - 3000 psi - 1000 hours

Results and  
Conclusions:

1. Screening evaluation of vendor alloys has been completed. The only vendor alloy found to meet requirements was DuPont's TD nickel, a Ni-2%ThO<sub>2</sub> dispersion strengthened alloy.
2. Alloy development work, based on increasing the solid solution strength of nickel base alloys, is continuing. Solid solution strengthened alloys containing up to 15% W and .1% La have been melted in 10# heats and successfully processed to sheet. Button heats of these compositions exhibited excellent oxidation resistance.

Period: 1 February 1962 to 1 August 1962

Title: Advanced Nickel Base Sheet Alloy for Service to 1800°F

Objective: The aim of this program is to develop a nickel base sheet alloy which can be utilized in high strength fabricated structures for service up to 1800°F. The present high strength sheet alloys are either not strong enough or, if they have the strength, are not capable of fabrication by welding into the structures needed.

The alloy required must have weldability properties comparable to those of Rene' 41 while retaining the following high temperature properties.

|                         | <u>Required</u> | <u>Best Present Material - Rene' 41</u> |
|-------------------------|-----------------|-----------------------------------------|
| 1800°F Rupture Strength |                 |                                         |
| 100 hrs.                | 14,000 psi      | 7,500 psi                               |
| 1000 hrs.               | 6,000 psi       | -                                       |

A weldable alloy meeting the strength goals is to be identified by 1 March 1963. Design data will be established and producibility of the alloy established by 1 January 1964.

Results and  
Conclusions.

Nine compositions, based on Astroloy and El826, have been melted and are currently being processed into sheet. The compositions selected are intended to be less dependent upon gamma prime strengthening and more dependent upon solid solution strengthening than Astroloy. The chemistries are also balanced so as to promote the formation of the  $M_6C$  carbide rather than the less stable  $M_7C_6$  carbide.

Results thus far indicate that all nine compositions are capable of being hot rolled into sheet. Strength test results on these alloys are not expected to be available until after 15 August 1962.

Period: 1 February 1962 to 1 August 1962

Title: Microstructural Study of Welded Rene ' 41

Objective: To determine if metastable microstructures contribute to the crack sensitivity in the heat-affected-zone of welded Rene ' 41.

Results and  
Conclusions: Restrained Rene ' 41 weld specimens for every heat treatable condition used in production have been prepared and are scheduled for study by x-ray diffraction and electron microscopy techniques.

GENERAL MATERIALS INFORMATION - PHASE II  
MATERIALS WORK IN PROGRESS

TITLE: Production Survey and Foundry Capability of 17-4PH  
Investment Castings

OBJECTIVE: To control the three initial casting lots of all foundries under contract to produce Norair castings of 17-4PH stainless steel. This effort is designed to select the best-qualified foundries and to assist in the production of the best possible castings.

MATERIALS: 17-4PH Stainless steel castings.

RESULTS: Three production lots have been qualified for 18 part numbers, while one part has had two lots qualified.

Initial casting problems such as excessive microshrinkage and homogenization heat treatment have been successfully overcome by the use of close foundry control practices.

CONCLUSIONS: The program has shown that the casting of 17-4PH can be successfully and consistently accomplished if the casting vendor is willing to exercise precise control over his casting procedure and to follow the process requirements. It has been found that deviations from these paths lead to subpar quality castings.

ESTIMATED COMPLETION DATE: 15 January 1962

GENERAL MATERIALS INFORMATION - PHASE II  
MATERIALS WORK IN PROGRESS

TITLE: Electron Beam Welding of Refractory Alloys and Beryllium Metal.

OBJECTIVE: To investigate the effects of prior alloy melting practice and pertinent welding parameters for the electron beam welding of refractory alloys and beryllium metal.

MATERIALS: F-82 Columbium sheet  
Molybdenum 0.5% Ti sheet  
PH 15-7 Mo sheet  
Beryllium sheet

RESULTS: This is a new program starting in October 1961, therefore there are no results or conclusions to be reported at the time of preparation of this progress report.

ESTIMATED COMPLETION DATE: 31 July 1962.

GENERAL MATERIALS INFORMATION - PHASE II  
MATERIALS WORK IN PROGRESS

TITLE: Fundamentals of Cold Welding in Vacuum

OBJECTIVE: To investigate the fundamentals of the cold welding of selected metals in a vacuum.

RESULTS: This is a new program starting in September 1961. Results to date have covered a literature search which revealed that most welding work reported used vacuum as a protective medium. Hot press welding has been performed up to  $10^{-5}$  mm Hg. Friction studies reported indicate that metal seizures increase as oxides are outgassed from metal surfaces, as surface area increases, and as load increases. Only one reference was found where parts were welded by outgassing techniques.

ESTIMATED COMPLETION DATE: 31 May 1962

GENERAL MATERIALS INFORMATION - PHASE II  
MATERIALS WORK IN PROGRESS

TITLE: Fusion Spot Welding for Mach 3 Aircraft Structures

OBJECTIVE: To continue the previous investigations of fusion spot welding of precipitation hardening corrosion resistant steel sheet for use in Mach 3 aircraft structures by developing design allowables, and preparing a process specification to control the procedures.

RESULTS: Weld parameters have been developed for fusion spot welding a variety of thicknesses of precipitation hardening corrosion resistant steel sheet. Successful welds were made in all thickness combinations which varied from 0.013 to 0.071 inch for base sheet, and from 0.020 to 0.040 for top sheet. Welded specimens are in preparation for a statistical analysis of joint properties.

ESTIMATED COMPLETION DATE: 15 March 1962

GENERAL MATERIALS INFORMATION - PHASE II  
MATERIALS WORK IN PROGRESS

TITLE: Recrystallization Parameters of Molybdenum and Columbium Alloys

OBJECTIVE: To investigate the recrystallation behavior of selected molybdenum and columbium alloys at temperatures and times corresponding to typical brazing cycles, and the effect of these thermal treatments on the microstructure and mechanical properties of these alloys.

RESULTS: This is a new program starting in October 1961, therefore, there are no results or conclusions to be reported at the time of preparation of this progress report.

ESTIMATED COMPLETION DATE: 31 July 1962

MATERIALS RESEARCH PROJECT SUMMARY

Period: 1 March 1961 to 1 September 1961

Material Classification: High Temperature Materials

Materials: Columbium Alloy FS82

Title: A Study of the High Temperature Base Metal, Welded Joint, and Mechanical Joint Properties of a Columbium Alloy.

Project No. REA 111-9107

Objective:

1. To develop methods for joining (mechanical and weld joints) a columbium alloy to itself and to other high-strength high-temperature materials.
2. To determine the high-temperature properties of the base metal and the various joints.

Results and Conclusions:

Electron beam welds and gas shielded tungsten arc welds have been made in Fansteel FS 82 and properties established. Room temperature and some elevated temperature mechanical properties of the base metal have been determined.

Base metal properties of the FS-82 tested in this program are about 25 percent higher at room temperature than those reported by the producer. At 2000°F the mechanical properties are about the same as those reported by the producer.

Electron beam welds were bent 140° over a 3/4T radius without failure. Grain size in this weld was quite large and hardness surveys showed no hardening from gas pick-up. These welds had a room temperature tensile strength of 51,600 psi with a ductile shear fracture in the weld. Weld efficiency was about 60%.

Gas shielded tungsten inert arc welds were bent 100° over a 3/4T radius without failure. A few small cracks were initiated with further bending. Grain size was relatively small and hardness measurements showed a slight increase in hardness which apparently is indicative of gas pickup during welding. Tensile strength at room temperature was 75,000 psi and fracture occurred in the heat affected zone. Weld efficiency is about 88 percent.

Braze welds between the columbium alloy and a high nickel base alloy (U500) were attempted with and without filler metal. No successful braze weld was formed. Braze welds cracked as they were formed and at present appears to be mostly a problem of different thermal expansion coefficients for the two materials.

## MATERIALS RESEARCH PROJECT SUMMARY

Period: 1 March 1961 to 1 September 1961

Material Classification: High Temperature Materials

Materials: Cb-FS82, 1/2Ti

Title: The Elevated Temperature Base Metal and Joint Properties of Refractory Metals

Project No. REA 111-9205

OBJECTIVE:

1. To determine the high temperature tensile and creep-rupture properties of columbium and molybdenum alloys and the properties of various joints at temperature up to 2500°F.
2. To determine the high temperature properties of fusion welds of Mo-1/2 Ti alloy prepared by TIG and electron beam welding.

Results and Conclusions:

Base metal and fusion weld tensile properties of the FS-82 columbium alloy (Cb+33Ta+0.7Zr) have been determined from ambient temperature to 2600°F. Base metal tensile properties were determined using two different heat-up periods prior to test: 30 seconds and 30 minutes. In general, the tensile properties determined using the short heat-up period were considerably lower than those found using the long heat-up period at temperatures below 1800°F, but much higher at higher temperatures. This behavior was related to strain aging at temperatures below 1800°F and recovery and/or recrystallization at temperatures above 1800°F. Creep-rupture properties of the base metal and fusion weldments were determined at 1800°, 2000° and 2200°F. Extrapolation techniques were employed to extend the data to cover temperatures, times and stresses not investigated in the experimental program. The creep behavior of the base metal was analyzed and the activation energy for creep was found to be 121,300 cal/mol. This was found to be in excellent agreement with the activation energy for self-diffusion of columbium (105,000 ± 3000 cal/mol) and/or the activation energy for self-diffusion of tantalum (110,000 cal/mol). This data strongly suggests that creep of the FS-82 columbium alloy is diffusion controlled above about 1800°F (0.45 Ta).

Electron beam fusion welds of FS-82 were found very ductile and free from contamination. Tungsten-arc shielded gas fusion welds (TIG welds) were contaminated slightly by gas pickup during welding but retained considerably ductility. Tensile weld efficiency of the TIG weldments decreased from 94 percent at ambient temperature to about 75 percent at 1800°F. Electron beam weld efficiencies were considerably lower; decreasing from 64 percent at ambient temperature to 54 percent at 1800°F. The rupture life of the fusion welds appear to be higher than the base metal rupture life at temperatures over 2000°F, but appears to be lower at lower temperatures. However, more data is required before this conclusion can be considered valid.

MATERIALS RESEARCH PROJECT SUMMARY

Period: 1 March 1961 to 1 September 1961

Material Classification: High Temperature Materials

Materials: 301 EPH Stainless Steel, and Titanium Alloys Ti-5Al-2.5 Sn and Ti-13V-11 Cr-3 Al.

Title: High Temperature Properties of Selected High Temperature Alloys

Project No. REA 111-9222

Objective:

1. To determine the influence of cold work on the high temperature properties of selected alloys.
2. To determine the effect of cyclic exposure to stress and temperature on the high temperature properties of selected alloys.
3. To determine the influence of melting practice on the high temperature properties of promising high temperature alloys.

Results and Conclusions:

The elevated temperature tensile and creep properties of 301 EPH stainless steel and two titanium alloys, Ti-5Al-2.5Sn (Al10AT) and Ti-13V-11Cr-3Al (B120VCA), were determined up to 900°F. In addition, the effect of creep strain on subsequent room temperature properties was studied.

On the basis of density compensated tensile and creep strength, the Ti-13V-11Cr-3Al alloy (B120VCA) was found to be the best alloy for use from room temperature to about 800°F. Above 800°F the Ti-5Al-2.5 Sn Alloy (Al10AT) is the better material. Between 400°F and 800°F the 301 EPH and Ti-5Al-2.5Sn alloys are quite competitive when compared on a density compensated basis. On an overall basis the stainless steel appears slightly superior in this temperature range. Below 400°F the Ti-5Al-2.5Sn alloy may be the better choice.

Creep damage (i. e. the decrease in room temperature tensile properties due to prior exposure to stress at elevated temperatures) was quite small. In general, changes in  $F_{tu}$  and  $F_{ty}$  did not exceed 6 percent. Decreases in ductility due to creep damage were quite large in some cases. For example, the elongation of the Ti-5Al-2.5Sn alloy decreased from 22 percent to about 7 percent when stressed for periods of 24 hours at 900°F.

MATERIALS RESEARCH PROJECT SUMMARY

Period: 1 September 1961 to 1 March 1962

Material Classification: High Temperature Materials

Materials: 301 XFH Stainless Steel, and Titanium Alloys Ti-5Al-2.5Sn and Ti-13V-11Cr-3Al

Title: High Temperature Properties of Selected High Temperature Alloys

Project No: REA 111-9222

Objective:

1. To determine the influence of cold work on the high temperature properties of selected alloys.
2. To determine the effect of cyclic exposure to stress and temperature on the high temperature properties of selected alloys.
3. To determine the influence of melting practice on the high temperature properties of promising high temperature alloys.

Results  
and  
Conclusions:

The creep behaviour of the three test materials under cyclic conditions was generally similar to that observed under constant conditions; however, some specific differences were noted.

Type 301 XFH stainless steel had increased creep resistance under cyclic conditions at the higher stresses and longer times, but no difference was noted at lower stresses or shorter times.

Although average creep curves under cyclic and constant conditions appear to be the same for the Ti-5Al-2.5Sn alloy, the large first stage creep observed at 600°F during the first loading cycle did not occur on subsequent loading cycles. Thus, pre-creep could be used as a means of strengthening Ti-5Al-2.5Sn alloy for use at 600°F.

Wide scatter in the cyclic creep data from tests of the Ti-13V-11Cr-3Al alloy prevented clear definition of cyclic creep effects, but the average cyclic creep curves fell below the constant creep curves under all test conditions.

Creep damage (change in room temperature tensile properties after creep testing) from cyclic conditions was similar to that resulting from steady state creep testing.

MATERIALS RESEARCH PROJECT SUMMARY

Period: 1 March 1961 to 1 September 1961

Material Classification: Metallic Materials

Materials: Aluminum Alloy 2014-T6  
Titanium alloy Ti-5Al-2.5 Sn  
Stainless Steels: 301 x PH, 310.

Title: A Study of the Effects of Nuclear Radiation on High Strength Aerospace Vehicle Materials at the Boiling Point of Hydrogen

Project No. REA 111-9212

Objective: To determine the extent of any deterioration in the mechanical properties of high strength sheet alloys as a result of exposure to nuclear radiation while at a temperature of -423°F. Any embrittlement incurred will be detected by determination of the notched/unnotched tensile strength ratio and plotted as a function of integrated neutron dose up to  $10^{17}$  nvt for selected alloys of titanium, aluminum, and stainless steels.

Results and Conclusions: The design of nuclear powered rockets using liquid hydrogen as a propellant may be seriously restricted by the radiation damage occurring in structural alloys at -423°F. To measure the magnitude of this effect, smooth, notched, and weld joint samples of selected high strength steel, aluminum, and titanium alloys were subjected to nuclear radiation while held at -423°F. These alloys were 301 and 310 stainless steel cold rolled 60 and 75 percent respectively, 5Al-2 1/2 Sn titanium (Al10AT), and 2014-T6 aluminum.

The largest and most consistent effect was a decrease in tensile strength after irradiation at -423°F. This effect varied from a 27 percent decrease for the 301 stainless steel to a 3 percent decrease for the 5Al-2 1/2 Sn titanium. Since the yield strengths were not significantly effected by cryogenic irradiation, it appears that the effect of cryogenic irradiation is to severely restrict the amount of plastic deformation the sample can sustain after yield and prior to fracture. Elongation measurements and optical examination, which will be made as soon as the samples can be handled are expected to lend further support to this theory. Notched tensile tests showed that small amounts of embrittlement occurred in the 301 stainless steel after cryogenic irradiation, while the 310 stainless steel showed no embrittlement. It is believed that this condition resulted from a radiation induced solid state phase transformation of austenite to the more brittle martensite phase in the 301 stainless steel. No such transformation occurs in type 310 stainless steel. The welded joint tests showed significant decreases for the 310 stainless steel and 5Al-1 1/2 Sn alloy, but the reasons for this behavior must await detailed examination of the samples. A final report will be issued after radioactive decay in the samples has reached a point where the samples can be studied visually.

MATERIALS RESEARCH PROJECT SUMMARY

Period: 1 March 1961 to 1 September 1961

Material Classification: Materials for Cryogenic Temperatures

Materials: Stainless Steels 301, 304, 310, AM 355  
Aluminum Alloys 2014-T6, 5052-H38, 5456-H34  
Titanium Alloys Ti-5Al-2.5 Sn, Ti-6Al-4V

Title: A Study of Crack Initiation and Propagation at Cryogenic Temperatures.

Project No. REA 111-9207

Objective:

1. To develop a test that results in a sensitive measurement of the ability of sheet materials to resist initiation and propagation at cryogenic temperatures.
2. To study mechanisms of crack initiation and propagation.

Results and Conclusions:

A viewing cryostat was designed to accommodate 19" x 38" center notched crack propagation specimens. A cryostat for 4" x 10" specimens was fabricated and is now in service.

The small 4" x 10" center notched specimen has been designed to supplement data obtained with the larger specimens. To date, 10 large specimens and 50 small specimens have been tested at room temperature, and 24 small specimens have been tested at -320°F.

MATERIALS RESEARCH PROJECT SUMMARY

Period: 1 March 1961 to 1 September 1961

Material Classification: Non-Ferrous Metals

Materials: Aluminum Alloys: 5052, 5086, 5154  
 Titanium Alloy: Ti-5Al-2.5 Sn  
 Nickel Alloys: K-Monel, Hastelloy B  
 Cobalt Alloy: Haynes 25  
 Stainless Steels: AM 355 CRT, A-286

Title: Effect of Cryogenic Temperatures on the Mechanical Properties of High Strength Non-Ferrous Sheet Alloys

Project No. REA 6089

Objective: To determine the effect of extreme subzero temperatures on the tensile properties of selected non-ferrous alloys in the notched and unnotched condition.

Results and Conclusions: Alloy AL10AT titanium, which possesses excellent weldability and corrosion resistance, was found to have strength/density characteristics about equal to extra full hard type 301 stainless steel at 78°F, but at -423°F this ratio for titanium exceeded that of the stainless steel by about 25 percent. This suggests weight savings of 25 percent when the low temperature properties of this alloy can be used as the basis of design allowables. These favorable low temperature properties were accompanied by good notched/unnotched tensile ratios (a criterion of resistance to brittle fracture), and weld joint efficiencies considerably in excess of 90 percent at all subzero temperatures. At elevated temperatures, this alloy loses its strength at temperatures in excess of 600°F. Recommended future studies of this alloy include low temperature axial fatigue tests of welded joints, correlation of interstitial alloy content with low temperature properties, and effects of cold-rolling on yield and tensile strength.

Alloys Haynes 25, 20 percent cold-rolled and Hastelloy B, 40 percent cold-rolled, show promise for limited application where combinations of good low and high temperature properties are required. These alloys retain most of their strength and exhibit good oxidation resistance at temperatures of 1400°F, and also have good low temperature properties, although their higher densities causes them to display less favorable strength/density ratios. This combination of properties suits them for limited applications in surfaces of cryogenic propellant tanks that may experience excessive heating during any portion of the flight profile.

Results and Conclusions: (continued)

Alloy K-Monel in the age hardened condition was found to remain tough at  $-423^{\circ}\text{F}$ , in spite of the presence of an intermetallic compound  $(\text{Ni}_3\text{Ti}_2\text{Al})_y$  precipitated during heat treatment. This alloy is suited to applications requiring a soft, formable material that can be drawn into intricate shapes such as liquid oxygen and liquid hydrogen manifolds, welded, and then strengthened by a low temperature (i.e., nondistorting) heat treatment. The favorable low temperature properties of this alloy suggests the study of higher strength nickel base alloys utilizing the same hardening mechanism such as Inconel-X, Rene' 41, and R-235.

Although aluminum alloy 5052-H38 exhibited the best combination of high tensile strength, and high notched/un-notched tensile ratio of the 5000 series, this alloy class was found to exhibit a marked decrease in toughness between  $-320^{\circ}\text{F}$  and  $-423^{\circ}\text{F}$ . This condition was associated with a microstructure containing large inclusions which acted as stress raisers. This condition suggested the development of a "cryogenic alloy" which could be made inclusion free by means of inert atmosphere melting, use of high purity alloying elements, and ultrasonic treatment during solidification. It is believed that an alloy of this type would exhibit excellent low temperature toughness.

MATERIALS RESEARCH PROJECT SUMMARY

Period: 1 March 1961 to 1 September 1961

Material  
Classification: Stainless Steels

Materials: Stainless Steels Type 301, 301N, 302, 304 ELC, 310.

Title: A Study of the Effect of Cryogenic Temperatures on the Mechanical Properties of Cold-Worked Stainless Steel Sheet.

Project No. REA 111-9009

Objective: To determine the effect of extreme subzero temperatures on the notched and unnotched tensile properties of selected cold-worked stainless steel sheet alloys.

Results  
and  
Conclusions: The mechanical properties of a series of cold-rolled austenitic stainless steels were determined at 78, -100, -320, and -423°F. Samples examined included smooth base metal, notched base metal (stress concentration factor,  $K_t=6.3$ ), and heliarc butt welds. The axial fatigue properties of complex welded joints are included for purposes of discussion. The notched samples were included in this study for the purpose of measuring notch sensitivity, which is a criterion of tendency toward brittle failure. Microstructural, x-ray diffraction, and magnetic studies were conducted to study the mechanism of deformation at cryogenic temperatures and to relate properties to microstructure. The steels listed were studied in the following tempers:

|                   |                                            |
|-------------------|--------------------------------------------|
| AISI Type 301     | 40-, 50-, 60-, and 80- percent cold rolled |
| AISI Type 301-N   | 60-percent cold rolled                     |
| AISI Type 302     | 40- and 60- percent cold rolled            |
| AISI Type 304 ELC | 50-percent cold rolled                     |
| AISI Type 310     | 40-, 60-, and 75 percent cold rolled       |

These studies showed that austenitic stainless steels of AISI types 301, 302, 304ELC, 310, and 301-N exhibit mechanical properties between 78 and -423° F that are microstructure dependent, and the dependence of this microstructure on chemistry, temperature, tensile stress, and prior deformation is in general accord with previous investigations which have measured the effects of each of these variables on structure, or more specifically, the austenite-to-martensite transformation. The behavior of fully stable alloys, such as AISI type 310, at cryogenic temperatures is in accord with the generalized behavior of face-centered cubic metals. This behavior includes the retention of toughness at low temperatures (i.e., high notched/unnotched tensile ratios) and moderate increases in yield and tensile strength with decreasing temperature for cold-worked tempers. The behavior of the unstable alloys at cryogenic temperatures is dependent upon the amount and composition of martensite formed during both cold rolling at room temperature and tensile testing at cryogenic temperatures.

Results and Conclusions: (continued)

Increasing amounts of martensite generally act to increase tensile and yield strengths and decrease toughness at any given temperature, although the magnitude of these effects is strongly dependent upon interstitial (i.e., carbon and nitrogen) content. Thus, type 304ELC forms large amounts of martensite during tensile testing at  $-320^{\circ}\text{F}$ , yet retains good toughness (notched/unnotched tensile ratio of 1.04) due to its low carbon content (0.023 percent). Type 301-N, which undergoes transformation during tensile testing at  $-320^{\circ}\text{F}$ , yet retains good toughness (notched/unnotched tensile ratio of 1.04) due to its low carbon content (0.023 percent). Type 301-N, which undergoes transformation during tensile testing at  $-320^{\circ}\text{F}$ , displays much more brittle behavior than type 301 due to its high interstitial content (0.13 percent nitrogen and 0.10 percent carbon). Alloys commonly regarded as stable at  $78^{\circ}\text{F}$  (e. g., type 302) are subject to the austenite-to-martensite transformation at  $-320$  and  $-423^{\circ}\text{F}$ , with resulting brittle behavior as measured by low notched/unnotched tensile ratios. The magnitude of this effect is dependent upon the degree of cold work at room temperature prior to tensile testing at low temperature. Generally, an optimum degree of cold work exists (such as 60 percent in type 301) which yields maximum toughness during tensile testing at low temperature.

