NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.
INVESTIGATION OF ULTRASONIC WELDING
OF REFRACTORY METALS AND ALLOYS

July 1963

Prepared under Navy Bureau of Naval Weapons
Contract No. NOw 63-0125-c

Bimonthly Progress Report No. 5
16 April 1963 through 15 June 1963

AEROPROJECTS INCORPORATED
WEST CHESTER, PENNSYLVANIA
INVESTIGATION OF ULTRASONIC WELDING
OF REFRACTORY METALS AND ALLOYS

July 1963

Prepared under Navy Bureau of Naval Weapons
Contract No. NOx 63-0125-c

Bimonthly Progress Report No. 5
16 April 1963 through 15 June 1963

AEROPROJECTS INCORPORATED
West Chester, Pennsylvania
INVESTIGATION OF ULTRASONIC WELDING
OF REFRACTORY METALS AND ALLOYS

ABSTRACT

The necessity for moving the experimental welder and instruments into a new area precluded continuation of actual welding studies during this period. The interruption of the experimental work provided time for the incorporation of modifications and improvements to the existing welding array, the necessity for which has become increasingly apparent during the course of the work.
# Table of Contents

**Abstract** .................................................. ii

**Investigation of Ultrasonic Welding of Refractory Metals and Alloys**

A. Power Programming ........................................ 1

B. Force Programming ......................................... 1

C. Equipment Integration ...................................... 1

Weldment Materials ............................................ 2

Future Work .................................................... 3
The power-force programming study of the welding behavior of 2024-T3 aluminum, AISI 304 stainless steel, and Inconel X, described in Progress Report No. I, revealed several minor difficulties with the welding array and instrumentation which required correction prior to continuation of the program. The necessity of moving the welder and instruments into a new location provided a convenient time for these corrective measures to be taken.

A. Power Programming

The initial studies had indicated that the variation in power delivered to the transducer had not always followed the linear variation set out on the program pegboard. The incremental steps of power over the effective range of the program controller have been made uniform by modification of the circuit of the program controller. The power input to the transducers may thus be divided into ten steps of equal magnitude throughout the power range used in the welding studies.

B. Force Programming

Two difficulties were observed in the force-measuring instrumentation. Information for recording the actual changing clamping force is provided by the signal from SR-4 strain gages mounted on the body of each hydraulic cylinder. A decrease in sensitivity of the output from the strain gages was observed during continued operation. Inspection of the gages revealed inadequate bonding to the cylinders. These gages were removed and replaced with securely bonded gages.

Pick-up of stray magnetic fields by the strain gage cables had disturbed the strain gage signals, necessitating a power-dependent correction factor. Cables have been shielded for use in magnetic fields to reduce magnetic pick-up.

C. Equipment Integration

The large number of recording and measuring instruments, with associated power supplies and interconnecting wiring, has made operation inconvenient. This unwieldy array of instrumentation has been integrated to provide greater accessibility and convenience of operation.
Weldment Materials

During this report period the following materials were received:

<table>
<thead>
<tr>
<th>Material</th>
<th>