The notched/unnotched tensile ratios were found to correlate with the number of cycles to failure in axial fatigue tests of complex weld joints in types 301, 301-N, and 310 cold-rolled 60, 65, and 75 percent, respectively. This correlation indicates that the relatively inexpensive notched/unnotched tensile test may be used to predict the fatigue behavior of complex welded joints, and thus greatly reduce the need for costly and time-consuming fatigue tests of complex joints.

As a result of this study, types 301, 304ELC, and 310 were found to exhibit the most promise for cryogenic application where high strength, good weldability, and resistance to brittle failure are required. Type 301 offers the highest strength for a given degree of cold work, but exhibits some tendencies toward brittle failure at  $-423^{\circ}\text{F}$ . Type 310 offers maximum resistance to brittle failure at cryogenic temperatures but has a slightly lower strength than type 301. Type 304ELC possesses good resistance to brittle failure at low temperature, but the toughness varies widely within the allowable chemistry range of this composition so that additional work is required to define acceptable composition limits for 304ELC.

Results and Conclusions: (continued)

In many cases the tensile and yield strengths increased with decreasing temperature while the toughness, as measured by notched/unnotched tensile ratios, remained uniformly high. This combination of effects emphasizes the advantage of using the increased low-temperature properties as the basis of design allowables in those cases where the structure is subjected to maximum stress only while at low temperature. This design concept offers possible weight savings of up to 40 percent where it is applicable.

MATERIALS RESEARCH PROJECT SUMMARY

Period: 1 March 1961 to 1 September 1961

Material Classification: Physical Properties of Metallic Materials

Materials: Stainless Steels 303, 321, and Copper.

Title: Measurement of the Elastic Properties of 300 Series Stainless Steels at Cryogenic Temperatures by Ultrasonic Techniques

Project No. REA 111-9108

Objective: To establish techniques for measuring elastic constants of materials by ultrasonic pulse techniques over a broad range of frequency applied stress and temperature. Particular emphasis is to be placed on the ability to make such measurements of extreme sub-zero temperature.

Results and Conclusions: Pulsed high frequency sound waves have been used to measure the velocity of sound propagation in metals. Frequencies used were 2.25 to 10 megacycles. The longitudinal and shear wave velocities are then used to calculate the elastic constants of the materials. Types 303 and 321 stainless steel and copper have been investigated. Results indicate a low temperature maximum in the longitudinal wave velocity of 321 stainless steel. No difference was observed in the longitudinal wave velocity between 303 and 321; however, the shear wave velocity of 303 was higher than that of 321.

MATERIALS RESEARCH PROJECT SUMMARY

Period: 1 March 1961 to 1 September 1961

Material Classification: Mechanical Properties of Metallic Materials

Materials: Stainless Steels: 301, 302, 304 ELC, 310

Title: A Study of Austenite Decomposition at Cryogenic Temperatures

Project No. SRP 112-4019

Object: To determine the effects of extreme subzero temperature upon the toughness of cold-worked stainless steels and to correlate these effects with changes observed in the microstructure. Particular attention is directed toward an understanding of the variables controlling the austenite to martensite solid state phase transformation in stainless steels.

Results and Conclusions: The austenite to martensite solid state phase transformation in the 300 series austenitic stainless steels was studied over the temperature range of 78°F to -423°F. The primary variables controlling this transformation are temperature, plastic strain, and chemical composition. Consequently, temperature effects were studied by measurements at 78°, -100°, -320°, and -423°F; plastic strain was controlled by cold-rolling the alloys varying amounts between 40 and 80 percent; and chemical compositions were varied by using 301, 302, 304 ELC and 310 stainless steel alloys which exhibit varying degrees of austenite stability.

A significant portion of this work was devoted to the development of a satisfactory technique of measuring the martensite content of a given sample. After investigating magnetic, metallographic, x-ray diffraction, and density techniques, a rapid and accurate magnetic method was developed. Using this technique, the martensite contents of various alloys were correlated with several mechanical properties including yield and ultimate tensile strength, elongation, and notched tensile strength ( $K_t=6.3$ ). The yield and tensile strengths generally increased with increasing martensite content, as expected, but no correlation was observed between elongation and martensite content. The notched/unnotched ratio ( $K_t=6.3$ ) at -423°F exhibited a maximum at about 65 percent martensite. This maximum was associated with a balance between toughness, as promoted by strain stabilized austenite, and embrittlement; as promoted by excessive conversion to martensite. Attempts to correlate austenite stability (as measured by the  $M_s$  temperature) with both resulting from tensile testing were generally unsuccessful because the variable of cold work could not be separated. As a result, only a general correlation of these variables was obtained.

Results and  
Conclusions:

(continued)

Certain of these alloys exhibited serrated stress-strain diagrams when subjected to tensile tests at  $-423^{\circ}\text{F}$ . The thermal instability theory which has been advanced to explain this behavior was investigated by controlling strain rate, thickness, cooling medium, and chemical composition. Higher strain rates, thicker samples, and gas cooling (at  $-423^{\circ}\text{F}$ ) were expected to cause these samples to exhibit more serrations in accordance with this theory. The first two variables had either no effect or the opposite effect to that expected on the number of serrations, while gas cooling gave significant increases in the number of serrations. In view of these conflicting data and circumstantial evidence derived from tensile tests on 75 percent cold-rolled 310 stainless steel and 80 percent cold-rolled 301 where no serrations were observed in either case (310 is full stable under all conditions of low temperature and cold work, while the 80 percent cold-rolled 301 was 100 percent martensite), it is believed that the mechanism of deformation accounting for the observed serrations in this particular alloy class is the discontinuous occurrence of the austenite to martensite reactions. It is also believed that the sudden shear type formation of martensite caused the drops in load due to the greater volume of the martensite phase which momentarily released the load on the specimen. The thermal instability mechanism may act as a second order effect in promoting the formation of serrations.

A (111) pole figure of austenite in a cold-rolled 301 stainless steel was prepared in an attempt to further investigate directionality as exhibited by both mechanical properties and number of serrations. Yield strength was correlated with this pole figure, but ultimate and notched tensile strengths were not. The latter two properties are presumed to be more dependent upon the martensite orientation rather than the austenite orientation.

MATERIALS RESEARCH PROJECT SUMMARY

Period: 1 September 1961 to 1 March 1962

Material  
Classification: Materials for Cryogenic Applications

Materials: 301, 304, and 310 stainless steel; 2014-T6, 2219-T81, and 5456-H321 aluminum alloys; and 5Al-2.5Sn Titanium alloy.

Title: Crack Propagation at Cryogenic Temperatures

Project No: REA 111-9302

Objective: To determine the resistance to brittle fracture of several sheet alloys at cryogenic temperatures.

Current  
Status: The test program includes the determination of  $K_{IC}$  and  $G_{IC}$  values from 78° to -423°F of parent metal and fusion welded 301, 304 ELC, and 310 stainless steels; 2014-T6, 2219-T81, and 5456-H321 aluminum alloys; and 5Al-2.5Sn titanium alloy.

Modification of the liquid hydrogen cryostat for testing of the 4" wide crack propagation specimens has been completed, and the cryostat for 19" wide specimens is being prepared for testing.

Twenty-two crack propagation specimens have been tested at -423°F during the first two months of this year.

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1.0 Index Code . . . . . (Alc-3)(VI-c)

2.0 Title - T.R. No. 513-209, Chem-Milling of Cast  
Aluminum Alloy.

3.0 Objective - To investigate and establish conditions for satisfactory removal of metal from aluminum alloy castings by chemical and/or electro-chemical methods. A satisfactory chem-milling technique would allow use of thinner cast sections, resulting in weight savings. The scope of this test program includes the following:

- a. Determination of electro-chemical method of metal removal that gives a satisfactory surface finish by varying the following parameters:
  1. Temperature of solution
  2. Solution composition
  3. Current density and distribution
  4. Electrode configuration
  5. Metal removal rates.
- b. Determination of the amount of metal removed and removal rate.
- c. Determination of the maximum amount of metal that can be removed satisfactorily.
- d. Visual observations of the etching characteristics (e.g., cavities, porosity, surface finish).

4.0 Status and Results - Chem-milling of cast aluminum surfaces using a solution consisting of ferric chloride and nitric acid with sulfuric and phosphoric acids as hydrogen ion replenishers gave unsatisfactory milling rates and surface finish. It has been found that hydrofluoric acid will replenish the hydrogen ion; however, further tests are necessary to determine the effect of hydrofluoric acid on milled surfaces.

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1.0 Index Code . . . . . (Mg-8)(I-K)  
(FeA-5)(I-K)  
(Ni-3)(I-K)

2.0 Title - T.R. No. 513-250, Evaluation of Resistance and  
Radiant Heating Methods for High Temperature  
Tensile Testing.

3.0 Objective - High performance aircraft, missiles, and space  
vehicles must withstand extremely high temperatures resulting  
from aerodynamic heating. Reliable, short time elevated  
temperature tensile data is required for design of these  
vehicles. The intent of this test program is to evaluate and  
compare the results of elevated temperature tensile tests using  
self resistance and radiant heating methods. A comparative  
evaluation of test data obtained will be used as a future  
guide in selecting a method of heating for developing elevated  
temperature tensile data. Elevated temperature tensile  
properties will be determined for HM21-T81, Type 321 stainless  
steel and Inconel X at 700°F, 1200°F and 1600°F

4.0 Status and Results - This test program is in the final stages  
of completion. Generally, the test data indicates that the  
self resistance heating method resulted in more erratic  
tensile data than that obtained when using a radiant heating  
method.

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1.0 Index Code . . . . . (FeUH-5)(I-e,f,h,k)(VI-a,h,o)

2.0 Title - T.R. No. 513-289, Evaluation of Vasco Max 250  
(18% Nickel Steel).

3.0 Objective - A newly developed ultra-high strength steel, Vasco Max 250 exhibits the following favorable characteristics:  
(a) useful high yield strengths to 250 KSI associated with exceptionally high ductility and superior toughness; (b) good stress corrosion resistance; (c) relatively simple (900°F temperature for three hours) hardening treatment. It is necessary to determine the fabrication characteristics and verify the mechanical properties of this alloy steel. The scope of this evaluation will include determination of the following:

- a. Tensile properties at room temperature.
- b. Tensile properties at elevated temperatures of 600°F, 900°F and 1200°F.
- c. Notched tensile properties at room temperature.
- d. Stability after exposure of 50 hours and 100 hours at 900°F.
- e. Heat treating characteristics.
- f. Weldability - automatic tungsten inert gas process.
- g. Formability - minimum bend radius, uniform elongation at room temperature, and rubber forming.
- h. Impact properties at room temperature, -110°F. and -320°F.
- i. Hardness after room and elevated temperature tensile tests and after stability tests.

4.0 Status and Results - This test program will begin upon receipt of the Vasco Max 250 sheet.

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1.0 Index Code . . . . . (FeA-5)(I-i)

2.0 Title - T.R. No. 513-271, Evaluation of AMS 4775 Nickel Braze Alloy Shear Strength in Tee Joints with Wide Root Openings.

3.0 Objective - Data relative to the effect of joint clearance on the shear strength of tee joints made using AMS 4775 brazing alloy are not available in the literature. Consequently, the objective of this test program is to determine the shear strength of tee joints brazed with AMS 4775 braze alloy when filleted with unusually wide clearances. The scope of this evaluation will include the following:

- a. Inert gas retort brazing of 321 stainless steel tee joints with fillet clearances ranging from 0.002" through 0.100".
- b. Determination of actual overlap and clearance joint parameters.
- c. Shear strength of brazed tee joints.

4.0 Status and Results - The test work has been completed and the final test report is being written. Test results indicate that strength of tee joints with 0.010 inch clearance are 95% of those with 0.002 inch clearance. Joints with 0.020 inch clearance are only 80% as strong as joints made with 0.002" clearance.

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1.0 Index Code . . . . . (FeAH-2,3)(I-i)(IV-a,c,e)

2.0 Title - T.R. No. 513-202, Low Temperature Brazing of Stainless Steel.

3.0 Objective - To investigate 88% Ag-7% Cu-5% Li, 74% Ag-23.5 Al-2.5 Li, 66% Au-34% Ga alloy compositions for brazing age hardening stainless steels PH15-7 Mo and 17-7PH at temperatures below the aging temperature or after completion of hardening heat treatment. The latter brazing sequence would be advantageous for repair brazing of honeycomb sandwich structures. Satisfactory brazing materials and techniques will have to be developed before elevated temperature shear strength, room temperature ductility properties, corrosion, oxidation, and thermal stability characteristics can be determined.

4.0 Status and Results - Preliminary test results indicate the following:

- a. Brazing filler metal composition of 88% Ag-7% Cu-5% Li melted at a temperature of approximately 1200°F.
- b. The 74% Ag-23.5 Al-2.5 Li composition showed no evidence of melting up to temperatures of 1750°F.
- c. The 66% Au-34% Ga sets hard in approximately 20 minutes at room temperature.

The results obtained to date have not been encouraging and the program has been terminated.

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1.0 Index Code . . . . . (FeAH-3)(I-1,k)

2.0 Title - T.R. No. 513-270, Overlap, Clearance, and Specimen Width of Braze PH15-7Mo Joints.

3.0 Objective - Because of inadequate and unreliable overlap, clearance, and specimen width design data for braze metal lap joints of PH15-7Mo thin sheet materials, it is necessary to determine the parameters that produce maximum joint strength. The scope of this test program includes the following:

## Phase I - Optimum Overlap

- a. Braze panels using overlaps of 1t through 15t (maintain a clearance of 0.003" and overlap tolerance of  $\pm \frac{1}{4}t$ ).
- b. Select optimum overlap based upon maximum joint stress of braze specimens tested in shear.

## Phase II - Optimum Clearance

- a. Using overlap selected from item (b) above, braze panels using joint clearances from 0 through 0.010".
- b. Select optimum clearance based upon maximum joint stress of braze specimens tested in shear.

## Phase III - Optimum Specimen Width

- a. Using optimum overlap and joint clearance determined in Phases I and II, braze panels with specimen widths of 1/4", 1/2", 1" and 2".
- b. Select optimum specimen width based upon maximum joint stress. Determine the shear strength of optimum braze joints at room temperature and 800°F.

In order to minimize atmospheric contamination, a pressure of less than 1 micron shall be maintained during the brazing cycle.

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4.0 Status and Results - The results of tests on overlap specimens indicates that joint strength increases with increasing overlap widths up to 15 times the material thickness. However, the ultimate shear stress of joints appears to be at a maximum for overlap widths of 5 times the material thickness. Future test work will be performed to determine optimum clearance and specimen width.

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1.0 Index Code . . . . . (Tl-7)(I-e,i,k)(VI-a,e,l)

2.0 Title - T.R. No. 513-295.01, Fabrication Characteristics of  
8Al-1Mo-1V Titanium Sheet.

3.0 Objective - 8Al-1Mo-1V is one of the three "super alpha" alloys being produced under the DOD titanium sheet rolling program. It would be highly advantageous to obtain preliminary mechanical properties data and fabrication characteristics of this titanium "super alpha" alloy and thereby permit early usage of this alloy in new design applications. The scope of this evaluation includes determination of the following:

- a. Hardness and tensile properties at room temperature of 0.025 and 0.063 annealed (as received) sheet.
- b. Uniform elongation tests at 400°F, 800°F, 1200°F and 1400°F.
- c. Minimum bend radius and springback.
- d. Contour flange forming.
- e. Dimpling.
- f. Hardness and tensile properties of TIG fusion welds.
- g. Hardness and shear strengths of resistance spot welds.
- h. Hydrogen pickup resulting from required chemical cleaning.

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4.0 Status and Results - This test program has been initiated.  
A tabular summary of test data obtained to date is presented below.

| Alloy               | Grain Direction | Material Thickness<br>Inch | Tensile Properties             |                                 |                          |
|---------------------|-----------------|----------------------------|--------------------------------|---------------------------------|--------------------------|
|                     |                 |                            | Ultimate Tensile Strength, KSI | Yield Strength 0.2% Offset, KSI | % Elongation In 2 Inches |
| 8Al-1Mo-1V Titanium | Parallel        | 0.022                      | 152.5                          | 148.0                           | 16.0                     |
|                     |                 | 0.063                      | 150.0                          | 143.0                           | 16.3                     |
|                     | Transverse      | 0.022                      | 156.0                          | 149.5                           | 13.7                     |
|                     |                 | 0.063                      | 151.0                          | 143.0                           | 17.5                     |
|                     |                 |                            | Elongation, 8 Inches           |                                 |                          |
|                     |                 |                            | Uniform                        | Total                           |                          |
|                     | Parallel        | 0.022                      | 3.0                            | 6.5                             |                          |
|                     | Perpendicular   | 0.022                      | 1.0                            | 4.0                             |                          |
|                     |                 |                            | Minimum Bend Factor            |                                 |                          |
|                     | Parallel        | 0.022                      | 3t                             |                                 |                          |
|                     | Parallel        | 0.063                      | 3t                             |                                 |                          |

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1.0 Index Code . . . . . (T1-6)(I-k)2.0 Title - T.R. No. 513-300, Effect of Hot Forming on the Tensile Properties of Aged Titanium Alloy Ti-13V-11Cr-3Al (B120 VCA).3.0 Objective - B120 VCA titanium alloy is presently being used in the solution treated/annealed condition. Hot forming of channel parts has also been performed at temperatures of 1080°F to 1100°F for approximately 25 minutes. These hot forming temperatures are within the aging temperature range for this titanium alloy and it becomes necessary to compare the tensile properties of B120 VCA for the following conditions:

- a. Hot formed without further thermal treatment.
- b. Hot formed and subsequently aged at 900°F for 60 hours.
- c. Unformed and aged at 900°F for 60 hours from the solution treated/annealed condition.

4.0 Status and Results - The test work has been completed and the final laboratory report is being prepared. Tensile results are presented in the following table.

| Specimen Number | 25 Minute Hot Sizing Temp.(°F) | Age Time At 900°F (Hours) | Tensile Strength (KSI) | Yield Strength 0.2% Offset (KSI) | Elongation In 2 Inch. (%) |
|-----------------|--------------------------------|---------------------------|------------------------|----------------------------------|---------------------------|
| 1               | -                              | 60                        | 197.5                  | 176.5                            | 11.0                      |
| 2               | -                              | 60                        | 196.5                  | 176.5                            | 8.0                       |
| 3               | 1080                           | 0                         | 136.0                  | 131.0                            | 20.0                      |
| 4               | 1100                           | 0                         | 133.0                  | 129.5                            | 22.0                      |
| 5               | 1100                           | 60                        | 191.0                  | 171.0                            | 9.5                       |
| 6               | 1080                           | 60                        | 192.0                  | 172.5                            | 9.0                       |

The test data indicate that hot sizing of B120 VCA titanium alloy at or near 1100°F, slightly decreases the tensile strength of the alloy after subsequent aging at 900°F for 60 hours.

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- 1.0 Index Code . . . . . (Ni-3)(I-d,k)
- 2.0 Title - T.R. No. 513-280, Examination of Electron Beam Weld Samples.
- 3.0 Objective - Available literature indicates electron beam weldments exhibit 100% joint efficiency with extremely narrow heat affected zones. This welding process can also be used for making blind welds. The objectives of this investigation are to validate the above findings and to determine the metallurgical characteristics, hardness and tensile properties of electron beam welded joints in Inconel X provided by Hamilton Electrona, Inc.
- 4.0 Status and Results - The laboratory test work has been completed and the final report is being prepared. Test results indicate excellent joint efficiency and extremely narrow heat affected zone of weldments made in annealed Inconel X.

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1.0 Index Code . . . . . (Ni-4)(I-e,i,k)(VI-a,e,h,l,o)

2.0 Title - T.R. No. 513-241.01, Evaluation of Inconel 718, Age  
Hardenable Nickel-Chromium Alloy (Phases II and III).

3.0 Objective - To determine the mechanical properties and fabrication characteristics of the nickel-chromium alloy, Inconel 718. The scope of this test program includes the following:

Phase II

- a. Tensile property determinations at room temperature and 1200°F for manual tungsten inert gas fusion weldments.
- b. Weld patch tests for manual tungsten inert gas fusion weldments.
- c. Lap shear tests of resistance spot welds.
- d. Cross tension tests of resistance spot welds.
- e. Lap shear tests of tungsten inert gas spot welds.
- f. Cross tension tests of tungsten inert gas spot welds.

Phase III

- a. Bending for minimum bend radius and spring back.
- b. Uniform elongation at room temperature.
- c. Dimpling.
- d. Rubber forming characteristics of stretch and shrink flanges.

4.0 Status and Results - The test specimens for Phase II work have been made and a mechanical properties testing schedule is being set up. Phase III work is in the scheduling state.

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- 1.0 Index Code . . . . . (Ni-4)(VI-b)
- 2.0 Title - T.R. No. 513-296, Initial Evaluation of Brazeability of Inconel 718 Nickel Chromium Alloy.
- 3.0 Objective - Inconel 718 will replace Inconel X in many elevated temperature applications. Many of these applications will require brazing techniques and brazing data is not presently available from the literature. The objective of this program is to investigate the feasibility of brazing Inconel 718 with various brazing alloys as determined by wetting tests. A subsequent investigation will be initiated to investigate the shear strength of the alloy, or alloys, selected from the above tests.
- 4.0 Status and Results - The final report is being prepared. Test results indicate the wetting and flow characteristics of the nickel base brazing alloys are superior to those of the silver base brazing alloys when applied to Inconel 718.

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1.0 Index Code . . . . . (Ni-4)(I-i)(VI-b)

2.0 Title - T.R. No. 513-304, Shear Strength of Brazed Inconel 718 Joints.

3.0 Objective - The new INCO nickel-chromium alloy, Inconel 718, is being considered by MAC for use in brazed assemblies. Further evaluation of CM52 and CM56LC nickel braze alloys, selected as being most feasible filler materials for brazing Inconel 718 in a prior test program, is needed to determine brazing cycles that result in maximum shear strength and joint efficiency.

4.0 Status and Results - This test program will begin when required Inconel 718 sheet is received.

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1.0 Index Code . . . . . (FeL)(I-d,k)(V-h)  
(FeUH)(I-d,k)(V-h)

2.0 Title - T.R. No. 513-287, Thread Rolling.

3.0 Objective - The thread rolling process offers a high quality threaded product with superior fatigue characteristics. Consequently, MAC has procured a thread rolling machine and this machine will be used to make NAS 600 series bolts for testing purposes because these bolts have high quality threads with definite structural requirements. The objectives of this test program include the following:

- a. Qualification of MAC for rolling threads to meet MIL-B-7838 requirements.
- b. Establishment of a process to assure conformance with MIL-B-7838 requirements.
- c. Determination of effects of processing variables on the ability of parts to meet the requirements of MIL-B-7838.

The scope of this evaluation will include the following:

## Phase I

Various methods of blank preparation prior to thread rolling will be investigated to determine the optimum method. The headed specimen blanks prepared by various methods will be thread rolled into 3/8" diameter threaded bolts and subjected to metallurgical and dimensional analyses and tension, fatigue and static fatigue tests. The blank preparation method that produces the best combination of required properties will be selected for subsequent evaluation.

## Phase II

Utilizing the optimum blank preparation method from Phase I, a series of several diameters of rolled threaded bolts will be made and subjected to metallurgical and dimensional analyses and tension, fatigue, and static fatigue tests.

4.0 Status and Results - Phase I testing of the 3/8" diameter roll threaded bolts is complete. The test results indicate that MAC rolled threads meet MIL-B-7838 requirements. Specimen preparation for Phase II work has just been initiated.

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1.0 Index Code . . . . . (Be)(I-k)(VI-a)

2.0 Title - T.R. No. 513-245, Mechanical Properties and Formability of Beryllium Sheet.

3.0 Objective - The high modulus of elasticity, low density, high specific heat, strength, and excellent nuclear radiation shielding characteristic of beryllium makes it a desirable candidate material for aerospace design applications if its brittle behavior can be overcome. The scope of this test program includes determination of the following:

- a. Room temperature directional tensile properties of as received and MAC annealed 0.040 inch beryllium sheet.
- b. Short time elevated temperature directional tensile properties of as received and MAC annealed beryllium 0.040 inch sheet.
- c. Hot bending characteristics of beryllium sheet.

4.0 Status and Results - Preliminary tensile results at room temperature indicate:

| Specimen Finish | Tensile Strength, KSI* | Yield Strength (0.2% Offset), KSI* | Elongation In 2 In. (%)* |
|-----------------|------------------------|------------------------------------|--------------------------|
| Unpolished      | 66                     | 65                                 | 1                        |
| Polished        | 74                     | 65                                 | 18                       |

\* Average values.

Elevated temperature tensile testing of the beryllium specimens is nearing completion.

Elevated temperature bend tests were conducted at 800°F, 1000°F, 1200°F, and 1300°F with the best results obtained at 1300°F.

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- 1.0 Index Code . . . . . (Be-Plstc-6,13A)(I-1)(V-h)
- 2.0 Title - T.R. No. 52-051.03.01, Ablation Shield Development  
Testing - Surface Preparation of Beryllium for  
Adhesive Bonding.
- 3.0 Objective - The purpose of this phase of the advanced Mercury  
ablation shield development program is to evaluate several methods  
of surface preparation of beryllium for adhesive bonding. The  
scope of this test program includes the following:
- a. Surface preparation of finger panels of Brush Beryllium  
Company's QMV-200-A press sintered block by anodic,  
chemical, and liquid honing methods.
  - b. Bonding the above panels with HT-424 film adhesive.
  - c. Lap shear testing of bonded specimens at room temperature,  
500°F, and 800°F.
  - d. Visual examination of failed specimens.
- 4.0 Status and Results - Of the six beryllium surface preparation  
methods investigated, the combined liquid honing and alkaline  
cleaning procedure produced the highest bond shear strength at  
800°F (1254 psi) and is a very efficient reproducible manufactur-  
ing process.

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1.0 Index Code . . . . . (Cb-3)(Mo-2)(I-1,k)(V-h)

2.0 Title - T.R. No. 513-210, Refractory Alloy Fasteners and  
Joint Evaluation Program.

3.0 Objective - To determine the shear strength, tensile strength  
and processing data for experimentally produced F48 columbium  
alloy fasteners and mechanically attached joints at tempera-  
tures of 1800°F-2200°F. Secondary objectives include the  
establishment of satisfactory fastener installation procedures  
and evaluation of conformance of fasteners to the dimensional  
requirements of applicable engineering drawings. The test  
program is divided into the following phases:

- a. Phase I - Determination of rivet temperature versus  
dwell time and rivet squeezing procedure.
- b. Phase II - Determination of room and elevated temperature  
tensile properties of F48 columbium alloy and molybdenum -  
0.5 Ti alloy sheet materials.
- c. Phase III - Determination of room and elevated temperature  
shear strength of universal head, 100° countersunk head,  
and blind rivet joints in refractory sheet materials.
- d. Phase IV - Determination of room and elevated temperature  
tensile strength of Hex head and flush head refractory  
alloy bolts.

4.0 Status and Results - All fasteners are available and test  
specimens for Phase I work have been completed. Phases II,  
III, and IV test work will be conducted utilizing elevated  
temperature vacuum test apparatus in the very near future.

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- 1.0 Index Code . . . . . (Cb-3)(I-k)
- 2.0 Title - T.R. 513-232, Directional Tensile Properties of  
F48 Columbium Alloy at Room Temperature and at 2200°F.
- 3.0 Objective - Preliminary work with F48 columbium alloy has  
indicated significant variations in tensile properties within  
individual sheets. The objective of this investigation is  
to establish the variation in directional tensile properties  
at room temperature and at 2200°F for F48 columbium alloy  
sheet in thicknesses ranging from 0.010" through 0.052".
- 4.0 Status and Results - Fabrication of test specimens for room  
and elevated temperature testing has been completed. These  
specimens have been taken from the longitudinal, transverse,  
and 45° directions of the referenced direction of rolling of  
the F48 columbium alloy sheet.

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1.0 Index Code . . . . . (Cb-4)(I-a,g,h,i,k)(IV-c)(VI-o)

2.0 Title - T.R. No. 513-279, Evaluation of Cb-10W-2.5 Zr  
(Cb-752) Columbium Alloy.

3.0 Objective - To make a comparative evaluation of the mechanical properties and reported fabricability of newly developed Cb-10W-2.5 Zr (Cb-752) columbium base alloy. The scope of this evaluation includes determination of the following:

- a. Tensile properties at room temperature, 2200°F, and 2500°F of uncoated specimens.
- b. Tensile properties at room temperature and 2200°F of coated specimens.
- c. Shear strength at room temperature and 2500°F of uncoated specimens.
- d. Bearing strength at room temperature and 2500°F of uncoated specimens.
- e. Notched tensile strength at room temperature of uncoated specimens.
- f. Lap shear strength at room temperature and 2500°F of resistance spot welded specimens.
- g. Cross tension strength at room temperature of resistance spot welded specimens.
- h. Tensile properties at room temperature and 2500 of fusion welded specimens.
- i. Formability at room temperature.
- j. Oxidation resistance of coated specimens exposed to a temperature of 2500°F for 15 minute and 60 minute intervals.

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- 4.0 Status and Results - The first four sheets of material for for this investigation were received on 10 April 1962. Flatness of the sheets (approximately 18" W x 36"L) was evaluated; all sheets were flat within 0.300". Thickness of all sheets was evaluated and found to vary only 0.001" in any sheet. Tensile properties of all four sheets have been determined at room temperature. Specimens for completing the required testing have been completed and testing has been initiated.

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1.0 Index Code . . . . . (Cb-6, Inorg Fin-1,4)(I-e-k)2.0 Title - T.R. No. 513-307, Tensile Properties of Coated D-36  
Columbium Alloy.

3.0 Objective - A newly developed columbium base alloy, D-36, is of interest for future aerospace usage. Although this alloy exhibits only moderate strength, it is reported to be readily producible, formable at room temperature, weldable and may be readily protectively coated. To consider this alloy for future applications, it is necessary to develop preliminary data by evaluating the tensile properties of the material after protective coating. The scope of this test program includes the following:

- a. Determination of the tensile properties of LB-2 coated D-36 specimens at room temperature, 1800°F, and 2500°F.
- b. Microhardness determinations of the LB-2 coated D-36 specimens after tensile testing at room temperature, 1800°F and 2500°F.
- c. Preparation of photomicrographs of sections through the coating before and after elevated temperature testing.

4.0 Status and Results - Room temperature tensile testing has been completed and the results are presented below.

| Thickness<br>(Inches) | Ultimate<br>Tensile Strength<br>KSI | Yield Strength<br>0.2% Offset KSI | % Elongation<br>in 2 Inches |
|-----------------------|-------------------------------------|-----------------------------------|-----------------------------|
| 0.016                 | 85                                  | 70                                | 12                          |
| 0.016                 | 82                                  | 73                                | 13                          |

Elevated temperature testing at 1800°F and 2500°F has been delayed due to repair of test facility.

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1.0 Index Code . . . . . (Cb-1, Inorg Fin-1,4)(I-e,k)

2.0 Title - T.R. No. 51-054, Effects on the Mechanical Properties of LB-2 Coated Columbium-5% Zirconium Alloy of Inspection by an Oxidation Check Test.

3.0 Objective - The oxidation check test used to detect coating defects of LB-2 coated columbium-5% zirconium alloy panels requires additional heating of these panels. There is some concern, however, regarding the effect that this additional heating cycle may have on the mechanical properties of the metallic substrate. It is necessary to determine if any adverse effects are incurred by this test before it can be specified for use. The scope of this evaluation includes determination of the following:

- a. Tensile properties of uncoated columbium-5% zirconium alloy specimens.
- b. Tensile properties of LB-2 coated columbium-5% zirconium alloy specimens.
- c. Tensile properties of LB-2 coated columbium-5% zirconium alloy specimens after heating for 1/2 hour to temperatures of 1800°F and 1900°F.
- d. Microhardness of all failed specimens.
- e. Thickness of unaffected base material remaining after coating for each condition investigated.

4.0 Status and Results - The test work has been completed and the laboratory report is being prepared. Test results indicate that the oxidation check test does not have any adverse effect on LB-2 coated columbium-5% zirconium alloy.

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- 1.0 Index Code . . . . . (Mo-2)(I-k)
- 2.0 Title - T.R. No. 513-228, Evaluation of Mechanical Properties of Molybdenum-0.5 Ti Alloy Extrusions.
- 3.0 Objective - To make a comparative evaluation of room and elevated temperature tensile properties of two extruded molybdenum-0.5 Ti 1.625 inch diameter bars furnished by ASD (Project No. 7351, WADD Technical Report 59-26).
- 4.0 Status and Results - Twenty 0.252 inch diameter tensile specimens will be tested at room temperature, 1600°F, 2000°F, 2200°F, 2500°F, and 2750°F. Tests will be conducted at pressures of 1 micron or lower with a 15-minute soak prior to loading. Elevated temperature tensile properties obtained thus far are presented below.

| <u>Specimen Number</u> | <u>Test Temp. °F</u> | <u>Ult. Tensile Strength, KSI</u> | <u>Yield Strength KSI</u> | <u>% Elongation in 1 Inch</u> |
|------------------------|----------------------|-----------------------------------|---------------------------|-------------------------------|
| 3                      | 1600                 | 61.6                              | 60.0                      | 18                            |
| 4                      | 1600                 | 59.6                              | 57.1                      | 18*                           |
| 5                      | 2000                 | 58.4                              | 53.5                      | 26                            |
| 6                      | 2000                 | 56.2                              | 51.4                      | 25                            |

\* Broken - Out of Gage

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1.0 Index Code . . . . . (Mo-4)(VI-a)

2.0 Title - T.R. No. 513-302, Evaluation of the Minimum Bend  
Radius of TZM (Mo-0.5 Ti-0.1Zr) Similar to MMS 184.

3.0 Objective - A new processing technique has been developed for producing TZM alloy sheet with double the ductility offered by the material specified in MAC Material Specification -184. A small quantity of 0.020 inch sheet has been furnished by the vendor for bend tests. If the vendor claims are valid, less scrap could be anticipated in the fabrication of future molybdenum assemblies when using this special grade sheet. The objective of this test program is to determine the minimum bend radius of 0.020 inch thick TZM alloy sheet at room temperature.

4.0 Status and Results - The test work has been completed. Bend test results show the special (extra ductile) TZM sheet to be only slightly more ductile than material procured to the requirements of MAC Material Specification -184. Both types of sheet 0.020 inch thick could be successfully bent around a 0.040 inch radius mandrel; however, with a 0.031 inch radius mandrel, the extra ductile sheet showed slight exfoliation but the MAC Material Specification sheet cracked the length of the bend.

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- 1.0 Index Code . . . . . (Mo-4, Inorg Fin-4,9)(V-g,h,j)
- 2.0 Title - T.R. No. 51-071, Effect of Oxidation Check Test  
on Dimensional Stability of Siliconized Coated  
Molybdenum Alloy Parts.
- 3.0 Objective - The usage of the oxidation check test as the  
only reliable method of inspecting coated molybdenum parts,  
poses a dimensional stability problem resulting from  
thermal warpage. This condition might result in unusable parts  
even though the coating was satisfactory. The objective of  
this test program is to determine the dimensional stability of  
coated molybdenum parts subjected to the elevated temperature  
oxidation test specified in MAC Material Specification -572.  
The scope of this evaluation includes:
- a. Fabrication of a corrugated panel with mating face sheet  
that has been match drilled, reamed, and countersunk to  
dimensions typical of re-entry vehicle parts. Recording  
hole diameters to the nearest 0.001 inch and specimen  
flatness within 0.005 inch.
  - b. Dimensional measurements of specimens before and after  
coating, and after oxidation tests.
  - c. Quality evaluation of the silicide coating before and  
after oxidation check test.
- 4.0 Status and Results - The corrugated panel-face sheet assembly  
specimens have been measured and photographed. These specimens  
will be sent to Chromalloy Corporation for silicide coating.  
Upon receipt of these coated specimens the oxidation check  
tests will be initiated.

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1.0 Index Code . . . . . (Mo-4, Inorg Fin-4,9)(V-g,h,j)

2.0 Title - T.R. No. 51-072, Determination of Siliconized Coating  
Thickness In and Around Holes and Countersinks in  
Molybdenum (TZM) Sheet.

3.0 Objective - The selection of silicide coatings on molybdenum  
alloy (TZM) sheet for re-entry vehicle applications, demands  
accurate specific information pertaining to dimensional changes  
and total coating thicknesses incurred by pack cementation  
silicide coating technique. The scope of this test program  
includes the following:

- a. Fabrication of test specimens that have been drilled,  
reamed, and countersunk to dimensions representative of  
re-entry vehicle parts. Accurate measurement of hole  
and countersink diameters to within 0.0005 inch and  
measurement of sheet thicknesses adjacent to holes within  
0.0005 inch.
- b. Dimensional measurements (within 0.0005 inch) all hole  
diameters, countersink diameters, and thicknesses adjacent  
to each hole, at the same locations as for specimens in  
the uncoated condition, after silicide coating.
- c. Photomicrographs of thicknesses of silicide coating at  
and in the vicinity of each hole and countersink.
- d. Quality evaluation of coated specimens.

4.0 Status and Results - The test specimens have been measured and  
photographed. The specimens will be sent to Chromalloy  
Corporation for silicide coating. Upon receipt of these coated  
specimens from the vendor they will be subjected to the test  
procedures outlined above.

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1.0 Index Code . . . . . (Mo-2,<sup>4</sup>)(VI-a,e,1)

2.0 Title - T.R. No. 184-007, Fabrication Evaluation of Molybdenum Alloy Sheet - Mo-0.5Ti and Mo-0.5Ti-0.1Zr (TZM).

3.0 Objective - This test work is a part of the overall program to evaluate molybdenum alloy sheet produced during the refractory metal sheet rolling program. The objectives of this program are to investigate bending, uniform elongation, and dimpling characteristics of Mo-0.5Ti and Mo-0.5Ti-0.1Zr molybdenum alloys in thicknesses ranging 0.016 inch to 0.06 inch, and to establish proper fabricating procedures. The scope of this evaluation includes determination of the following:

- a. Room temperature and elevated temperature minimum bend radii and effect of pickling on bend radii.
- b. Uniform elongation at room temperature, 550°F and 750°F.
- c. Dimpling conditions.

4.0 Status and Results - Bend specimens are being prepared. The major part of the test material will not be received until after July 1962.

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1.0 Index Code . . . . . (Ta )(I-e,j)(VI-j)2.0 Title - T.R. No. 513-272, Elevated Temperature Rupture  
Strength of Ta-30Cb-7.5V Alloy.3.0 Objective - The primary interest in Ta-30Cb-7.5V alloy sheet  
is for structural usage at temperatures of 2200°F to 3000°F.  
This alloy has high strength, excellent fabricability, and  
good weldability. The objectives of this test program are:

- a. To determine the stress required to cause rupture of  
Ta-30Cb-7.5V alloy in 1 hour and 10 hours at tempera-  
tures of 2200°F, 2400°F, 2700°F and 3000°F.
- b. To determine the total elongation of all ruptured  
specimens.
- c. To obtain machining information such as feeds, speeds,  
amount of metal removed during machining operations of  
the test specimens.

4.0 Status and Results - Stress rupture data obtained thus far is  
presented in the table below.

| <u>Test Temp.</u><br><u>°F</u> | <u>Rupture Stress</u><br><u>Level KSI</u> | <u>Time to Failure</u><br><u>Hours</u> | <u>% Elongation</u><br><u>in 1 Inch</u> |
|--------------------------------|-------------------------------------------|----------------------------------------|-----------------------------------------|
| 2200                           | 35                                        | 0.9                                    | 45                                      |
| 2200                           | 35                                        | 0.9                                    | 42                                      |
| 2200                           | 35                                        | 1.1                                    | 39                                      |
| 2200                           | 35                                        | 1.7                                    | 37                                      |
| 2400                           | 32                                        | 0.3                                    | 68                                      |
| 2700                           | 10                                        | 0.8                                    | 37                                      |
| 3000                           | 1                                         | 6.6                                    | 24                                      |

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- 1.0 Index Code . . . . . (Alwt-3,FeUH-3,Plat-2)(IV-a,e)  
(Mg-8,Ti-1,FeA-5)(IV-a,e)  
(Ni-3,Co-1)(IV-a,e)
- 2.0 Title - T.R. No. 513-265, Effects of High Temperature Exposure on Dissimilar Metal Joints.
- 3.0 Objective - MAC P.S. 13603 requires glass tape between the faying surfaces of dissimilar metal joints when exposed to temperatures above 300°F in order to minimize corrosion. The temperatures at which compatibility problems occur for many dissimilar metal combinations are higher than 300°F. Eliminating the use of glass tape at lower temperatures would significantly reduce costs. The objective of this test program is to determine the effects of elevated temperature exposure for extended time on the corrosion properties of dissimilar metal joints. Dissimilar metal combinations to be evaluated are tabulated below.

## Dissimilar Metal Combinations and Temperatures

| Metal                | 4340 Cad.<br>Plated | HM21  | Ti<br>AMS 4901 | 4340<br>Bare | 321    | Incon-<br>el X | L-605  |
|----------------------|---------------------|-------|----------------|--------------|--------|----------------|--------|
| 2024-T6              | 350°F               | 350°F | 350°F          | 350°F        | 350°F  |                |        |
| 4340<br>(Cd.Plated)  |                     | 500°F | 500°F          |              | 500°F  | 500°F          | 500°F  |
| Titanium<br>AMS 4901 |                     |       |                | 875°F        | 875°F  | 875°F          | 875°F  |
| 4340<br>(Bare)       |                     |       |                |              | 1000°F | 1000°F         | 1000°F |
| 321                  |                     |       |                |              |        | 1300°F         | 1300°F |
| Inconel X            |                     |       |                |              |        |                | 1500°F |

- 4.0 Status and Results - The laboratory test has been completed and the final report is being written. Test results indicate no problems in any of the dissimilar metal joints investigated for 500 hour elevated temperature exposures in air and subsequent exposure to a corrosive environment.

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d. Determination of shear strength of the brazed joints.

- 4.0 Status and Results - All testing has been completed on the N-155 brazed specimens, and the PH 15-7Mo specimens are in the process of being tested.

Elevated temperature shear strength data obtained thus far on vacuum brazed N-155 is presented below.

| Base Metal | Brazing Alloy Used | Elevated Temperature Shear Strength KSI |       |        |        |
|------------|--------------------|-----------------------------------------|-------|--------|--------|
|            |                    | Room Temp.                              | 800°F | 1200°F | 1600°F |
| N-155      | CM-52              | 23.1                                    | 17.3  | 17.4   | 12.9   |
|            | CM-53              | 81.2*                                   | 66.3* | 67.9*  | 38.2*  |
|            | 130                | 24.4                                    | 19.0  | 18.4   | 7.7    |

\* Failed in tension-base metal.

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1.0 Index Code . . . . . (Plat-8)(I-d,k)

2.0 Title - T.R. 513-277, The Development of Electroforming Techniques.

3.0 Objective - The capability of electroforming would allow this technique to be used for producing aerodynamically smooth models for wind tunnel testing. The objectives of this test program are to produce heat transfer models with nickel and to obtain further information on electroforming techniques. The scope of this evaluation includes the following:

a. Molding a two-piece mandrel of Cerrobend to proper dimensions.

b. Nickel plating the Cerrobend mandrel to the following thickness:

0.030"  $\pm$  0.005" except leading edge and nose

0.030"  $\pm$  0.015"  
- 0.005" leading edge and nose.

c. Machining of two tensile specimens from excess trim on each model.

d. Hardness and tensile properties of tensile specimens.

4.0 Status and Results - Preliminary tests are being performed on wood mandrels to produce a uniform nickel plating thickness of low stress concentration. Based on information acquired from simulated mandrels, a heat transfer model can be electroformed.

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- 1.0 Index Code . . . . . (Plat-3,8)(I-k)(II-c)(IV-a)(VI-g)
- 2.0 Title - T.R. 513-277.02, The Development of Electroforming Techniques.
- 3.0 Objective - The objectives of this test program are the following:
- a. Evaluation of mandrel materials (permanent and expendable) most suitable for producing intricate or specific designs requiring precise tolerance control.
  - b. Evaluation of conductive coatings compatible with mandrel materials.
  - c. Evaluation of plating solutions applicable to electroforming.
  - d. Development of electroforming techniques.
  - e. Determination of physical and mechanical properties data for electroformed specimens.
- 4.0 Status and Results - Preliminary test results indicate that it is necessary to define objectives and further develop electroforming techniques utilizing new plating processes and materials.

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Issued December 1, 1961

### 2.2.9.1 LOW ALLOY STEELS HEAT TREATED TO 240-300,000 PSI

#### METALLURGICAL EVALUATION OF INTERNATIONAL NICKEL COMPANY'S 20 AND 25% NICKEL ALLOYS

##### Objective

The metallurgical evaluation was conducted in an effort to evaluate new materials which are applicable to Solar's products today and possibly in the future.

##### Results and Conclusions

A wide range of mechanical properties are attainable with variations in heat treat cycles. These range from 150,000 psi ultimate tensile strength, 85,000 psi ultimate yield strength, with 16% elongation in the "as received" condition to 296,000 psi ultimate tensile strength, 248,000 psi ultimate yield strength, with 3.5% elongation in the maraged condition.

Room temperature properties of 229,000 psi ultimate tensile strength, 203,000 psi ultimate yield strength, and 8.5% elongation were obtained on the 25% nickel grade. When tested at cryogenic temperature of -320 F the material showed a substantial increase in strength, as well as in ductility; i.e., 300,000 psi ultimate tensile strength, 265,000 psi ultimate yield strength, with 12% elongation.

Welding of the 20 and 25% nickel alloys is relatively simple and may be compared with welding of the more familiar grade of stainless steel Type 310. However, butt-welded tensile specimens have a tendency to fail at the edge of the weld, exhibiting low ductility and low weld joint efficiency. Planishing of the welds after welding and annealing has improved the weld joint efficiency but results still leave much to be desired.

Both alloys were susceptible to pitting corrosion from condensed moisture during the sub-zero temperature exposure and should be protected. Spraying with "Acrylon" has been effective.

Surface decarburisation is not a problem with the 20 and 25% nickel alloys, however, surface oxidation occurs during the annealing treatment of 1500F. The oxidation which occurs at the annealing temperature appears to be intergranular. Methods to prevent or remove this condition should be used.

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7.2.6.1.1 MISCELLANEOUS METALS AND ALLOYS (REFRACTORY METALS)

FABRICATING TECHNIQUES FOR REFRACTORY MATERIALS APPLICABLE  
TO SOLID PROPELLANT ROCKET NOZZLES

Objectives

Investigate fabricating techniques for the forming of tungsten, 98W-2Mo, and 90Ta-10W alloys.

Investigate the joining of tungsten by solid state bonding and ultrasonic welding.

Investigate the tungsten inert arc welding of 90Ta-10W.

Results and Conclusions

Hot die forming of tungsten segments is feasible for segments of 0.10 to 0.90" in thickness, and for 60 to 120 degree included angle.

Centrifugally cast 98W-2Mo rings can be shear spun in the as cast condition to produce thin shells of worked material. Centrifugally cast tungsten is more difficult to spin.

Solid state or diffusion bonding of tungsten can produce joints with usable strengths at temperatures in excess of 4000 F. Bonds can be produced with nickel or rhenium interfacial materials at 2000 F with remelt temperatures in excess of 4200 F.

Ultrasonic welding can produce welds of good quality in thin tungsten sheet, but the scatter of weld strength values is large.

90Ta-10W can be TIG welded with no filler wire, Ta filler wire, and 90Ta-10W filler wire. Superior properties are obtained with 90Ta-10W filler wire. Welds made in this manner can be shear spun successfully.

December 1, 1961

## 7.2.6.1.2 MISCELLANEOUS METALS AND ALLOYS (REFRACTORY METALS)

## MULTIPLE LAYER NOZZLE

Objective

The objective of this program is to design, develop and manufacture a solid propellant rocket motor nozzle of novel configuration. The nozzle throat will consist of multiple wrought tungsten washers formed to a bellville cone angle and brazed. The assembly will be cradled in copper and retained by a Ta-10W cup.

Results and Conclusions

A process of electrochemical anodic milling of tungsten has been developed and used to electrochemically cut 0.125" gage tungsten shims.

Tungsten shims or laminates have been successfully hot formed with only a 10% spallage rate.

Multiple layer nozzles have been brazed successfully using O.F.H copper as the brazing alloy. The brazed nozzles have been machined and are presently in final stage of assembly.

SOLAR

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#### 7.2.6.1.3 MISCELLANEOUS METALS AND ALLOYS

##### LITHIUM FILLED NOZZLE HOUSING AND ASSEMBLIES

#### Objective

Program is to determine the processing techniques for loading lithium and other metals in rocket nozzles which will be evaluated under firing conditions.

#### Results and Conclusions

We have developed the capability to load rocket nozzles with liquid metals (lithium, sodium, and magnesium) utilizing laboratory techniques, and utmost safety precautions.

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7.2.6.1.5 MISCELLANEOUS METALS AND ALLOYSNOSE CAP STUDYObjective

This program consists of research and development on high temperature materials leading to the fabrication and test of three each of two nose cap configurations that will withstand the time-temperature-load conditions of orbital and super orbital vehicles.

The present experimental phase is being directed towards determining the solution of many unolved elevated temperature problems. Most important of which is a refractory metal coating system which will withstand the thermal stresses, not be affected by carbonaceous ablating overlays, and provide a high emissance surface.

Results and Conclusions (To Date)

Refractory metallic carbides have good oxidation resistance up to the temperatures and pressures at which molten products are formed. At 20 mm Hg pressure, this temperature is 2600-3000 F for TiC and 4100-4480 F for ZrC and HfC.

A small increase in the refractoriness of the oxidation products of ZrC and HfC will permit these materials to be used at 4500 F.

Silicon carbide is unsuitable for overlay material(s) because of destructive oxidation.

Thoria is compatible with tantalum and tungsten for 10 minutes at 4900 F and 5000 F respectively.

Thoria, yttria stabilized hafnia, monoclinic zirconia, hafnium carbide, and zirconium carbide are compatible with tungsten for 10 minutes at 4500 F.

Thoria, yttria stabilized hafnia, and hafnium carbide are compatible with tantalum for 10 minutes at 4500 F. There is, however, some increase in the microhardness of the tantalum.

Magnesium reacts with tantalum and tungsten at 2480 F and 4260 F respectively.

Thoria is an effective barrier between magnesium and tungsten at 4500 F.

Plasma sprayed HfC appears to be more thermal shock resistant than ThO<sub>2</sub>, HfO<sub>2</sub>, and ZrO<sub>2</sub> on tungsten, although all of the materials remained bonded to the tungsten rod specimens during heating and cooling. No appreciable change in weight of any coat resulted from this test. No coating flow occurred.

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#### 7.2.6.1.5

Plasma sprayed thorium, 0.008" to 0.015" thick, provides good protection to tungsten, having withstood 4000 F in oxidizing conditions for 20 minutes with a weight loss of only 0.1 g/min or a metal loss of only 0.0001" to 0.001"/min depending on air flow.

Hafnia rates high in oxidation protection, but HfC and zirconia do not show as much promise.

Both thorium and hafnia warrant further detailed investigation, but HfC and  $ZrO_2$  cannot be eliminated as yet by the few tests conducted to date.



#### 7.2.6.1.5 MISCELLANEOUS METALS AND ALLOYS

##### NOSE CAP STUDY

##### Objective

The program consists of research and development on high temperature materials leading to the fabrication and test of three each of two nose cap configurations that will withstand the time-temperature-load conditions of orbital and super orbital vehicles.

The present experimental phase is being directed towards the solution of a refractory metal coating system which will withstand the thermal stresses, not be affected by ablating overlays, and provide a high emittance surface. In addition, emphasis of the program is changing from materials testing to fabrication. Fabrication areas that are presently being investigated are shear forming, solid state bonding, brazing, plasma arc coating, and reinforced troweled on overlays.

##### Test Results and Conclusions

Of three new materials tested for oxidation resistance, tungsten-thoria, tantalum-10 hafnium, and pyrolytic boron nitride, only the tungsten alloy appears to have sufficient oxidation resistance to be considered for structural application to the nose cap.

Hafnia and thoria remain the most stable, high temperature candidate overlay materials.

Based on the poor oxidation resistance of tantalum-hafnium alloys, no further work is planned with the tantalum alloy system.

Compatibility tests of various agents with the refractory oxides,  $ZrO_2$ ,  $HfO_2$ , and  $ThO_2$ , with tungsten showed the following:

- 1) Phosphate bonded  $HfO_2$  or  $ThO_2$  has 4500 F capability in contact with tungsten.
- 2) Magnesia alone, or in the presence of thoria, is very corrosive to tungsten at 4200 F.

Joining of tungsten by solid state bonding is being conducted in an attempt to reduce the time, temperature, and/or pressure necessary. Present diffusion bonds having the highest reliability are produced at 2050 F and at a pressure of 20,000 psi for 30 minutes.

R.D.R. 1234-6

May 31, 1962



Spot brazing of tungsten has been accomplished with a resistance spot welder. Tantalum and rhenium foils were used as the braze materials. Spot brazing with rhenium foil was very difficult, and resulted in severe deformation and cracking of the tungsten, as well as rapid deterioration of the welding electrode.

Spot brazing with tantalum was more successful and could be accomplished without difficulty.

Efficient deposition of plasma sprayed overlays can be obtained by precoating thoria grains with tungsten and mixing the coated grains with pure tungsten.

Considerable additional work will be required in developing tungsten reinforcements for joining the overlay to the base metal to prevent failure under the severe environments to be reached.

December 1, 1961

### 8.1.2.2 PERCUSSION WELDING

#### INVESTIGATION OF PERCUSSION WELDING ON MOLYBDENUM

##### Objective

To develop a process for the percussion welding of 1/2" diameter molybdenum rods required for testing.

##### Results and Conclusions

The welding time characteristics of transformer machines appear to be too great for percussion welding molybdenum. The resulting excessive metal expulsion could not be controlled, and no welds were obtained on 1/2" diameter bars.

A capacitor-discharge machine produced partially welded specimens, but the power capacity was not adequate to permit a comprehensive evaluation of the process. Metallographic examination indicated structures that might be compatible with useful welded properties, but a more extensive investigation would be necessary to evaluate this possibility.

December 1, 1961

8.1.2.4.3 BRAZINGLOW TEMPERATURE BRAZING OF ALUMINUMObjective

The objective of this preliminary investigation was to demonstrate the feasibility of a 1000 F aluminum brazing system, a step towards the ultimate goal of a 925 F aluminum brazing system. It was recognized that aluminum brazing at 1000 F would also require the development of a new brazing alloy and a new flux.

Results and Conclusions

Lap joint specimens of Type 6061 aluminum alloy were brazed successfully at 1010 F and at 1000 F with a new brazing alloy and new flux. In order to braze at these low temperatures, a furnace atmosphere of titanium foil gettered argon appears essential; for with a furnace atmosphere of bottle argon, minimum brazing temperatures were increased to 1030 F and 1020 F respectively.

Quality and ductility of the development alloy brazements are comparable to those made with the commercial brazing alloys.

The new flux proved adaptable to the brazing of all brass alloys used in this investigation, over the temperature range of 1000 - 1120 F.

December 1, 1961

2.1.2.4.5 BRAZINGDEVELOPMENT OF LOW TEMPERATURE BRAZING ALLOYS FOR TITANIUM  
HONEYCOMB SANDWICH MATERIALSObjective

To develop a process for brazing titanium honeycomb sandwich compatible with its aging cycle (below 1100 F). Also, the braze joints were to be capable of service up to 850 F.

Results and Conclusions

An-Sn-Ti brazing alloys have shown that titanium can be brazed at temperatures below 1100 F. Although the brazed joints have exhibited good resistance to corrosion and high temperature air oxidation, strength and ductility are viewed as marginal.

The use of a preplaced reactive powder to increase the remelt temperature of the brazed joints, which supports the idea of brazing and aging titanium alloys at the same temperature, has been successfully demonstrated with titanium powder additions. In addition, the titanium powder has been shown to increase the wetting and flow of the braze alloy.

To obtain more favorable mechanical properties in the brazed joint, further modification of the braze alloy system would be necessary.

REPORT R.D.R. 1234-6  
ISSUED May 31, 1962



#### 8.1.2.4.5 BRAZING

##### DEVELOPMENT OF LOW TEMPERATURE BRAZING ALLOY FOR TITANIUM HONEYCOMB SANDWICH MATERIALS

#### Objectives

The objectives of the program are to develop alloys for the brazing of titanium alloys in the aging temperature range and to develop techniques for brazing titanium alloy honeycomb sandwich materials with these alloys suitable for use up to 850 F.

#### Results and Conclusions

Alloy development is progressing; systems studied to date include the following: Ag-Cu-Ge, Ag-Cu-Sn, and Ag-Ge-In. Thermal analysis results of the Ag-Cu-Ge system showed that an alloy of the following composition: Cu 20.0, Ge 20.0, and Ag balance, has a liquidus and solidus of 1000 F.

Although the Ag-Cu-Sn system is more complex than the Ag-Cu-Ge system, it appears promising on the basis of the thermal analyses. An alloy of 10.0 Cu, 20.0 Sn, with Ag balance has a liquidus of 1260 F, and a solidus of 1000 F.

Three alloys of the Ag-Ge-In system have been melted and thermal analyses made. These indicate that the melting range of the alloys is too high to be useable without modification.

R. D. R. 1234-3

December 1, 1961

8.1.2.4.7 BRAZING

## DEVELOPMENT OF LOW TEMPERATURE BRAZING OF TUNGSTEN FOR HIGH TEMPERATURE SERVICE

Objective

To develop a low temperature reactive brase system to its full potential. The program was proposed in five phases:

- Phase I - Study the effect of boron content
- Phase II - Study the effect of mode of tungsten addition
- Phase III - Develop optimum joint thickness
- Phase IV - Determine optimum joint thickness
- Phase V - Alloy development

The program is incomplete as of November 22, 1961. However, results and conclusions obtained thus far are listed below.

Results and Conclusions

Results indicate that the maximum usable boron content of the platinum boron alloy is about 4.5%. At heating rates up to 2000 F/min, powder size of the tungsten addition to the alloy up to about 74 microns has little significance in the absence of other tungsten.

Tungsten specimens, reaction brazed with Pt-B alloys plus tungsten powder at 2000 F, have given remelt temperatures as high as 3760 F. Subsequent three hour diffusion treatments of the brazed joints at 2000 F have increased the remelt temperature up to 3840 F.

The Pt-B (hypereutectic) and Pt-B (eutectic) alloys showed a sharp decrease in remelt temperature with tungsten powder additions exceeding 20% of the Brase alloy tungsten powder mixture.

The hypereutectic Pt-B alloy has shown no decrease in remelt temperature with tungsten additions as high as 38.5% of the brase alloy - tungsten powder mixture.

The Ir-B alloys with no powder additions have not yielded the higher remelt temperatures as previously anticipated. The values obtained, however, are comparable to the highest values obtained with the Pt-B alloys.

R. D. R. 1234-3

SOLAR

December 1, 1961

8.1.2.4.7

Joints containing preplaced powder additions of osmium, ruthenium, rhenium, and tungsten, brazed with Ir-B alloys, yielded no increase in remelt temperature over those specimens containing no additions.

R. D. N. 1234-3

December 1, 1961

§.1.2.4.7 BRAZING

## BRAZING PROCESS DEVELOPMENT ON MOLYBDENUM

Objective

To develop a brazing process for molybdenum components brazed at 1800 F capable of developing a remelt temperature above 3000 F.

Results and Conclusions

The specimens brazed with Ni-10P, Cu-Ti, and Ti-Ni were unsatisfactory in that braze alloy would not flow into a joint containing a reactive powder.

The Pt-B-Ti alloy flowed well to provide sound joints. With proper diffusion treatments after brazing and joint gaps of 0.001" and less, service temperatures of approximately 3000 F can be expected.

Iridium and molybdenum additions to the Pt-B-Ti alloy offer firm opportunities for improving the high temperature strength of the joints and for reducing the brazing temperature.

R.D.R. 1234-6

May 31, 1962



#### 8.1.2.4.6 BRAZING

##### REACTIVE BRAZING OF MOLYBDENUM FOR 3000 F SERVICE

#### Objective

To develop a braze system to join molybdenum that flows and wets well at 2000 F, yet have a potential remelt and use temperature well over 3000 F.

#### Results and Conclusions

Molybdenum and molybdenum alloy brazements brazed with Solar RGN-3 at 2000 F possess sufficient strength and stability for many important applications to 3000 F.

Solar RGN-3 should be particularly suitable for brazing molybdenum assemblies required for current and proposed lift-glide vehicles.

The advantages of Solar RGN-3 over competitive braze systems are:

- 1) The ability to braze molybdenum and molybdenum alloys at a low temperature, without causing recrystallization and embrittlement of the base material.
- 2) The ability to furnace braze large molybdenum assemblies cheaply using conventional low temperature furnaces and related equipment.

REPORT R.D.R. 1234-6  
ISSUED May 31, 1962



#### 6.2.5.1 WASPALOY

##### MECHANICAL PROPERTIES, PROCESSING REQUIREMENTS AND FABRICATION CHARACTERISTICS OF WASPALOY SHEET

#### Objective

The program was concerned with a metallurgical evaluation conducted on Waspaloy which included numerous tests utilizing a wide selection of annealing, solution treating, stabilizing, and aging studies as well as a limited amount of elevated temperature tensile tests. In addition, the effects of welding, brazing, and forming were evaluated. The results were obtained on material from production size sheets supplied by Universal Cyclops Steel Corporation.

#### Results and Conclusions

The results and conclusions that follow apply to sheet material up to 1/16" in thickness. Some variation in mechanical properties and processing characteristics could logically be expected in plate or bar stock.

Waspaloy in the as received condition when aged at 1400 F for 16 hours results in the best combination of room temperature properties. Tensile strength 181,000 to 191,000 psi, yield strength 130,000 to 140,000 psi, with 25% elongation in 2 inches.

Exposure to elevated temperatures in excess of 1400 F, such as stabilizing treatment or interstage anneal, lowers the strength on subsequent aged Waspaloy sheet material. In addition, intergranular oxidation occurs on material exposed to temperatures above 1550 F in an air atmosphere; controlled atmospheres are therefore indicated and definitely mandatory in solution heat treating thin gage Waspaloy sheet.

Waspaloy sheet is harder to form (will require more force) than the 300 series stainless steels. In addition, Waspaloy work-hardens at a very fast rate necessitating intermediate anneals during deep drawing operations.

Automatic and manual welding of this material will present problems. Waspaloy apparently has a small tolerance for mistakes and any slight variation from established welding schedules will probably result in continuous porosity and/or cracking of the weld.

Welding schedules producing crack free welds have been established for 0.025" and 0.043" material welded by automatic TIG process. However, we were unable to produce 100% crack free manual TIG welds during the present evaluation.

Waspaloy in the over-aged condition will regain most of its strength upon subsequent aging at 1400 F for 16 hours and therefore may be considered a reversible aging alloy.

Good strong joints were made on Waspaloy sheet with gold base brazing alloys.

REPORT R.D.R. 1234-6  
DATE May 31, 1962



#### 8.1.2.4.8 BRAZING

##### BRAZING OF PYROLYTIC GRAPHITE

#### Objective

This program was concerned with developing techniques for brazing pyrolytic graphite to either commercial graphite or to the molybdenum -  $\frac{1}{2}$ % titanium alloy. The requirements originally set forth was that joints should retain some useful strength at a short time peak temperature of 1500 F.

#### Results and Conclusions

There is a high degree of incompatibility between the surface of pyrolytic graphite and metallic braze alloys in general. This arises from the combination of properties exhibited by the pyrolytic graphite and the typical metallic properties of braze alloys. Commercial braze alloys capable of operation up to 1500 F (and other high expansivity alloys) are not suitable for brazing pyrolytic graphite to ordinary graphite or molybdenum -  $\frac{1}{2}$ % titanium unless some means of transferring the thermal stresses below the surface of the pyrolytic graphite is used.

Silicon base alloys can be used to produce moderate strength joints to pyrolytic graphite without surface stabilization. Indicated shear strengths at 1500 F ranged from 244 to 380 psi.

It appears probable that carbide or graphite-carbide type joints, formed in place, would have the best chance of successfully reaching high strengths. Such a joint should have good strength to relatively high temperatures.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

CHEMICAL; CHEMICAL BLANKING; BERYLLIUM

**DESCRIPTIVE TITLE:**

Chemical Milling Beryllium as a Method of Material  
Cutting

**OBJECTIVE:**

To chemically cut beryllium sheet material into small  
specimens by selective masking and etching.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Beryllium sheet was completely masked using a neoprene material and fine  
lines of maskant were cut and stripped to give any part configuration  
desired.

The masked parts were then immersed in the BAC 5737 chemical milling  
solution and allowed to remain until the acid had etched through the  
exposed metal. The parts were then removed from the solution, rinsed  
and the protective mask was removed leaving detail parts chemically  
blanked to size.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

CHEMICAL; CHEMICAL BLANKING; MOLYBDENUM

**DESCRIPTIVE TITLE:**

Chemical Blanking of Parts

**OBJECTIVE:**

To develop a process for precision blanking of sheet material. This process must be capable of producing straight edges, holes, slots, etc. without delamination.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

The following process was developed:

1. Clean per BAC 5789, Method 1
2. Dip coat with KMER maskant
3. Air cure overnight or oven cure 30 minutes at 225°F
4. Contact print image using a photographic negative and a high intensity ultra violet light source.
5. Dissolve unexposed maskant by vapor degreasing per BAC 5408.
6. Etch through the exposed areas using nitric-hydrofluoric acid per BAC 5789, Method 3.
7. Strip remaining maskant using Xylene.

This process produced 100% delamination-free parts.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

**METAL; ALUMINUM ALLOYS; CRACKING CHARACTERISTICS**

**DESCRIPTIVE TITLE:**

**Evaluation of Cracking Characteristics of Aluminum Alloys**

**OBJECTIVE:**

To establish the transverse grain cracking characteristics of selected 2000 and 7000 series aluminum alloys subjected to various stresses in corrosive media.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

The limited amount of data tabulated so far indicates that ring or "C" specimens machined from extrusion alloys of 2024, 7075, 7178 and 7079 exhibit basically the same life expectancy except 7178 which was considerably less.

**BOEING AIRPLANE COMPANY**

**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM ALLOYS; SPINNING

**DESCRIPTIVE TITLE:**

Spinning Tests on Several Alloys

**OBJECTIVE:**

The purpose of this test program was (1) to determine the magnitude of directional properties in selected alloys after flow spinning, (2) to determine the shapes, (3) to determine the maximum practicable thickness reductions which may be made by flow spinning without intermediate annealing, (4) to determine the mechanical properties of the alloys tested after flow spinning and heat treating and (5) to determine if spinning and flow spinning the alloys by varying amounts will transform the cast structure of welded specimen areas into a wrought structure.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

X2219, X200, VASCOJET 1000, 4340, and 321 may be spun from flat circular blanks to cylindrical shapes at room temperature. Directionality of mechanical properties after spinning was not marked.

The mechanical properties, with the exception of elongation, of all spun alloys was generally higher after heat treatment than control specimens which were not spun.

The "cast" structure of the welded specimens, X2219 and 321, showed some transformation to a wrought structure.

Detail results are reported in Test Report T2-1850 dated 7/20/60.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM LAMINATED; TEAR RESISTANCE

**DESCRIPTIVE TITLE:**

Tear Resistance and Crack Propagation in Aluminum  
Laminated Sheets

**OBJECTIVE:**

A theoretical method for predicting crack growth rates in laminated sheets was attempted. The following program was designed in part to test the theory.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

2024-T3 clad, 2024-T81 clad and 7075-T6 clad aluminum alloy panels, consisting of both single sheet and two-ply laminated sheets, were subjected to the following tests: seven laminated panels fabricated from 7075-T6 clad aluminum alloy with central cracks of varying lengths (in one-ply only) were static tested to failure. Crack yawnings and slow crack extensions were observed in these tests. Twelve single sheet panels (4 of each alloy and heat treat) and 3 laminated sheets (1 of each alloy and heat treat) were fatigue tested to observe fatigue crack growth behavior.

The results of this program indicate that: (a) for sufficiently long cracks, the static tear strength for laminated panels is greater than for single sheets of equivalent metal thickness; however, if the cracks are short (i.e. less than 4.0" in this test) laminated panels exhibit no greater static tear strength than single sheets of equivalent metal thickness (b) the fatigue life on laminated panels in which only one-ply is cracked is much greater than the fatigue life for cracked single sheets of equivalent metal thickness. Data for the fatigue crack growth behavior of 2024-T3 clad, 2024-T81 clad, and 7075-T6 clad aluminum alloy sheets were also obtained.

**BOEING AIRPLANE COMPANY**

**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM AND MAGNESIUM ALLOYS; IMPACT STRENGTH

**DESCRIPTIVE TITLE:**

Tension Impact Strength

**OBJECTIVE:**

To determine relative energy absorbing of aircraft structural materials. As a secondary objective an attempt to correlate notched-tensile impact strength to tear resistance is being conducted.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Five aluminum alloys and one magnesium alloy have been subjected to notched tensile impact tests. A chart of energy per square inch from the Izod shows rather remarkable agreement with the relative "standings" of these alloys.

Specifically, the alloys tested are:

2024  
7075  
7178  
X2020  
7079  
HK-31

Testing of this nature is never really "completed" so-to-speak. As more tests and analyses are performed, the confidence level rises. If the notched tensile can be "confidently" viewed as a good measure of energy absorbing ability, it will afford a rapid, economic form of laboratory testing.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

**METAL; ALUMINUM AND MAGNESIUM CASTINGS; DESTRUCTION TESTING**

**DESCRIPTIVE TITLE:**

**Destruction Testing of High Strength Aluminum and Magnesium Castings**

**OBJECTIVE:**

To demonstrate the feasibility of obtaining high strength light alloy castings with mechanical properties guaranteed in the part.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

A special destructive test casting with an I test section was used. Seven aluminum and eight magnesium casting alloys from a total of fifteen vendors were involved in the procurement of the test vehicle. Tensile control specimens were taken from each part and compared to the calculated failing stress for the destruction test.

The following conclusions were reached:

1. Close control of gating, risering, and chilling is necessary.
2. Heavy chilling and close dimensional tolerances are not compatible.
3. Greater casting reliability is primarily due to the increase in elongation.

Ultimate tensile strengths of 47,000 psi for C355-T6 aluminum alloys and 38,000 psi for QE22A-T6 magnesium alloy were obtained in a cast part. The desired strength level was achieved only for A356-T6 and C355-T6 aluminum alloys and ZK51A-T5 and QE22A-T6 magnesium alloys.

Reference - BAC Document No. D5-6979.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM AND MAGNESIUM; CASTING;  
MECHANICAL PROPERTIES

**DESCRIPTIVE TITLE:**

Short Time Elevated Temperature Properties of  
Premium Quality Light Alloy Castings

**OBJECTIVE:**

To determine the elevated temperature strength of various high strength aluminum and magnesium casting alloys under conditions of rapid heating and loading and short exposure times.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Tension, stress-rupture, and compression testing was accomplished on three high strength aluminum alloys and four high strength magnesium alloys. Temperatures from 70°F to 700°F and soak times of 10 seconds, 15 minutes, and 30 minutes were used. A load rate of 4-6 KSI/sec for the magnesium alloys and 8-10 KSI/sec for the aluminum alloys was used.

The combination of short soak times and rapid loading produced a considerable increase in the mechanical properties over those indicated by standard short time tests. The highest strength aluminum alloy was C355-T6 and the highest strength magnesium alloy was QE22A-T6. Some of the room temperature ultimate strengths reached 50,000 psi for aluminum and 40,000 psi for magnesium.

Reference - BAC Document No. D5-6896

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM; TEAR RESISTANCE

**DESCRIPTIVE TITLE:**

Tear Resistance of Some Commercial Gages of Several  
Aluminum Alloys

**OBJECTIVE:**

To obtain some tear-resistance data on some commercial  
gages of several aluminum alloys.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Wide specimens (15" - 48") of several aluminum alloys and commercial gages were centrally cut half their width and then pulled in simple tension to failure.

Results were as follows:

| <u>Material</u> | <u>Gage Range<br/>- Inches</u> | <u>Gross Failure Stress As<br/>% of Nominal Tensile Yield</u> |
|-----------------|--------------------------------|---------------------------------------------------------------|
| 2024-T3         | .010-.500                      | 30-45                                                         |
| 7075-T6         | .010-.500                      | 10-30                                                         |
| 7178-T6         | .040-.500                      | 10-25                                                         |
| 7079-T6         | .040-.500                      | 15-35                                                         |

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM, TENZALOY; WELDABILITY

**DESCRIPTIVE TITLE:**

Fusion Welding Evaluation of Tenzaloy Aluminum Casting Alloy

**OBJECTIVE:**

Evaluate the weldability of Tenzaloy, establish feasibility of repair welding Tenzaloy castings and determine the compatibility of joining wrought alloys to Tenzaloy castings.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Tenzaloy is readily weldable to itself and to two 5000 series wrought aluminum alloys using both the MIG and TIG welding processes. It is possible to achieve 100% joint efficiency (30 ksi) in welded Tenzaloy using base metal or 5356 filler metals. Tenzaloy is somewhat prone towards weld cracking and caution should be used in welding restrained parts.

Tenzaloy is a casting alloy which ages naturally from the cast condition. The mechanical properties are dependent upon section thickness - the thinner the section the better are the strength and ductility. It is possible to artificially age this alloy but no significant improvements in the mechanical properties are realized from such a treatment.

Details are reported in Metals Unit Summary Report WS-59, dated 5-11-60.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM, 2014; FORMING TESTS

**DESCRIPTIVE TITLE:**

Preliminary Forming Tests on 2014 Sheet Material

**OBJECTIVE:**

The purpose was to determine the minimum bend radius on several gages of 2014 sheet material.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

The minimum room temperature bend radius, for the material tested, bent through an angle of 120 degrees, is as follows:

$$\begin{array}{ll} 2014-O & \leq 0.5T^* \\ 2014-T6 & \leq 4.1T^* \end{array}$$

The springback ranged from 1-18 degrees.

Detail results are reported in Metals Unit Summary Report MSR-771, dated 9/7/60.

\* T - nominal thickness

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM, X2020; EVALUATION

**DESCRIPTIVE TITLE:**

Evaluation of Production Lots of Aluminum Alloy X2020

**OBJECTIVE:**

To determine the mechanical properties of X2020 produced in commercial lots of sheet, rod, and extrusions.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Clad sheet, cold finishes rod extruded angle and extruded bar supplies from commercial heats were evaluated. Tensile tests provided ultimate and yield strengths, elongation, reduction of area, modulus of elasticity and Poisson's ratio. Compressive tests provided yield strength, modulus of elasticity, tangent modulus and secant modulus. These properties were determined at temperatures ranging from -80°F to 400°F and from specimen exposed for 1/2, 100, and 500 hours to temperatures up to 400°F.

Good metallurgical stability was observed up to 300°F for up to 500 hours. Short time properties remained high for all test temperatures. Tensile and compressive moduli of elasticity were somewhat higher than for other aircraft structural aluminum alloys.

Results are published in Boeing Airplane Company Test Report No. T2-1746 dated 8-18-59.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM 2024-0; SHEARTURNING CAPABILITY

**DESCRIPTIVE TITLE:**

Investigation to Establish Maximum Angular  
Shearturning Capability 2024-0 Aluminum

**OBJECTIVE:**

Establishment of maximum angular limits for shearturning  
quality.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Data plots for tested material having similar shapes show the best  
material performance on blank thicknesses of .090" through .190". The  
maximum angles for 2024-0 for thicknesses of .018" through .260" vary  
from 20° to 14-1/2° and back to 16-1/2°. Maximum angular limit  
established for 2024-0 was 16-1/2°.

**BOEING AIRPLANE COMPANY**

**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM, 2024-T3; CRACK GROWTH

**DESCRIPTIVE TITLE:**

Crack Growth Due to Cyclic Loading

**OBJECTIVE:**

To obtain test data on 2024-T3 sheet material purposely cracked and then subjected to cyclic tension loading; ambient conditions.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Combinations of gross stress level and crack-length produced equal crack-growth-rates under ambient conditions and sinusoidal loading at 2 cps when:

1.  $\frac{\text{Max. Cyclic Load}}{\text{Min. Cyclic Load}} = \text{Constant}$
2.  $K = \text{unique value}$

$$\text{where } K = \frac{2b}{\sigma} \tan \frac{a}{2b}$$

= gross stress (tension) psi

Definitions     $a$  = half crack length (normal to loading)  
                   $2b$  = test panel width

**Sample results:**

|           |      | K      | Growth Rate                 |
|-----------|------|--------|-----------------------------|
|           | 20   | 15,000 | 110 Microinches per Cycle   |
|           | 2.5  | 15,000 | 45 Microinches per cycle    |
| Index No. | 1.25 | 15,000 | 2 1/2 Microinches per Cycle |

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM 2024-T3; FORMING EFFECTS

**DESCRIPTIVE TITLE:**

Effect of Forming 2024-T3 Sheet Prior to Artificial Aging

**OBJECTIVE:**

To determine whether the -T81 condition in formed parts would approach properties of the -T86 condition due to the forming.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Specimens were stretched to permanent sets up to 12.5% in the -T3 condition then aged to the -T81 condition. Maximum change in tensile properties in the -T81 condition were as follows:

| <u>Pre-Age Stretch</u> | <u>UTS</u> | <u>YTS</u> | <u>ELONG</u> |
|------------------------|------------|------------|--------------|
| 0%                     | 68,000 psi | 62,000 psi | 7.3%         |
| 12.5%                  | 70,000 psi | 65,000 psi | 6.6%         |

Based on the above results -T81 properties in severely formed areas would be approximately half-way between typical -T81 and typical -T86 properties. Details are reported in Metallurgical Summary Report No. 767.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM, 2024-T3, T81; FORMING

**DESCRIPTIVE TITLE:**

Effect of Forming 2024-T3 Sheet Prior to Artificial  
Aging to -T81

**OBJECTIVE:**

To determine whether cold formed (stretched) 2024-T3  
material will approach -T86 properties when aged to  
-T81.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Cold forming (stretching) 2024-T3 resulted in a small increase in  
ultimate and yield and a slight decrease in elongation. The cold  
forming will not enable the material to develop T86 properties.

Detail results are reported in Test Report MSR-767, dated 8/3/60.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM 2024-T81; FORMING TESTS

**DESCRIPTIVE TITLE:**

Preliminary Forming Tests on 2024-T81 Sheet Material

**OBJECTIVE:**

The purpose of these tests were to determine the minimum bend radius, the maximum cup depth, and the minimum straight flange length for hydropressed parts.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

The minimum room temperature bend radius, for the material tested, bent through an angle of 120°, is  $\leq 4.3 T^*$ .

Cup test results indicate that the two dimensional formability of 2024-T81 is superior to 2014-T6 and 2024-T86 and inferior to 7075-T6 and 2024-T36.

Detail results are reported in Metals Unit Summary Report MSR 765 dated 8/16/60.

\* T - nominal thickness

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM, 2024-T81; TEAR RESISTANCE

**DESCRIPTIVE TITLE:**

Some Engineering Properties of 2024-T81 Aluminum Alloy

**OBJECTIVE:**

To obtain mechanical properties, crack growth rate, and  
tear resistance data for .065 2024-T81 aluminum alloy.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

| <u>Test Temperature-(°F)</u> | <u>Ultimate Tensile<br/>(psi, Avg)</u> | <u>Tensile Yield<br/>-0.2% Offset<br/>(psi, Avg)</u> | <u>Elongation<br/>(% in 2", Avg)</u> |
|------------------------------|----------------------------------------|------------------------------------------------------|--------------------------------------|
| 70                           | 72,100 L*<br>70,500 T                  | 66,300 L<br>64,400 T                                 | 6.5 L<br>6 T                         |
| 250                          | 63,400 L<br>62,600 T                   | 60,100 L<br>59,400 T                                 | 8 (Approx) L<br>8.5 T                |

Crack growth rate for 2024-T81 is greater than that for 2024-T3 but less than that for 7075-T6, where maximum gross area stress is 15,000 psi and ratio of maximum gross area stress to minimum gross area stress is 2.5.

A 3.5% salt spray environment seems to have very little effect upon the crack growth rate of 2024-T81. The tear resistance increases with an increase in test temperature from -65° to 250°F. Values as determined by  $dP/dA$  vary from 374 to 719, depending upon panel size, initial crack width, grain direction, and test temperature.

\*Grain direction (longitudinal or transverse)

# **BOEING AIRPLANE COMPANY**

## **MATERIALS PROGRAM ABSTRACTS**

### **MATERIAL CLASSIFICATION:**

METAL; ALUMINUM, 2618-T81; TEAR RESISTANCE

### **DESCRIPTIVE TITLE:**

Some Engineering Properties of 2618-T81  
Aluminum Alloy

### **OBJECTIVE:**

To determine mechanical property, crack growth rate, and tear resistance data for .064 2618-T81 aluminum alloy.

### **ABSTRACT OF RESULTS AND CONCLUSIONS:**

| <u>Test Temperature-(°F)</u> | <u>Ultimate Tensile (psi, Avg)</u> | <u>Tensile Yield -0.2% Offset (psi, Avg)</u> | <u>Elongation (% in 2", Avg)</u> |
|------------------------------|------------------------------------|----------------------------------------------|----------------------------------|
| 74                           | 54,900 L*<br>55,000 T              | 47,700 L<br>46,300 T                         | 6 L<br>8 T                       |
| 250                          | 50,200 L<br>49,600 T               | 46,100 L<br>44,900 T                         | 6.5 L<br>7 T                     |

\*Grain direction (longitudinal or transverse)

Crack growth rate for 2618-T81 is approximately the same as that for 2024-T3 and less than that of 7075-T6 and 2024-T81, where maximum gross area stress is 15,000 psi and ratio of maximum gross area stress to minimum gross area stress is 2.5.

The tear resistance increases with an increase in test temperature from -65°F to 250°F. Values as determined by  $dP/dA$  vary from 660 to 1180; depending upon panel size, initial crack width, grain direction, and test temperature. Generally, 2618-T81 has a greater tear resistance than 2024-T81 through the above temperature range.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM, 5456; WELDABILITY

**DESCRIPTIVE TITLE:**

Fusion Weldability of 5456 Aluminum Alloy

**OBJECTIVE:**

Investigate the weldability of 5456 aluminum in two different tempers to obtain preliminary strength and quality data.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Sound welds were readily obtainable by the TIG welding process using 5556 aluminum alloy filler wire.

Static tensile tests revealed that joint efficiencies of 80-83% were obtainable for both temper conditions (40-45 ksi). Bend tests revealed that an average bend angle of 70-73° was obtained about a 2" radius.

Details are reported in Metals Unit Summary Report WS-53, dated 3-28-60.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM; ALCON 6012; WELDABILITY

**DESCRIPTIVE TITLE:**

Weldability Evaluation of Alcon 6012 Wrought Plate  
and Roll Forged Rings

**OBJECTIVE:**

Determine the weldability of Alcan 6012 and compare it to  
Alcoa 2219 for use in determining minimum requirements for  
production machine certifications.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

The results revealed that the mechanical properties of Alcoa 2219 plate welded to Alcan 6012 forging were superior to those of Alcan 6012 plate welded to Alcan 6012 forging but that both combinations could be welded with equal ease. The effect of solution treating times was investigated, as was also the effect of repair welding and weld quality.

A significant difference in grain size was noted between the Alcoa and Alcan alloy plates. This difference has been attributed primarily to manufacturer rolling techniques rather than chemistry modifications.

Details are reported in Test Report T2-1859, dated . 50.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM, ALCAN 6012 AND ALCOA 2219; EVALUATION

**DESCRIPTIVE TITLE:**

Evaluation of Welded and Base Metal Properties of  
Alcan 6012 Aluminum Alloy

**OBJECTIVE:**

Obtain test data which could be used to determine interchangeability between Alcan 6012 and Alcoa 2219.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Alcan 6012 plate and ring forgings were the products used in the evaluation. Room and elevated temperature tensile properties, bend properties, pressure test fatigue properties, dimensional stability, and metallographic characteristics were determined.

Reheat treatment of the as-furnished plate resulted in large grain size and reduced tensile properties. Tensile properties of the ring forging were satisfactory and are listed below:

| <u>Test Temp.</u> | <u>Time at Temp.</u> | <u>UTS(psi)</u> | <u>TYS(psi)</u> | <u>Elong. (%)</u> |
|-------------------|----------------------|-----------------|-----------------|-------------------|
| 75°F              |                      | 58,000          | 43,000          | 7                 |
| 350°F             | 15 min.              | 49,000          | 41,000          | 10                |
| 400°F             | 15 min.              | 40,000          | 33,000          | 17                |
| 500°F             | 15 min.              | 26,000          | 20,000          | 27                |

The above data and the results of the other tests indicated that in ring forgings Alcan 6012 can be considered interchangeable with Alcoa 2219 under the conditions of testing. A test report will be written.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

**METAL; ALUMINUM 6061; WELDMENTS**

**DESCRIPTIVE TITLE:**

**Investigate Load Carrying Capabilities of 4340  
Weldments in 6061 Alloy**

**OBJECTIVE:**

**Determine whether heat treatment after welding improved  
the load carrying capabilities of weldments containing  
crack-like defects.**

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Sharp notch tensile (notch radius .001" or less) tests were performed on as-welded and heat treated weldments in 6061 plate. Griffith-Irwin theory of fracture toughness was applied to the notch tensile results. The stress intensity parameter,  $K$ , was computed from the relationship  $K = 2.33 \sigma_{\text{net}} \sqrt{D}$  where  $D$  is the gross diameter (.250") of the specimen. Values of  $K$  obtained were substituted in the relationship  $K = 1.1 \frac{2}{\pi} \sigma_{\text{gross}} \sqrt{a}$  for a semicircular crack exposed to the surface where  $a$  is the radius or depth of the crack. Theoretical gross area fracture tensile stress,  $\sigma_{\text{gross}}$ , was calculated for a crack-like defect .100" deep to be approximately 19,000 psi for both the as-welded and heat treated weldments. The case investigated concerned application of tensile stress perpendicular to the weldment. Additional details are contained in Metallurgical Summary Report No. 812.

# **BOEING AIRPLANE COMPANY**

## **MATERIALS PROGRAM ABSTRACTS**

### **MATERIAL CLASSIFICATION:**

**METAL; ALUMINUM - 6061-7075 SHEET; JOINING**

### **DESCRIPTIVE TITLE:**

**Joining Sheet by Heat and Pressure Rolling**

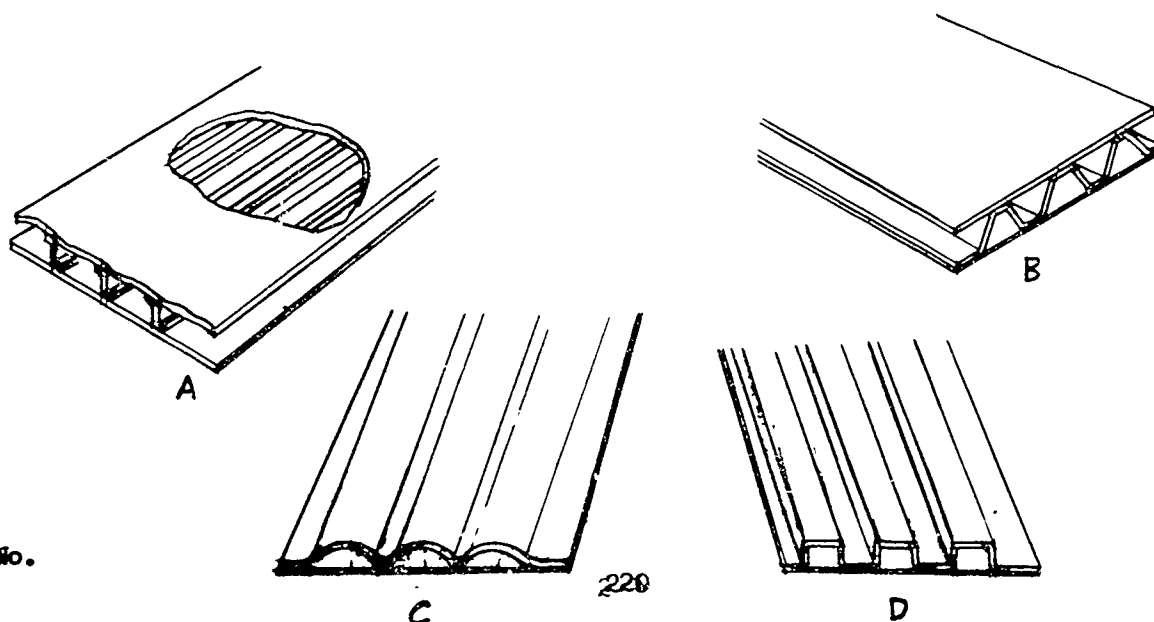
### **OBJECTIVE:**

**Determine production feasibility and physical properties data of sandwich panels produced by roll bonding under heat and pressure.**

### **ABSTRACT OF RESULTS AND CONCLUSIONS:**

**Panels using commercial techniques have been produced. Patterns shown on sketches A and B are expanded from multilayer flat sheets. Problems regarding flatness of skin sheets are not resolved. The patterns shown on sketches C and D are formed, then rolled. Flatness is maintained.**

**Testing and property data evaluation is in progress. Bond strength is approximately equivalent to the strength of the cladding alloy.**



**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM 7075-0; SHEARTURNING CAPABILITY

**DESCRIPTIVE TITLE:**

Investigation to Establish Maximum Angular Shearturn  
Capability for 7075-0 Aluminum

**OBJECTIVE:**

The establishment of maximum angular limits for shearturning  
7075-0 aluminum.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Data plots for tested material having similar shapes show the best material performance on blank thicknesses of .090" through .190". The maximum angles for 7075-0 for thicknesses .040" through .190" varied for 16° to 15° and back to 16°. The maximum angular limit established for 7075-0 was 16-1/2°.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; BERYLLIUM; CHEMICAL BLANKING

**DESCRIPTIVE TITLE:**

Chemical Milling Beryllium as a Method of Material  
Cutting

**OBJECTIVE:**

To chemically cut beryllium sheet material into small  
specimens by selective masking and etching.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Beryllium sheet was completely masked using a neoprene material and fine  
lines of maskant were cut and stripped to give any part configuration  
desired.

The masked parts were then immersed in the BAC 5737 chemical milling  
solution and allowed to remain until the acid had etched through the  
exposed metal. The parts were then removed from the solution, rinsed  
and the protective mask was removed leaving detail parts chemically  
blanked to size.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; COLUMBIUM ALLOYS; BEND DUCTILITY

**DESCRIPTIVE TITLE:**

Bend Ductility of 0.020-in. Cb-0.75% Zr (FS80) Sheet and  
0.020-in. Cb-33% Ta-0.75% Zr (FS82) Sheet in the Stress  
Relieved and Recrystallized Conditions

**OBJECTIVE:**

To determine the bend ductility of Cb-0.75% Zr sheet  
and Cb-33% Ta-0.75% Zr sheet with respect to temperature  
in the stress relieved and recrystallized conditions.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

These alloys were more formable at room temperature than at 1200°F  
for both the stress relieved and recrystallized conditions. The  
brittle-ductile bend transition temperature for these alloys in  
either condition was below -320°F. For further details, see MSR-763,  
1 August 1960.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; COLUMBIUM-10% Ti-10% Mo; BEND DUCTILITY

**DESCRIPTIVE TITLE:**

Bend Ductility of Stress Relieved 0.020 Inch Cb-10% Ti-10% Mo Sheet at Subzero, Room, and Elevated Temperatures

**OBJECTIVE:**

To determine the tensile and bend ductility of a stress relieved Cb-10% Ti-10% Mo sheet with respect to temperature.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

The tensile ductility decreased progressively from room temperature to 600°F. The bend ductility decreased appreciably from 600°F to 1200°F. The brittle-ductile bend transition was in the -253°F to -320°F temperature range. The stress relief cycle of 1750°F for one hour did not produce recrystallization. For further details see MSR773, 12 Sept, 1960.

**BOEING AIRPLANE COMPANY**

**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; COLUMBIUM-33 TANTALUM-0.7 ZIRCONIUM; FORMING  
VARIABLES

**DESCRIPTIVE TITLE:**

Preliminary Evaluation of Columbium Alloy 82  
(53 Ta-0.7 Zr-bal-Cb)

**OBJECTIVE:**

To determine forming and resistance welding properties  
of 0.010 gage annealed F.S. 82 sheet.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Formability requirements are met under room temperature operating conditions. Minimum bend radius ( $R/t$ ) is one or less in both grain directions. The formability properties of F.S. 82 alloy are comparable to the standard aluminum alloys 2024-0 and 6061-0. Gage and flatness variations are slightly greater than generally found in standard aluminum or steel alloys of similar thickness. Surface roughness of No. 82 alloy is in line with other good quality as-received sheet stock.

Although slight "gumminess" is observed in machining of No. 82 alloy, no sticking occurs at the low cutting speed used (approximately 7.5 surface ft./min.).

The 0.010 gage sheet does not give resistance weld quality meeting present standards or specifications. However, relatively acceptable welds can be made by outer shimming with 0.010 Cb or F.S. 82 stock. The shim material may require mechanical removal because of sticking; this should be done by machining rather than peeling.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; GENERAL; BEADING TESTS

**DESCRIPTIVE TITLE:**

Beading Tests on Several Alloys

**OBJECTIVE:**

The objective was to determine the maximum percentage of stretch that may be obtained by beading a given material at room and elevated temperatures.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Beading test conducted on 2024-O, 7075-T6, annealed AM350, 321, HS-25, annealed B120VCA, annealed 6Al-4V, and annealed Rene' 41 showed that all of the alloys with the exception of 6Al-4V could be beaded at room temperature. Elevated temperatures increased the maximum percentage of stretch on .063-inch thick 7075-T6 and annealed AM350, and were mandatory for beading 6Al-4V. Elevated temperatures did not improve the beading characteristics of the other alloys and gages.

Detail results are reported in Test Report T2-1855 dated 8/9/60.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; GENERAL; JOINT ALLOWABLES

**DESCRIPTIVE TITLE:**

Interface Joint Friction Tests

**OBJECTIVE:**

To determine allowable lap joint loads carried by friction in bolted joints subjected to tension, compression, and bending loads.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Six single shear and 225 double shear small scale specimens with 1/4 or 5/16 inch, 160 KSI, protruding head bolts were tested. Sheet materials used were: M-255 and 4340 steel; 2014-T6, 6061-T6, 2024-T4, and 2024-T86 aluminum alloys; and fiberglass. Variables examined included faying surface finishes with and without intermixed abrasives, torque, cyclic loading, vibration loading, water soaking, and loading rates. Results were obtained at 70°F and 225°F.

Tests of full scale cylindrical specimens provided friction properties of single shear 2024-T3 to steel and 2014-T6 to steel bolted joints with 5/16 inch bolts in clearance holes.

The following conclusions were drawn from the test results:

1. A combination of zinc chromate on one surface and zinc chromate with 20% carborundum provided the best friction capability.
2. Torques of 150 inch pounds for steel to aluminum joints and 105 inch pounds for all aluminum joints with 5/16 inch bolts were necessary to obtain adequate friction loads.
3. Prior slippage resulted in reduced friction load capabilities.

Reference - BAC T2-1767

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; MOLYBDENUM - .5 Ti; BEADING

**DESCRIPTIVE TITLE:**

Beading Tests on Mo-.5 Ti

**OBJECTIVE:**

The purpose of these tests was to determine the  
beading capabilities of Mo-.5 Ti

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Mo-.5 Ti sheet material, received before February, 1960, can be beaded at a maximum of ten percent stretch only at room temperature. Elevated temperatures detract from the formability of the material.

Best results are obtained when the material is formed as a sandwich between two pieces of aluminum.

Removal of the contaminated surface layer is essential to obtain maximum formability.

Detail results are reported in Metals Unit Summary Report MSR 770, dated 8/23/60.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; MOLYBDENUM-.5 Ti; CUTTING METHODS

**DESCRIPTIVE TITLE:**

Evaluation of Various Cutting Methods on Mo-.5 Ti

**OBJECTIVE:**

The purpose of this program was to determine whether shearing, hot or cold, with or without backup produces acceptable edges in Mo-.5 Ti sheet material.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Shearing does not produce a satisfactory edge in Mo-.5 Ti sheet material.

Abrasive sawing produces crack-free edges in Mo-.5 Ti, however, the edges must be deburred.

Detail results are reported in Metals Unit Summary Report MSR-203, dated 10/31/60.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; MOLYBDENUM-.5 Ti; FORMING

**DESCRIPTIVE TITLE:**

Evaluation of Bandsawing, Punching, and Grinding  
as Methods of Cutting Mo-.5 Ti

**OBJECTIVE:**

The purpose of this evaluation was to determine  
whether bandsawing, punching, and grinding produced  
acceptable edges.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

All of the edges produced by bandsawing or punching contained  
delaminations and are considered unsatisfactory.

Grinding is a satisfactory method of radiusing corners on Mo-.5 Ti  
parts.

Detail results are reported in Metals Unit Summary Report MSR 804,  
dated 11/3/60.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; MOLYBDENUM-0.5% TITANIUM; FORMING VARIABLES

**DESCRIPTIVE TITLE:**

Investigation of Effects of Temperature and Surface Condition on Formability of Molybdenum-0.5 Titanium (Mo-0.5Ti) Alloy.

**OBJECTIVE:**

To determine effects of temperature and prior surface preparation on formability of 0.010-0.020 gage Mo-0.5 Ti sheet, as received in either a) pickled or b) ground surface conditions.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

A ductile-brittle transition point can appear around room temperature in the case of tensile properties. For maximum forming reliability, Mo-0.5 Ti sheet may require preliminary heating to 150-200°F. Hammer forming, however would have to be tried at a higher temperature level corresponding to the impact ductile-brittle transition temperature (reported in the literature to be 600-700°F). Where heating of the sheet is required in forming, tools should also be heated to minimize drops in sheet temperature during the forming operations.

Minimum bend radius-to-gage ratio (R/t) of bolt-sanded sheet is slightly lower than for sheet that has been pickled only.

Directionality is pronounced in thin gage sheet; however, its effects may not be evident in simple forming operations especially if run at elevated temperatures

**BOEING AIRPLANE COMPANY**

**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; RENE' 41; HEAT TREATING

**DESCRIPTIVE TITLE:**

Metallurgical Study of Salt Bath Heat Treatment  
of Rene' 41

**OBJECTIVE:**

To determine if Rene' 41 can be heat treated in a  
neutral salt bath without the incidence of severe  
surface attack.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

A total of 240 .040" Rene' 41 sheet coupons were fabricated and divided into three principle groups; the first to be tested immediately following activation of the salt bath facility, the second to be tested one week later, and the third to be tested on the fourth week of bath operation. Testing of the specimens within these groups consisted of immersion in the salt at 1975°F, 2050°F, and 2100°F for times ranging from 1 minute to 25 minutes. The salt bath used was Houghton Liquid Heat No. 1550, and rectification to a 1.5% BaO content was based upon daily checks for alkalinity. The test specimens were measured for thickness before and after immersion and then metallographically examined to determine the total depth of surface attack. It was concluded that the surface attack was predominantly intergranular, and that the depth of the attack did not exceed .0006".

Details of work are reported in Metals Unit Summary Report MSR-819,  
dated 11-30-60.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; RENE' 41 AND HS-25; HIGH TEMPERATURE EXPOSURE

**DESCRIPTIVE TITLE:**

The Effect of High Temperature Exposure on Rene' 41  
and HS-25

**OBJECTIVE:**

To show the effect of intergranular oxidation on  
Rene' 41 and HS-25 after exposure to high temperatures.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Twenty-four tensile specimens were tested at room temperature after exposure to temperatures up to 2000°F in either air or argon atmospheres.

Tensile and yield strengths of Rene' 41 were reduced by exposures to high temperatures. The effect was greatest for the highest exposure temperature. Exposure in an air atmosphere was more detrimental than that for the argon atmosphere.

The tensile strength of HS-25 increased slightly when exposure to either air or argon atmospheres at high temperatures. The yield strength, however, showed about a 20 KSI decrease.

Pre cent elongation behaved erratically with material, exposure temperature, and atmosphere. The greatest effect appeared to be that for Rene' 41 exposed in air at 1600°F.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; M-252 and RENE' 41: STRENGTH AND DUCTILITY

**DESCRIPTIVE TITLE:**

The Effect of Material Gauge on the Strength  
and Ductility of M-252 and Rene' 41

**OBJECTIVE:**

To determine the strength and ductility characteristics  
for .01 and .04 gage M-252 and Rene' 41.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Twenty-seven tensile specimens were tested from room temperature to 1800°F. The per cent elongation of both Rene' 41 and M-252 increased slightly for the thicker gage material. There was no apparent difference in tensile and yield strengths for M-252 in the .010 and .040 gages. The .040 gage Rene' 41 showed approximately 10 KSI increase over the .010 gage for both ultimate and yield strength.

**BOEING AIRPLANE COMPANY**

**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; RENE' 41; WELDMENTS

**DESCRIPTIVE TITLE:**

Evaluation of the Effect of Cyclic Thermal Exposures  
on Hastelloy "W" and Hastelloy "X" Weldments in Rene' 41

**OBJECTIVE:**

To evaluate the relative merits of Hastelloy "W" and  
Hastelloy "X" filler alloy for use in joining Rene' 41.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Rene' 41 was fusion welded using Hastelloy "W" and Hastelloy "X" filler alloy. Samples were welded, aged for 16 hours at 1400°F and exposed to air for 0, 1, 4, and 10 minute cycles at 1850°F. After thermal cycling, the test pieces were tensile tested at room temperature, 1400, 1500, 1600, and 1800°F.

Test results revealed a decrease in room and elevated temperature mechanical properties as a result of thermal cycling. The mechanical properties of Hastelloy "W" welds were far superior to those of the Hastelloy "X" welds. Hastelloy "W" welds, after being cycled 4 times or more, revealed a joint efficiency of 100% as measured by room temperature testing.

Metallographic evaluation revealed no serious detrimental effects of the short time cyclic exposures upon the microstructure of the Hastelloy "W" welds.

Hastelloy "W" appears to be a suitable filler wire for use in Rene' 41 when thermal exposures above 1400°F are held relatively short. In long time applications, Hastelloy "W" may be somewhat inferior to Hastelloy "X" because of its lower oxidation resistance.

Details of work are reported in Metals Unit Summary Report MSR-818, dated 11-30-60.

# **BOEING AIRPLANE COMPANY**

## **MATERIALS PROGRAM ABSTRACTS**

### **MATERIAL CLASSIFICATION:**

**METAL; SILVER BRAZING ALLOYS; TUBE CONNECTIONS**

### **DESCRIPTIVE TITLE:**

**Brazed Tube Connection**

### **OBJECTIVE:**

To evaluate available silver brazing alloys, and to determine the alloy that will give the highest joint efficiency up to 800°F and provide the maximum corrosion and oxidation resistance. Also the optimum method of heating for plant fabrication and field rework of a brazed system will be evaluated.

### **ABSTRACT OF RESULTS AND CONCLUSIONS:**

This report is concerned with silver brazing permanent tube connections and evaluating commercially available silver brazing alloys from the standpoint of flow, wetting of base metal, oxidation resistance, and corrosion resistance. Tests were run by using a flat disc tack welded, at various joint clearances, to a square bottom plate and placing the alloy in a predrilled hole in the flat disc. These specimens were then subjected to brazing temperatures in a sand sealed retort using argon as the protective atmosphere.

Of the eight (8) alloys evaluated, four (4) were considered for further investigation and are in order of preference as follows:

1. Handy and Harmon BTLi Ag 72- cu 27.5 - Li 0.5
2. Handy and Harmon Lithobraz 925 Ag 92.5-Cu 7.3-Li 0.2
3. Handy and Harmon 404 Ag 40 - Cu 30 - Ni 5 - Zn 25
4. Handy and Harmon 541 Ag 54 - Cu 40 - Ni 1 - Zn 5

The selected alloys showed excellent flow and wetting in the 0.000 - in. to 0.003 - in. joint clearance range. Each alloy showed minor oxidation penetration into the joint although the corrosion resistance was good on all four alloys evaluated.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; SINTERED ALUMINUM POWDER; MECHANICAL PROPERTIES

**DESCRIPTIVE TITLE:**

Investigation of Some Engineering Properties of  
Sintered Aluminum Powder

**OBJECTIVE:**

To obtain room temperature ultimate tensile strength,  
tensile yield, and elongation values for two types of  
sintered aluminum powder sheet (SAP produced by  
Aluminum Industry Aktien-Gesellschaft).

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

| <u>Material Class</u> | <u>Ultimate Tensile<br/>(psi, Avg)</u> | <u>Tensile Yield<br/>0.2% Offset<br/>(psi, Avg)</u> | <u>Elongation<br/>(% in 2", Avg)</u> |
|-----------------------|----------------------------------------|-----------------------------------------------------|--------------------------------------|
| SAP 930 SF 3A*        | 38,050                                 | 33,250                                              | 11                                   |
| SAP 895 S 68B**       | 48,300                                 | 42,000                                              | 9                                    |

\* Aluminum plus 7% (approximate weight) of aluminum oxide,  
Aluminum Industry Aktien-Gesellschaft

\*\* Aluminum plus 10-11% (approximate wieght) of aluminum oxide,  
Aluminum Industry Aktien-Gesellschaft.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; STEEL; RESIDUAL STRESS

**DESCRIPTIVE TITLE:**

Residual Stress Measurements by Means of X-Ray Diffraction  
in Hardened Steel

**OBJECTIVE:**

To determine the magnitude of residual stresses in  
hardened steel parts due to heat treatment, fabrication,  
or installation.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

The detrimental effect of high residual stresses in hardened steel airplane parts is common knowledge. Application of x-ray diffraction techniques as a means of determining the magnitude of residual stresses has shown that x-ray diffraction techniques can be used to measure stresses in a part without either destroying the part or having to start with a zero stress reference. In the past, most x-ray diffraction stress measurement work has been restricted to small parts because of equipment limitations. The purpose of this investigation was to develop a technique using "film patterns" which is applicable to any size part or structure, provided that certain geometric problems are not encountered. Accuracy of residual stress measurements in 4330M steel, heat treated to 220,000-240,000 psi tensile strength, has been determined to be  $\pm 10,000$  psi.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

   METAL; STEEL 321-A; SHEARTURNING CAPABILITY

**DESCRIPTIVE TITLE:**

Investigation to Establish Maximum Angular  
Shearturning Capability

**OBJECTIVE:**

To establish maximum angular limits for shearturning of  
321-A stainless steel.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

The data plots for tested materials having similar shapes showed the best material performance on blank thicknesses of .090" through .190". The maximum angles for 321-A were thicknesses of .090" through .190" varied from 15° to 14° and back to 15°. Maximum angular limit established for 321-A Stainless Steel was 15°.

# BOEING AIRPLANE COMPANY

## MATERIALS PROGRAM ABSTRACTS

### MATERIAL CLASSIFICATION:

METAL; STEEL, AM 350 CRT SHEET; PROPERTIES

### DESCRIPTIVE TITLE:

Determination of Some Engineering Properties of  
AM 350 CRT

### OBJECTIVE:

To determine mechanical properties, crack growth rate, suitable tempering conditions and stress corrosion susceptibility of AM 350 CRT sheet.

### ABSTRACT OF RESULTS AND CONCLUSIONS:

| <u>Temper<br/>Condition</u> | <u>Gage</u> | <u>Ultimate Tensile<br/>(psi, Avg)</u> | <u>Tensile Yield<br/>-0.2% Offset<br/>(psi, Avg)</u> | <u>Elongation<br/>(% in 2", Avg)</u> |
|-----------------------------|-------------|----------------------------------------|------------------------------------------------------|--------------------------------------|
| 1.5 Hrs.<br>@ 850°F         | .060        | 200,600                                | 171,600                                              | 29.5                                 |
| 2 Hrs<br>@ 850°F            | .060        | 199,900                                | 174,400                                              | 27                                   |
| 3 Hrs.<br>@ 850°F           | .060        | 216,700                                | 197,400                                              | 21                                   |
| 3 Hrs.<br>@ 800°F           | .060        | 219,400                                | 199,400                                              | 20                                   |
| 3 Hrs.<br>@ 950°F           | .060        | 209,100                                | 193,200                                              | 15.7                                 |

Crack growth rate for AM 350 CRT appears to be less than that for AM 355 CRT at stress intensity factor of 25 and greater, where maximum gross area stress = 50,000 psi, ratio of maximum gross area stress to minimum gross area stress = 2.5 and 20, T = 70°F, .020 gage.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; STEEL, AM 350 CRT SHEET; PROPERTIES (Continued)

**DESCRIPTIVE TITLE:**

**OBJECTIVE:**

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

A temperature of 850°F for 3 hours appears to be suitable for tempering AM 350 CRT.

AM 350 CRT was not susceptible to stress corrosion cracking when subjected to such media as alternate immersion in 3.5% sodium chloride solution, cyclic humidity, roof top weathering, and alkaline soil under the specific conditions tested. Stress corrosion cracking appeared to be caused by sulfur dioxide exposure; the susceptibility to stress corrosion cracking was less for AM 350 CRT than for AM 355 CRT.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; STEEL, AM 355 CRT SHEET; PROPERTIES

**DESCRIPTIVE TITLE:**

Determination of Some Engineering Properties of  
AM 355 CRT

**OBJECTIVE:**

To determine mechanical properties, crack growth  
rate, suitable tempering conditions, stress  
corrosion susceptibility, and spotweldability of  
AM 355 CRT sheet.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

| Test<br>Temp.<br>(°F) | Gage | Ultimate Tensile<br>(psi, Avg) | Tensile Yield<br>-0.2% Offset<br>(psi, Avg) | Elongation<br>(% in 2", Avg) |
|-----------------------|------|--------------------------------|---------------------------------------------|------------------------------|
| 70                    | .010 | 258,700 L*<br>253,800 T        | 226,200 L<br>204,800 T                      | 19.8 L<br>12.5 T             |
| 70                    | .040 | 239,300 L<br>245,800 T         | 201,500 L<br>197,100 T                      | 28.3 L<br>20.0 T             |
| 550                   | .020 | 226,400 U**                    | 201,300 U                                   | 4.3 U                        |

\* Grain direction longitudinal or transverse

\*\* Grain direction unknown

(Continued on next page)

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; STEEL, AM 355 CRT SHEET; PROPERTIES (CONTINUED)

**DESCRIPTIVE TITLE:**

**OBJECTIVE:**

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Crack growth rate for AM 355 CRT appears to be greater than that for AM 350 CRT at stress intensity factor level of 25 and greater, where maximum gross area stress = 50,000 psi, ratio of maximum gross area stress to minimum gross area stress = 2.5 and 20, T = 70°F, .020 gage. The rate of crack growth in AM 355 CRT is greater at 550°F than at 70°F above stress intensity factor of 25, where ratio of maximum gross area stress to minimum gross area stress is 20, also 2.5, other conditions the same as above.

A temperature of 850°F for 3 hours appears to be suitable for tempering AM 355 CRT.

AM 355 CRT was not susceptible to stress corrosion cracking when subjected to such media as alternate immersion in 3.5% sodium chloride solution, cyclic humidity, roof top weathering, and alkaline soil under the specific conditions tested. Stress corrosion cracking appeared to be caused by sulfur dioxide exposure.

AM 355 CRT is spotweldable generally in the same gages and combinations as austenitic stainless steels (AISI Type 302, etc.).

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; STEEL, Cr-Ni; WELDMENTS

**DESCRIPTIVE TITLE:**

Evaluation of Specific Joints used in Supersonic Wing  
Components

**OBJECTIVE:**

To evaluate processing techniques and determine the effect of common weld defects on some of the more critical joints applicable to the Supersonic wing.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Tee joints were made using two different configurations, one a two piece joint and the other a three piece joint where the edges of the three pieces are joined with a single weld. Welding of the two-piece joint was very cumbersome because the vertical leg was not visible and slight run-out causes incomplete penetration.

A major problem of age cracking developed and was associated with the presence of an oxide film on the weld underbead. The film was eliminated by careful pre-weld cleaning, increased welding heat and by directing the flow of the backing gas on to the underbead.

The effect of defects such as porosity, inclusions, undercutting and cracks were investigated. It was found that porosity and inclusions had little influence on the static mechanical properties and that undercut and cracks lowered the strength in proportion to their size.

Details are reported in Test Report T2-1818.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; STEEL, LADISH D-6; ROCKET CASE FAILURE

**DESCRIPTIVE TITLE:**

Investigation of Reason for Failure of Rocket Case

**OBJECTIVE:**

Determine any material factors contributing to failure of  
MM 2nd stage rocket case.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

The origin of failure was determined and various tests applied to  
measure the material properties.

A contributory cause of failure was the presence of small cracks  
in the case caused by spotwelding of foil strips to the heat  
treated case for affixing instrument wiring.

Details of work are reported in Metals Unit Summary Report MSR-787,  
dated 10-6-60.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; STEEL, SAE H-11; METALLURGICAL EVALUATION

**DESCRIPTIVE TITLE:**

The Evaluation and Processing of New Materials

**OBJECTIVE:**

The object of this program is to determine process variables and properties of new materials prior to their use in production.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

H-11 sheet material was received and inspected to insure conformance to the procurement specification. All sheets met requirements except the .180" thick sheet which was slightly out of tolerance in flatness. Photomicrographs were made of as-received material and as-received and heat treated material. The as-received structure was spheroidal and homogeneous. The heat treated structure was banded and showed evidence of segregation but little or no decarburization.

Tensile specimens were austenitized over the temperature range 1750-2000°F and air cooled. All specimens were double tempered at 1050°F. The results of testing indicated that the optimum tempering temperature was about 1850°F. However, test values were abnormally low which suggested possible decarburization in the salt pot, that was used for austenitizing. Metallographic examination indicated about .005" decarburization which accounted for about 30% of the total specimen cross section. Since the purpose of these tests was to determine optimum austenitizing temperature, the results are valid. However, absolute values are inaccurate.

(Continued on next page)

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; STEEL, SAE H-11; METALLURGICAL EVALUATION (Continued)

**DESCRIPTIVE TITLE:**

**OBJECTIVE:**

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

To eliminate difficulties encountered with decarburization, a short study of salt bath conditions existing at the time of austenitizing was made. It was found that normal salt bath rectification with a carbon rod was not sufficient unless the salt was relatively fresh.

Using the optimum austenitizing temperature of 1850°F, tensile specimens were double and triple tempered in the temperature range of 950°F to 1300°F. Very little difference was noted in double and triple tempering. A secondary hardening peak was found at about 975°F. Metallographic examination was made of specimens over the entire range of temperature and for both triple and double tempering. X-ray diffraction was used to determine the percentage of austenite present in these specimens.

**BOEING AIRPLANE COMPANY**

**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; STEEL 4330M; EXPLOSIVE FORMING

**DESCRIPTIVE TITLE:**

Effect of Explosive Forming on Mechanical Properties  
of 4330M Steel

**OBJECTIVE:**

To assess the effect explosive forming has upon mechanical properties when the process is used for sizing purposes, i.e., the sizing of cylindrical pressure vessels components requiring close tolerances.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

The steel sheet strained quasi-statically demonstrated acceptable isotropic properties, indicating that prior mill history had little effect upon the explosive forming portion of the program.

Prestrained material subjected to additional straining resulting from explosive forming accentuates directionality in the material. Serious degradation of mechanical properties may result.

The results of this research project has been reported in Metals Unit Summary Report No. MSR-779.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; STEEL 4330M; TEAR RESISTANCE

**DESCRIPTIVE TITLE:**

Effect of High Stress Levels Upon Tear Resistance  
of 4330M 0.080" Thick Sheet Material

**OBJECTIVE:**

To determine the effect of high nominal stresses upon  
tear resistance and evaluate dimensional and test set-up  
requirements for Griffith-Irwin flat specimen.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

1. The tear resistance ( $G_c$ ) remains unchanged for nominal stresses up to the proportional strength limit (0% offset) for the material tested.
2. For the stress levels above the proportional limit the tear resistance ( $G_c$ ) drops at a constant rate according to the following equation.

$$G_c = \frac{2a}{E} \left( \frac{\text{ult.} - \text{P.L.}}{\text{ult.}} \right)$$

Where: E = Modulus of elasticity  
          = Nominal (gross) stress  
Ult = Ultimate strength for the material  
PL = Proportional strength limit at 0% offset

3. The experimental tear resistance values ( $G_p$ ) determined on flat specimens with identical crack (2.0 inches) but of varying widths (up to 20.0 inches) have shown a linear dependence upon absolute width dimensions. The question of possible additional dimensional requirements and limitations of Irwin's dimensional correction factor are being further explored.

**BOEING AIRPLANE COMPANY**

**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; STEEL, 4330M and 300M: HEAT TREATING

**DESCRIPTIVE TITLE:**

Unconventional Heat Treating Techniques for  
Strengthening Steels

**OBJECTIVE:**

To investigate 4330M and 300M steels heat treated by four new heat treating techniques aiming for optimum properties of strength and ductility.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

- A. Stress Tempering - Stress tempering of 4330M steel increased the ultimate strength from 235 ksi to 316 ksi, the yield strength from 185 ksi to 284 ksi but reduced the ductility from 8% elongation to 3%.
- B. Stress Transformation - Stress transformation techniques appeared to improve slightly the ductility of vacuum melted 300M steel from 42% RA to 50% RA approximately.
- C. Stress Austenitizing - This technique improved slightly the strength of vacuum melted 300M steel from 286 ksi to 298 ksi without effecting the ductility.
- D. Bassett Treatment greatly increased the strength of vacuum melted 300M steel (F<sub>tu</sub> from 280.6 to 340 ksi; F<sub>ty</sub> from 237 to 340 ksi) but reduces the ductility (% RA dropped from 42.3 to 27). This heat treatment had a marked surface effect which was partially removed by machining away the surface after treatment. Use of the normal tempering temperature for this material will restore the properties to values similar to those obtained by normal heat treating practices.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; STEEL, 4340; NI PLATE; FATIGUE TESTING

**DESCRIPTIVE TITLE:**

Fatigue Testing of 4340 R.R. Moore Specimens  
Plated with Bart Laboratories SHD Nickel

**OBJECTIVE:**

To determine the effect of the Bart SHD nickel  
plating system on fatigue strength of 4340 steel  
HT150-170,000 psi.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Thirty-six (36) R. R. Moore specimens were tested in this study. Varying the conditions under which the Bart SHD nickel plate (i.e. current density, pH, and additional agent concentration) is deposited has a corresponding effect on the endurance limit of 4340 steel specimens. Reductions in the endurance limit of from 10 to 20% were noted. Additional test work is required to pursue more fully the effect of the individual plating variables.

The Bart SHD nickel plating system as employed herein as part of an overall program to improve the erosion resistance of metal rotor blades consists of .001" thick cyanide zinc, .0005" copper, and .005" SHD nickel.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; STEEL, 4340; QUENCH CRACKING

**DESCRIPTIVE TITLE:**

Cracking During Heat Treat Quench

**OBJECTIVE:**

Determine cause for rash of cracking.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

1. Oil quenching of 4340 critical dynamic helicopter part caused high percentage of cracking.
2. It was found that the particular configuration and section change of this particular part could not withstand the severity of an oil quench.
3. The problem was disposed of by martempering.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; STEEL, PH 15-7 Mo; RESIDUAL STRESSES - WELDMENTS

**DESCRIPTIVE TITLE:**

Residual Stresses in Welded PH15-7Mo Sheet

**OBJECTIVE:**

To investigate the extent of residual stresses inherent in welding rigid structures and to examine several methods of effecting stress relief.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Large panels (24" x 30") of .080" gage PH15-7Mo sheet were spot brazed to a rigid frame and welded using semi-automatic TIG welding equipment. The stresses set up by welding were measured by electric strain gages and "Photostress" using the direct reading method rather than by a relaxation method. It was found that the "Photostress" was not satisfactory for this application because of the intense heat of the welding arc in close proximity to the "Photostress".

Stress measurements revealed that residual stresses of up to 19,000 psi in the transverse direction and up to 14,000 psi in the longitudinal direction were present after welding the panels with a single pass. It was found that the length of the weld influenced the longitudinal stresses but not the transverse stresses. Multiple pass welding increases both the shrinkage and residual stresses in the transverse direction but does not influence the longitudinal stresses by a significant extent. Localized repair welding increases the residual stresses (both directions) by a factor of 2.

Moderate spot peening and mechanical removal of the weld crown have almost no influence on stress relieving the weld. Preheating the joint by use of an oxyacetylene torch mounted a few inches in front of the welding arc reduced the residual stresses by approximately 10%.

Details are reported in Test Report T2-1817, dated 2-2-60.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; STEEL, 17-7 PH; SPRING FAILURE

**DESCRIPTIVE TITLE:**

Investigation of Failed 17-7 PH Cres Springs

**OBJECTIVE:**

To determine cause of failure of tension spring.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

1. Fracture occurred in fatigue at O. D. surface of coil.
2. Nucleus in untransformed skin on surface of wire at pit.
3. Untransformed layer at surface several thousand deep believed caused by carbon or nitrogen pickup during thermal treatment.
4. Core hardness of spring wire was DPH 620 (300,000 uts) as compared with surface hardness of DPH 420 (200,000 uts).
5. Armco Steel Corp. and the spring vendor are participating in the investigation.
6. Reduced fatigue strength of surface layer with stress raiser (pit) apparently cause for fatigue failure.

**BOEING AIRPLANE COMPANY**

**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; STEEL 17-7 PH; STRAIN AGING

**DESCRIPTIVE TITLE:**

Strain Aging of 17-7PH Steel

**OBJECTIVE:**

To study the effect of strain aging on tensile properties of 17-7PH in the following heat treat conditions:

- |                                        |                             |
|----------------------------------------|-----------------------------|
| A. RH 1100 per BAC 8600                | C. Predominantly austenite  |
| B. RH 1100 with high austenite content | D. Predominantly martensite |

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

1. No embrittlement due to strain aging in all conditions.
2. Yield strengths increased after strain aging in all conditions.
3. The low carbon martensite of 17-7PH is quite ductile possessing a tensile strength of 150 ksi and 40% R.A.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; STEEL, T-1 AND NAX-TRA-90; FUSION WELD

**DESCRIPTIVE TITLE:**

Fusion Welding Evaluation of T-1 and NAX-TRA-90 Steel

**OBJECTIVE:**

To determine the relative fusion weldability of NAX-TRA-90 steel vs. T-1 steel and to evaluate the welds for quality, consistency, strength, crack susceptibility, and ductility.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

The weldability of the two steels was found to be excellent, but the T-1 material exhibited a slightly greater tendency to crack during welding than did the NAX-TRA-90.

The mechanical property values were generally within the range expected for welds in these two steels; 100,000-112,000 psi yield; 115,000-126,000 psi ultimate for T-1 and 90,000-95,000 psi yield, 110,000-120,000 psi ultimate for NAX-TRA-90 when the base material is properly heat treated.

The use of preheat and postheat was found to be unnecessary to prevent cracking in these two materials for the degree of restraint which was normally possible to achieve under laboratory conditions. Preheat and postheat actually proved to be detrimental to the mechanical properties with the yield strength being affected to the greatest extent.

Details of the program are reported in T2-1588.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; TANTALUM-10W; BEND RADIUS

**DESCRIPTIVE TITLE:**

Preliminary Minimum Bend Radii of Ta-10W at Room  
and Elevated Temperatures

**OBJECTIVE:**

This work was to determine the minimum bend radii of  
Ta-10W at room and elevated temperatures.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

The bend ductility of Ta-10W in the "as received" and stress relieved conditions decreased slightly as temperature was increased from room to 1200°F. Bend ductility of recrystallized Ta-10W did not change significantly as temperature was increased.

Detail results are reported in Metals Unit Summary Report MSR-790, dated 9/20/60.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; TANTALUM; SPINNING

**DESCRIPTIVE TITLE:**

Manual Spinning of Commercially Pure Tantalum

**OBJECTIVE:**

This work was to spin two parts of commercially pure tantalum for use as closures on a cylinder.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Commercially pure tantalum can be manually spun at room temperature to cylindrical and spherical shapes. The tantalum materials has similar spinning characteristics to mill annealed 3003-0 except that the force required to mate the material to the mandrel compares with that required for mill annealed 2024-0.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; 6Al-4V TITANIUM; CREEP STUDIES

**DESCRIPTIVE TITLE:**

Creep tests of 6Al-4V titanium alloy under conditions of constant and varying stress.

**OBJECTIVE:**

To evaluate two semi-empirical methods of predicting cumulative creep deformation occurring under conditions of constant temperature and varying stress.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Fifteen specimens were creep tested under conditions of constant or varying stress levels at 1000, 1100, 1200°F. The results were compared to strain-hardening and time-hardening methods of predicting cumulative creep. The strain-hardening method best predicted the strain obtained from the cumulative creep testing conducted in this program.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; TITANIUM-B-120 VCA; FORMING VARIABLES

**DESCRIPTIVE TITLE:**

Preliminary Evaluation of B-120 VCA (All Beta)  
Titanium Alloy

**OBJECTIVE:**

To investigate formability properties of solution-annealed "All-Beta" Ti alloy sheet (0.025 gage) by true-stress true-strain analysis of tensile data.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

1. General formability is good at room temperature, with minimum bend radius of 1T; however, stretch-formability and "spin-ability" factors are marginal. A small improvement in formability properties is observed at higher temperature (500°F).
2. A yield point discontinuity, which could lead to stretcher strains in forming, appears at room temperature and is accentuated by higher strain rate. This sharp yield point is eliminated at 500°F.
3. Forming at about 500°F should be tried when room temperature operation gives marginal results. This applies particularly to spinning and stretch-forming, or to drawing that is found to produce stretcher strains and fluting.
4. Springback is comparatively high (e.g. 20% at bend radius of 1T); appropriate allowance should be made in tool set-up and design.
5. Grain direction has no pronounced effect on forming characteristics.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

**METAL; TUNGSTEN; FORMING VARIABLES**

**DESCRIPTIVE TITLE:**

**Preliminary Evaluation of Fabrication Properties of  
Tungsten Sheet**

**OBJECTIVE:**

To determine forming properties of tungsten sheet, with investigation of principal manufacturing operations and fabrication of a typical leading edge configuration.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Results show the necessity of hot-forming the sintered and rolled sheet at about 800°F. Stress relief may be done below 2200°F (e.g. 1800-2000) without recrystallization embrittlement. Chemical cleaning and descaling can be done with standard nitric-hydrofluoric acid or caustic solutions. Chem milling is not feasible because of laminated structure.

Although machining development was adequate to produce components for the leading edge, the processes used were not completely successful; in grinding, abrasive cutting, milling, bandsawing and drilling, the tungsten had a tendency to flake, delaminate and crack. TIG fusion welding joints were low in both strength and ductility, and subject to fracture under slight impact or restraint.

1. MATERIAL CLASSIFICATION: Corrosion
2. TITLE: Environmental Materials Studies for Advanced Organic Moderated Reactors
3. OBJECTIVE: To obtain dynamic corrosion test data on materials exposed to polyphenyl coolants used in organic moderated and cooled nuclear reactors. Areas of particular interest include the effects of flow rate and impurity content on corrosion rates, the nature of the corrosion products, and the types of corrosion products released into the coolant stream by materials now used and proposed for use in organic-cooled reactors. This is an extensive effort.
4. ABSTRACT OF RESULTS OR CONCLUSIONS:

The following table shows the weight change results on a number of materials exposed for 720 hours to 800°F Santowax OMP with a 500 ppm water addition.

CORROSION RATES OBSERVED IN RUN 14  
(mg/cm<sup>2</sup> -mo)

| Material                                             | 15 fps, Liquid* | 7.5 fps, Liquid* | Static, Vapor |
|------------------------------------------------------|-----------------|------------------|---------------|
| A212B Steel                                          | -9.15, -9.20    | -8.72, -10.1     | -1.82, -1.70  |
| 304 SS (12 Cr)                                       | +0.03           | +0.02            | +0.06         |
| 306 SS (13 Cr, 4 Al)                                 | -0.02           | -0.02            | +0.02         |
| Beryllium                                            | +0.05           | +0.03            | -0.02         |
| Ni (High Purity)                                     | +0.78           | +0.72            | +0.74         |
| Ni (Less Pure)                                       | +0.81           | +0.72            | +0.64         |
| 1100-S Al                                            | +0.19, +0.12    | +0.11, +0.09     | +0.05, +0.03  |
| M-257, Heat<br>No. 602307                            | +0.08           | +0.09            | +0.05         |
| M-257, Heat<br>No. 602614                            | +0.15           | +0.12            | +0.07         |
| M-257, Impact<br>Extruded Tube                       | +0.02           | +0.09            | +0.05         |
| M-583, Impact<br>Extruded Tube                       | +0.07           | +0.07            | +0.06         |
| Zircaloy II                                          | -11.7           | -1.7             | +0.20         |
| ATR (½ % Mo, ½ %<br>Cu, Bal Zr; a<br>Canadian alloy) | -55.6           | -30.8            | +0.51         |

\* Linear velocity in ft/sec of the specimens suspended in the Santowax OMP

NA-61-1049-1  
11-1-61

Other autoclave test work has shown the undesirability of permitting the water content of the organic coolant to exceed 1000 ppm when aluminum or APM-clad fuel elements are used. Niobium is embrittled by nitriding as a result of using nitrogen as a cover gas. The ferritic and austenitic stainless steels have shown excellent resistance to attack under all conditions tested to date. Beryllium has also exhibited good resistance to attack. Magnesium, copper and zirconium alloys are unsuitable due to oxidation or hydriding.

This work was AEC-sponsored.

Submitted by Atomics International Division

1. MATERIAL CLASSIFICATION: Corrosion
2. TITLE: Environmental Materials Studies for Advanced Organic Moderated Reactors
3. OBJECTIVE: To obtain dynamic corrosion test data on materials exposed to polyphenyl coolants used in organic moderated and cooled nuclear reactors. Areas of particular interest include the effects of flow rate and impurity content on corrosion rates, the nature of the corrosion products, and the types of corrosion products released into the coolant stream by materials now used and proposed for use in organic-cooled reactors. This is an extensive effort.
4. ABSTRACT OF RESULTS OR CONCLUSIONS:

CORROSION RATES MEASURED IN RUN "H"

Virgin Santowax OMP, no additions, 650 +3 F, 100 psig average N<sub>2</sub>

Results expressed in Mg/cm<sup>2</sup>-mo\*\*

| Hours | Carbon Steel |          | Niobium  |          | XAP - 001 |           |
|-------|--------------|----------|----------|----------|-----------|-----------|
|       | 11.6 fps     | 23.2 fps | 11.6 fps | 23.2 fps | 11.6 fps  | 23.2 fps  |
| 90    | --           | +0.05    | --       | +0.10    | --        | (none)*   |
| 164   | --           | +0.25    | --       | +0.29    | --        | (none)*   |
| 330   | +0.32        | +0.16    | +0.31    | +0.16    | -0.03     | (tinted)* |
| 448   | +0.23        | --       | +0.20    | --       | -0.01     | --        |
| 670   | --           | +0.10    | --       | +0.09    | --        | -0.05     |
| 1117  | --           | +0.10    | --       | +0.06    | --        | -0.02     |

Other Coupons at 23.2 fps

| Hours | Croloy 2 <sup>1</sup> / <sub>2</sub> | Croloy 5 | Croloy 7 | Croloy 9 | 406 SS | 304 SS |
|-------|--------------------------------------|----------|----------|----------|--------|--------|
| 448   | +0.18***                             | +0.18*** | +0.12    | +0.12*** | --     | --     |
| 787   | --                                   | --       | --       | --       | +0.02  | -0.01  |

In addition, six coupons of 1100 aluminum which were exposed 448 hours at 11.6 fps, were clean and bright although badly worn by abrasion.

\* Large weight loss caused by abrasion; results based on appearances.

\*\* Averaged for three duplicate specimens.

\*\*\* For one specimen only; the duplicates suffered abrasion weight losses.

NA-51-1049-2  
4-15-62

Page 2

In general, the corrosion resistance of aluminum, XAP-001 (improved M-257) and stainless steels Type 304 and 406 were excellent. There probably is no significant difference between the results obtained for any of the Croloys and carbon steel.

This work was AEC-sponsored and was performed by Atomic International Division.

1. MATERIAL CLASSIFICATION: Corrosion
2. TITLE: Physical Chemistry of Oxide Films on Zirconium and its Alloys
3. OBJECTIVE: To obtain fundamental information concerning oxide films on zirconium, to help understand the mechanisms by which zirconium is oxidized in various media and to understand the transport of hydrogen through oxide films. Results of the study should aid in a better understanding of the corrosion and hydrogen embrittlement of zirconium and its alloys. This is an extensive effort.
4. ABSTRACT OF RESULTS OR CONCLUSIONS:

A diffusion coefficient for hydrogen through oxide films on zirconium has been determined. Resulting value is,

$$D = 5 \times 10^{-7} \exp(-30,000/RT) \text{ cm}^2 \text{ sec}^{-1}.$$

- T This value compares well with that for the diffusion of hydrogen into  $\text{ZrO}_2$  powder samples.

$$D = 5.9 \times 10^{-7} \exp(-30,000/RT) \text{ cm}^2 \text{ sec}^{-1}.$$

Above a temperature of  $500^\circ\text{C}$ , neither zirconium nor any of the alloys studied (Sn, Mo, Al, or Zircaloy 2) have exhibited transition from parabolic to linear rates when oxidized in liquid sodium. Transition has been observed for all of the alloys except Zircaloy 2 and pure zirconium in the temperature range 400 to  $500^\circ\text{C}$ . The rate of oxidation of Zircaloy 2 in sodium is independent of oxygen concentration above 10 ppm.

This work is AEC-sponsored.

Submitted by Atomics International Division.

1. MATERIAL CLASSIFICATION: Corrosion
2. TITLE: Corrosion of Jo-Bolts
3. OBJECTIVE:

A number of JoBolts have been failing in service. It is thought that corrosion may be contributing to this JoBolt failure problem. One of the items to be tested is the detrimental effect on JoBolts due to the corrosion of the exposed unprotected fractured skin after installation. Effect of protective measures around the heads of fractures is also to be tested under this limited program.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

No data available. Estimated completion; November 1961. This work is being performed under Bureau of Naval Weapons sponsorship by the Columbus Division.

4-15-62

1. MATERIAL CLASSIFICATION: Corrosion2. TITLE: Corrosion of Jo-Bolts3. OBJECTIVE:

A number of Jo-Bolts have been failing in service. It is thought that corrosion may be contributing to this Jo-Bolt failure problem. One of the items to be tested is the detrimental effect on Jo-Bolts due to the corrosion of the exposed unprotected fractured skin after installation. Effect of protective measures around the heads of fractures is also to be tested.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Test assemblies simulated aircraft structure of 2020-T6 material using F-200 series Jo-Bolts for attachment. Metal treatment included sulfuric acid anodize and chemical film (Alodine #1200). Specimens were exposed to 100% relative humidity atmosphere at 80°F and 120°F both with the fractured Jo-Bolt stems and heads protected with wash primer (MIL-C-8514) and unprotected.

First rust detection on the unprotected stems occurred after 120 hours at 80°F, 100% R.H. with heavy rust encrustation observed after an additional 120 hours at 120°F, 100% R.H..

Protected fractured stems showed first traces of rust after 430 hours (120 hours 80°F plus 310 hours 120°F, 100% R.H.). No detectable increase was noted at 506 total hours when test was concluded.

The use of wash primer (MIL-C-8514) is sufficient to prevent rusting of fractured Jo-Bolt stems during aircraft assembly and normal storage periods prior to painting of the completed ship.

This work was of limited magnitude, and sponsored by the Bureau of Naval Weapons at the Columbus Division.

1. MATERIAL CLASSIFICATION: Corrosion

2. TITLE: Intergranular Corrosion in Overheated Stabilized Stainless Steels.

3. OBJECTIVE:

To determine whether heating of stabilized stainless steels (321, 347) at temperatures to 2000°F as occurs during brazing operations has a deleterious effect on the resistance of the alloys to intergranular attack. This work was a limited program.

4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Sheet samples were annealed for 30 minutes at temperatures of 1800, 1900, 2000, 2100 and 2200°F, and water quenched. They were then sensitized at 1200°F for 2 hours, exposed in a standard Strauss test for 48 hours and examined metallographically. It was found that intergranular attack is a problem in 321 stainless steel heated above 2000°F, but that the 347 was not attacked in that way up to 2200°F.

This work was company sponsored by Rocketdyne and is complete.

4-15-62

1. MATERIAL CLASSIFICATION: Corrosion
2. TITLE: Sea Water Corrosion
3. OBJECTIVE: A moderate effort to determine the effect of sea water on the physical and chemical properties of the materials of construction on the G26B engine. Included in the studies of the components will be the determination of residual stresses, the examination for the various types of corrosion, the effect on elastomeric compounds and other similar examination.
4. ABSTRACT OF RESULTS OR CONCLUSIONS:

Macro examination of the various materials showed that the elastomeric compounds, such as the Kel-F seals, the nylon coating of electrical wires, Buna-N O-rings appeared to be least affected. The galvanic corrosion of dissimilar metals was clearly demonstrated. Every metal has a certain inherent electrical potential; and where one metal is placed in contact with a metal of a different potential in the presence of an electrolyte, such as sea water, an electric current flows from one metal to the other, resulting in the dissolution of the more anodic metal. The severity of the corrosion caused by dissimilar metal contact can be predicted by the amount of difference in the electrical potential of the metals involved. The aluminum alloy sand casting were severely attacked, whereas, nickel and stainless steel were undamaged.

Metallographic studies, including microsectioning, will be conducted to determine the extent of galvanic corrosion and loss of other physical properties.

Residual stress studies of 2014 ST aluminum alloy IOX dome indicated that stress lines were present. The stresscoat pattern revealed on the interior surface, mild uniaxial tension at the inside diameter progressing to biaxial tension in the flat section to the outer flange area. On the outer flange area itself was uniaxial compression. On the exterior surface, it was all compression progressing from uniaxial at the internal diameter to biaxial in the flat section to uniaxial at the outer flange area. All values of compression and tension were low but sufficient to cause stress corrosion. This work is being performed by Rocketdyne, sponsored by NASA, and is approximately 35% complete.

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1.0 Index Code . . . . . (FeL-1)(I-d,k)(IV-d)

2.0 Title - T.R. No. 513-297, Delayed Failure of Steel Components  
in Aqueous Environment.

3.0 Objective - The delayed failures of cadmium plated - 180 to 200 KSI hardened steel fastener components under clamping loads and exposure to aqueous environment have been attributed to hydrogen embrittlement/stress corrosion. The evolution of hydrogen may be attributed to local galvanic cell action made possible by ruptures or scratches through the cadmium plating. The objectives of this test program are to substantiate or disprove this hypothesis and to determine whether vacuum cadmium plating is superior to cyanide cadmium plating for exposure to this type of environment. The scope of this evaluation will include the following:

- a. Tensile properties of unplated smooth and notched specimens in a dry environment and wet environment of 1 weight percent NaCl solution.
- b. Sustained load test at 80% of ultimate tensile strength for 100 hours duration of unplated smooth and notched specimens in a dry environment and wet environment of 1 weight percent NaCl solution.
- c. Sustained load test at 80% of ultimate tensile strength for 100 hours duration of cyanide cadmium plated and vacuum cadmium plated smooth and notched specimens in a dry environment and wet environment of 1 weight percent NaCl solution. The cadmium plated specimens to be exposed to the aqueous environment under sustained load will be scratched prior to exposure in order to establish anodic and cathodic areas in the specimen gage length. Scratches will be 3/16" to 1/4" in length, centered longitudinally in the specimen gage length and equally spaced every 90° around the circumference of the specimen.

4.0 Status and Results - Specimens for this test program are being machined at the present time.

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MODEL \_\_\_\_\_

- 1.0 Index Code . . . . . (FeUH-3, Plat-10)(I-d,e,h,k)
- 2.0 Title - T.R. 513-255, Investigation of Hydrogen Embrittlement of Silver-Plated 4340 Steel at Various Strength Levels.
- 3.0 Objective - To investigate the hydrogen embrittlement susceptibility of silver plated 4340 steel in the strength ranges of 180-200 KSI, 220-240 KSI, and 260-280 KSI. The scope of this test program will include determination of the following:
  - a. Hardness and tensile properties of unnotched bare specimens.
  - b. Notched tensile strength and hardness of bare specimens.
  - c. Static fatigue properties of silver plated notched specimens.
  - d. Static fatigue properties of bare notched specimens.
  - e. Static fatigue properties of bare notched specimens which have been chemically cleaned for plating.
- 4.0 Status and Results - The laboratory test work has been completed and the test report is being prepared. Test results indicate the following:
  - a. Cleaning process prior to plating did not produce hydrogen embrittlement.
  - b. Plating produced some embrittlement and a three-hour bake of plated specimens accelerated failure.
  - c. A 23-hour bake improved the static fatigue life of all specimens loaded to 75% of notched tensile strength.
  - d. No appreciable data was obtained from specimens loaded at 90% of notch tensile strength because the majority of plated and unplated specimens failed on loading.

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1.0 Index Code . . . . . (FeUH-3,Plat-7)(I-d,e,h,k)

2.0 Title - T.R. No. 513-286, Investigation of Hydrogen Embrittlement  
of Hard High Chromium Alloy Plated 4340 Steel.

3.0 Objective - To determine the effect of hard, dense, non-magnetic  
chromium alloy plating on the fatigue strength of 4340 steel  
hardened to the 220-240 KSI range and to certify three plating  
vendors' application of this chromium alloy plating process.  
The scope of this evaluation will include the following:

- a. Hardness testing of each specimen.
- b. Determination of tensile properties of smooth specimens.
- c. Determination of notched tensile strength of notched  
specimens.
- d. Static fatigue test of all notched specimens loaded to 75% and  
to 90% of notched tensile strength for 100 hours.

4.0 Status and Results - Notched tensile specimens have been forwarded  
to three vendors for application of chromium plating.

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1.0 Index Code . . . . . (FeUH-2)(I-d,3,h,k)(IV-a,c,e)

2.0 Title - T.R. No. 513-197.01, Static Fatigue Testing of Vascojet 1000 After Plating for Corrosion and Oxidation Resistance.

3.0 Objective - To determine the effect of protective coatings on the fatigue strength of 260 to 280 KSI hardened Vascojet 1000 steel. The coatings to be evaluated are diffused nickel-cadmium, hard chromium, vacuum metallized aluminum, and sprayed molybdenum-aluminum. The scope of this evaluation will include determination of the following:

- a. Hardness and tensile properties of unexposed unnotched bare specimens.
- b. Notched tensile strength of unexposed notched bare specimens.
- c. Hardness of a representative number of unexposed notched bare specimens.
- d. Static fatigue properties of coated notched specimens after 850°F-900°F exposure for 500 hours.
- e. Salt spray resistance of vacuum metallized aluminum and sprayed molybdenum-aluminum coated 4130 steel control panels prior to and after 850°F-900°F exposure for 500 hours.
- f. Corrosion and oxidation resistance of coated notched specimens after 850°F-900°F exposure for 500 hours.
- g. Stability of vacuum metallized aluminum and sprayed molybdenum-aluminum coated specimens exposed at 850°F-900°F for 500 hours.

4.0 Status and Results - The test work has been completed and the test report is being written. The test results indicate that all of the protective coatings tested were acceptable and that all of the coated notched specimens passed the critical static fatigue test criteria of 90% of the notched tensile strength of approximately 340 KSI for 100 hours with the exception of the diffused nickel-cadmium plated specimens.

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1.0 Index Code . . . . . (Ti-6)(VI-c)

2.0 Title - T.R. No. 513-301, Protection of Titanium From Hydrogen Embrittlement During Chem-Milling and Pickling.

3.0 Cojective - Aerospace vehicles require parts fabricated from various titanium alloys. Many of these parts will be subjected to chemical processes such as chemical milling and pickling where the possibility of hydrogen embrittlement is prevalent. Consequently, it is necessary to evaluate and establish methods for the prevention of hydrogen embrittlement of B120 VCA titanium alloy. The scope of this evaluation will include the following:

- a. Attachment of protective platinum strips to titanium specimens.
- b. Imposition of DC current to titanium specimens in suitable electrolyte with carbon cathodes.
- c. Hydrogen absorption analyses of unprotected and platinum protected titanium specimens before and after exposure to chemical milling solutions of hydrofluoric and nitric-hydrofluoric acids.
- d. Hydrogen absorption analyses of titanium specimens before and after exposure to DC in electrolyte baths of hydrofluoric and nitric-hydrofluoric acids using carbon cathodes.
- e. Determine the amount of metal removed from titanium specimens by chemical milling and electrolytic pickling processes.

4.0 Status and Results - Preliminary tests on specimens without attached platinum strips indicate that specimens chem-milled in 10% hydrofluoric acid contained an average of 884 parts per million hydrogen. Specimens chem-milled in nitric-hydrofluoric acids contained 48 parts per million hydrogen. The chem-milled protected specimens are being prepared for hydrogen analyses.

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1.0 Index Code . . . . . (Alwt-6, FeL-1, Plat-2)(IV-a)(V-h)

2.0 Title - T.R. 32-889, -889.01, -889.04, -889.05, -889.06,  
Evaluation of Corrosion Prevention Materials for  
Mechanically Fastened Aluminum Skin Joints.

3.0 Objective - The extent of corrosion around fasteners in present fleet aircraft has become a major maintenance problem, because of difficulty encountered when removing fasteners in access doors and removal panels. The objectives of this test program are to evaluate special primers, coatings, anti-seizing materials, sealants, platings, washer materials, and vinyl tapes for use as barriers to reduce corrosion between fasteners and aluminum skins without causing joint assembly problems or reduction of the allowable joint load. The scope of this test program includes the following:

- a. Load preconditioning of pre-treated aluminum panel joint specimens at  $-65^{\circ}\text{F} \pm 10^{\circ}\text{F}$ .
- b. Salt spray exposure of pre-treated aluminum panel joint specimens for total exposure time of 672 hours.
- c. Examination for the presence of corrosion on the fastener heads and panel areas adjacent to fastener heads.

4.0 Status and Results - Test results indicate that barrier materials evaluated thus far were effective in preventing corrosion but their usage presented the following problems:

- a. Impede joint assembly.
- b. Extrude under load.
- c. Necessitate reduction of allowable joint load.

In an effort to eliminate these problems, future test work will include testing of tin and aluminum plated screws, and Minnesota Mining and Manufacturing Company Nos. 470, 473 vinyl tapes as plastic barriers.

December 1, 1961

7.2.6.1.4 MISCELLANEOUS METALS AND ALLOYS

CORROSION RATES OF MOLTEN METALS AND ROCKET EXHAUST GASES  
ON REFRACTORY METALS

Objectives

To investigate the corrosion rates of lithium, sodium, potassium, and magnesium on several of the refractory metals (tungsten, tantalum, molybdenum, 90Ta-10W, and columbium alloy C-103 and columbium -1 zirconium) at temperatures up to the boiling point at atmospheric pressures.

To examine the corrosion rate of simulated rocket gases containing up to 11% HCl with test specimens of the above mentioned refractory metals. (Note: test data on this objective is incomplete.)

Results and Conclusions

Molten magnesium shows no corrosive effects on the refractory metals up to 1600 F in 10 to 20 minutes.

Molybdenum and tungsten suffer an even attack in liquid lithium and are corroded more than any of the other refractory metals.

Tantalum is not corroded to any extent by molten lithium up to 1600 F.

Tantalum - 10% tungsten alloy was attacked by lithium slightly more than tantalum.

The columbium alloys showed a weight loss in lithium somewhere between the tantalum alloy and molybdenum or tungsten.

Lithium, near the boiling point, appears to attack tungsten about twice as rapidly as it attacks tantalum.

Photomicrographs of corroded tantalum show a pitting attack by lithium, while tungsten surfaces are corroded evenly.

Sodium attacks all six refractory metals more than does lithium.

Tantalum, tungsten, and molybdenum corrode about the same in sodium, while the alloys of columbium and the 90Ta-10W are attacked a little more severely.

Potassium attacks the refractory metals more than does sodium.

All six metals appear to suffer about the same degree of corrosion under potassium.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM X2020; STRESS CORROSION

**DESCRIPTIVE TITLE:**

Stress Corrosion Study of X2020

**OBJECTIVE:**

To determine the susceptibility of X2020 aluminum alloy  
to stress corrosion.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Specimens of X2020-T6 have withstood constant load alternate immersion  
tests at 80% of T.Y.S. for 2700 hours.

Comparative samples of 2024-T86 have failed after approximately 1600  
hours under the same conditions.

Both alloys are considered quite resistant to stress corrosion cracking  
in the condition tested. However, X2020 has been found to be superior  
in these tests.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM 7075; SALT SPRAY RESISTANCE

**DESCRIPTIVE TITLE:**

Investigation of Corrosion Resistance

**OBJECTIVE:**

Determine whether alkaline etch cleaning prior to Alodine or anodize improves salt spray resistance of 7075 aluminum alloy.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Results of testing indicated that alkaline etch cleaning prior to Alodine or anodize conversion coatings of rolled 7075 aluminum alloy did not improve corrosion resistance with respect to salt spray exposure.

When an aluminum alloy such as rolled 7075 is not subject to machining operations, the use of an alkaline etch cleaning does not improve the salt spray resistance within the limits of Military Specs MIL-C-541 or MIL-A-8625A.

**BOEING AIRPLANE COMPANY**

**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM 7178; SALT SPRAY RESISTANCE

**DESCRIPTIVE TITLE:**

Investigation of Corrosion Resistance Aluminum  
Alloy 7178

**OBJECTIVE:**

Determine whether alkaline etch cleaning prior to  
Alodine or anodize treatment of 7178 aluminum alloy  
improves salt spray resistance.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Results of testing Alodine or anodized conversion coatings with the  
alkaline etch treatment shows improved corrosion resistance with  
respect to salt spray exposure.

The corrosion initiating nuclei are more easily trapped in the occlusions  
of machined metal and unless removed by a process such as alkaline etch  
cleaning, salt spray resistance will be poor.

**BOEING AIRPLANE COMPANY**

**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; MOLYBDENUM, ALUMINUM COATED; OXIDATION RESISTANCE

**DESCRIPTIVE TITLE:**

Fabricability and Oxidation Resistance of Al-12% Si  
Roll Clad Mo-.5 Ti-.08 Zr

**OBJECTIVE:**

To evaluate both fabricability and re-entry oxidation resistance of Mo-.5% Ti-.08% Zr sheet after cold roll welding a coating of Al-12% Si to the sheets surfaces.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Due to an excessive amount of cold reduction (75%) imparted to the sheet during the roll cladding process, the sheet was laminous, thus the formability quality was poor. However, after diffusion of the coating, the re-entry protective quality was encouraging. The re-entry test environment was flowing air at 2700°F in 30 minutes. Detailed information on this program is reported in MSR-798, dated 10/17/60.

**BOEING AIRPLANE COMPANY**

**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; MOLYBDENUM, PLATINUM COATED; OXIDATION RESISTANCE

**DESCRIPTIVE TITLE:**

Platinum as a Re-Entry Protective Coating for  
Refractory Metals

**OBJECTIVE:**

This work was to determine the re-entry oxidation-erosion protection afforded refractory metals by a coating of vapor deposited platinum.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

A 1-1/2 mil coating of platinum imparted excellent protection to a Mo-.5 Ti substrate during a 20 minute exposure in flowing air at 2200°F. A 200 Å coating of platinum afforded good protection through the same exposure. Detailed information on this program is reported in MSR-806, dated 10/12/60.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; RENE' 41; OXIDATION RESISTANCE

**DESCRIPTIVE TITLE:**

The Effect of Process Residues on the Oxidation  
Characteristics of Rene' 41 During Aging and Thermal  
Exposures.

**OBJECTIVE:**

To determine whether entrapped residues of penetrants,  
machining oils, and cleaning agents have detrimental  
effect on the oxidation characteristics of Rene' 41.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

A total of 75 Rene' 41 sheet sandwiches were treated with various penetrants, machining oils, and cleaning agents and then subjected to various thermal exposures. It was determined that:

1. Residues from phospho-silicate alkaline cleaner caused excessive oxidation attack under all thermal exposures tested.
2. Two of the machining oil combinations - Cutmax No. 569 and Cutmax No. 569 diluted in kerosene - produced excessive oxidation attack during the combined aging and Hot Structures thermal exposure cycle.
3. The combined aging and Hot Structures thermal exposure cycle caused excessive oxidation attack in the presence of all but two - (ZL2 Pentrex + ZE4 Emulsifier + ZP4 Dry (or ZP5 Wet) Developer) penetrant material combinations tested.
4. The above mentioned and other process materials produced less oxidation attack when subjected to exposure less severe than the combination exposure mentioned in 2 and 3.

Details are reported in Metals Unit Summary Report MSR-807, dated 10-15-60.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METALS; RENE' 41, HASTELLOY X, AS-25; OXIDATION RESISTANCE

**DESCRIPTIVE TITLE:**

Cyclic Exposure Oxidation Studies: Rene' 41,  
Hastelloy X, and H.S.-25

**OBJECTIVE:**

To determine oxidation characteristic of Rene' 41,  
H.S.-25, and Hastelloy X when exposed to air.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

The purpose of this investigation was to supplement existing information concerning the oxidation characteristics of Rene' 41, Hastelloy X, and H.S.-25 under conditions of cyclic thermal exposure. A total of ten test coupons per alloy were fabricated and tested as follows:

- Series I. One hour cycles in air at 1800°F  
(1 and 10 cycles)
- Series II. One hour cycles in air at 2000°F  
(1 and 10 cycles)
- Series III. Ten minute cycles in air at 1800°F  
(1, 4, and 10 cycles)
- Series IV. Ten minute cycles in air at 2000°F  
(1, 4, and 10 cycles)

The alloy found to be most resistant to intergranular oxidation attack under all conditions of test was Hastelloy X, followed by H.S.-25 and Rene' 41. Chemical alteration of a surface zone was also observed on a surface zone on all specimens. This zone was deepest in Rene' 41, followed by H.S.-25 and Hastelloy X.

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Details are reported in Metals Unit Summary Report MSR-811, dated 10-25-60

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; STEEL, AM350 CRT AND AM355 CRT; STRESS CORROSION

**DESCRIPTIVE TITLE:**

Stress Corrosion Cracking Investigation on AM350 CRT  
and AM355 CRT

**OBJECTIVE:**

To determine the susceptibility of AM350 CRT and  
AM355 CRT to stress corrosion cracking.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

The heat treat conditions were investigated. CRT 850, 900, and 950, were found resistant to stress corrosion cracking when subjected to (1) alternate immersion in a standard salt solution, (2) cyclic humidity, (3) general weathering and (4) alkaline soils. Both alloys, in all heat treat conditions, were susceptible to cracking in an SO<sub>2</sub> atmosphere.

Detail results are reported in Test Report T2-1876, dated 7/27/60.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; STEEL, 17-7 PH; SALT BATH CORROSION

**DESCRIPTIVE TITLE:**

Salt Bath Heat Treatment of 17-7 PH *ores.*

**OBJECTIVE:**

To determine degree of intergranular attack.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

1. Salt bath heat treatment of 17-7 PH was suspected of causing intergranular attack on work surface.
2. The severity of attack during heat treatment in Class 5 neutral high temperature salt was found to be in the order .003"- .005". Material was exposed for standard soak time at 1400°F.
3. Effect on fatigue strength to be evaluated.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

CHEMICAL; ALKALINE ETCH; ALUMINUM 7075

**DESCRIPTIVE TITLE:**

Investigation of Corrosion Resistance

**OBJECTIVE:**

Determine whether alkaline etch cleaning prior to Alodine or anodize improves salt spray resistance of 7075 aluminum alloy.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Results of testing indicated that alkaline etch cleaning prior to Alodine or anodize conversion coatings of rolled 7075 aluminum alloy did not improve corrosion resistance with respect to salt spray exposure.

When an aluminum alloy such as rolled 7075 is not subject to machining operations, the use of an alkaline etch cleaning does not improve the salt spray resistance within the limits of Military Specs MIL-C-5541 or MIL-A-8625A.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

CHEMICAL; ALKALINE ETCH; ALUMINUM 7178

**DESCRIPTIVE TITLE:**

Investigation of Corrosion Resistance Aluminum  
Alloy 7178

**OBJECTIVE:**

Determine whether alkaline etch cleaning prior to Alodine or anodize treatment of 7178 aluminum alloy improves salt spray resistance.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Results of testing Alodine or anodized conversion coatings with the alkaline etch treatment shows improved corrosion resistance with respect to salt spray exposure.

The corrosion initiating nuclei are more easily trapped in the occlusions of machined metal and unless removed by a process such as alkaline etch cleaning, salt spray resistance will be poor.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

CHEMICAL; ALKALINE ETCH; ALUMINUM

**DESCRIPTIVE TITLE:**

Cleaning and Alodizing Aluminum Forgings after Steel  
Shot Peening

**OBJECTIVE:**

To remove surface contamination from 7079 aluminum forgings  
after shot peening with steel shot.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Boost pump support forgings (7079 aluminum) were shot peened with steel shot to improve stress corrosion properties. Surface contamination was observed to be particles and dust of steel plus oil from the air compressor used in shot peening. Normal immersion cleaning and deoxidizing did not produce a clean surface. Application of MIL-C-5541 color inspectable conversion coating resulted in a gray to brown finish having considerable smut.

Dry abrasive blasting with aluminum oxide removed almost all contamination. However, this gave the aluminum surface such a dark gray color that color inspectability of the conversion coating was impossible.

The best cleaning process found was alkaline etch cleaning for two to four minutes to remove about 0.00015 inch of metal. This was followed by smut removal in a mild acid deoxidizer, then application of MIL-C-5541 colored conversion coating.

Finish color is very good - generally a light golden color. Salt Spray resistance is very good; almost no corrosion was found on test specimens after 168 hours.

Etch cleaning time can be considerably reduced by controlling the quality of the shot peening operation. Clean, good quality shot and clean, oil-free air are essential.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

CHEMICAL; CONVERSION COATING; MAGNESIUM ALLOYS

**DESCRIPTIVE TITLE:**

Conversion Coating Prepaint Treatment for Rare  
Earth Magnesium Alloys

**OBJECTIVE:**

To develop an immersion coating process for magnesium.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

An immersion prepaint coating process known as BMC was developed for coating rare earth magnesium alloys without corrosion of spot-welded faying surfaces.

The coating withstood six months exposure to weather and 100 hours condensing humidity testing.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

CHEMICAL; PLATING; ZINC

**DESCRIPTIVE TITLE:**

Increase in Thickness of Zinc Plating for Improved  
Erosion Resistance

**OBJECTIVE:**

To develop a production procedure for the application of a heavier deposit of zinc plating on the leading edge of metal rotor blade spars.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

A conforming type steel anode was designed to as to permit the deposition of .003" zinc plating on the nose section and .001" on the aft portion of the D-spar section of the metal rotor blades. In addition, existing processing equipment was modified to provide suitable current distribution and adequate solution agitation.

The increased zinc plate thickness on the nose of the spar will improve the resistance of the rotor blade to erosion by sand, dust, and rain. The .001" thick zinc plate on the aft portion, in addition to saving weight, is a more desirable surface for structural adhesive bonding.

**BOEING AIRPLANE COMPANY**

**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; GENERAL; ELECTROPOLISHING

**DESCRIPTIVE TITLE:**

Investigation of Electropolishing Techniques on New Metals

**OBJECTIVE:**

To aid mechanical polishing of cold worked specimen by the removal of cold worked surfaces produced in rough polishing.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

Metals subject to cold working and flow in both rough and final polishing operations have been successfully electropolished after the rough polishing operations with new electrolyte solutions.

In cases where electropolishing to completion would destroy the edges of the specimens, a lower current density was applied until the cold worked rough polished surface was removed and then the specimen was taken to the final polishing wheels. Some metals did not show edge destruction and were polished to completion after the rough polishing operation.

Some of the metals polished by the above techniques are titanium, molybdenum, tungsten, tantalum, niobium, Rene' 41 and H.S. 25.

**BOEING AIRPLANE COMPANY**  
**MATERIALS PROGRAM ABSTRACTS**

**MATERIAL CLASSIFICATION:**

METAL; ALUMINUM HONEYCOMB CORE; CORE SHEAR STRENGTH

**DESCRIPTIVE TITLE:**

Effect of Sandwich Variables on Core Shear Strength

**OBJECTIVE:**

To determine the effect of facing thickness, core thickness, span length and type of loading (one point or two point) on apparent core shear strength.

**ABSTRACT OF RESULTS AND CONCLUSIONS:**

1. In determining core shear strength by mid-span loading, one- or two-point, failure of the specimen can occur by skin buckling, or failure other than core shear failure when; (1) one-point, rather than two-point loading is used; (2) the span is too long; (3) the facings are too thin; (4) the cores are too thick.
2. Indications are that the effects of span, core thickness and facing thickness on apparent core shear strength are different for each core type.
3. The effects of varying individual factors are as follows:
  - a. Increasing the span length decreases the apparent core shear strength.
  - b. Increasing the facing thickness increases the apparent core shear strength.
  - c. Increasing the core thickness decreases the apparent core shear strength.
4. Details of the tests as well as three-dimensional graphs showing the effects of the above variables on the apparent core shear strength of 3-10P and 3-20P cores are reported in Wichita Job Report AP-1-21.

# BOEING AIRPLANE COMPANY

## MATERIALS PROGRAM ABSTRACTS

### MATERIAL CLASSIFICATION:

METAL; ALUMINUM - 2024-T3 SHEET; DIMPLE PAN SANDWICH

### DESCRIPTIVE TITLE:

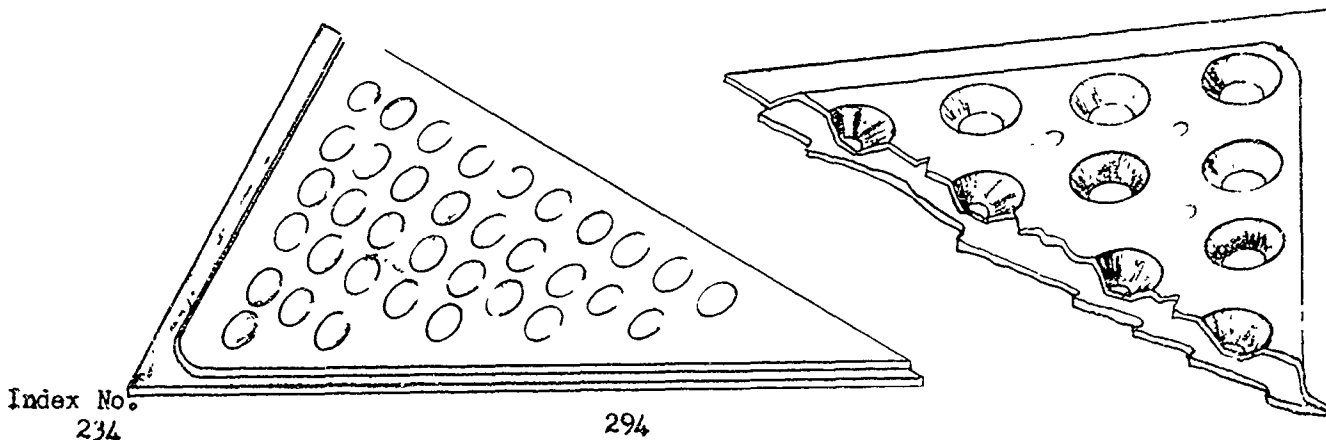
Dimple Pan Sandwich Panel Structures

### OBJECTIVE:

To determine physical, producibility, and economic characteristics of a rigidized pan and skin sandwich construction compared to honeycomb or other conventional structures.

### ABSTRACT OF RESULTS AND CONCLUSIONS:

Panels were constructed to prove that production of configurations were feasible and to evaluate the effects of dimple patterns. The pattern and alignment of dimples has an effect on directional strength of the panels. Pressure and edge compression loads tests indicate the bonded dimpled sandwich is a uniformly rigid construction more resistant to buckling and requiring fewer external stiffeners to develop approximately the same strengths to weight when compared with conventional skin-stringer-frame assemblies. Panel tests indicate the bonded dimpled sandwich more resistant to shear buckling and stronger under shear loading than comparable weight skin-stringer-frame assemblies. Tests indicate that the adhesive bonded dimpled panel has a sonic fatigue resistance far superior to the spot welded dimpled panel and approximately equivalent to the comparable weight skin-stiffener panel.



*BOEING AIRPLANE COMPANY*  
MATERIALS PROGRAM ABSTRACTS

MATERIAL CLASSIFICATION:

METAL; METALLIZED LIGHTWEIGHT STRUCTURES; SOLAR CONCENTRATORS

DESCRIPTIVE TITLE:

Solar Concentrators

OBJECTIVE:

To develop lightweight (approx. 0.2 lb./ft.) solar concentrators, capable of performing at high watts/lb. efficiency in space environment.

ABSTRACT OF RESULTS AND CONCLUSIONS:

1. Tooling methods have been evolved and adapted for use in fabricating sandwich type paraboloids having apertures greater than 10 feet in diameter.
2. The complex relationship of the several materials and processes that are involved in the fabrication of large aperture replica optical devices has been proven out by actual fabrication and tests of three foot diameter concentrators.
3. A paper entitled "Lightweight Solar Concentrator Development" was prepared and accepted for presentation at the December, 1960 annual meeting of the ASME.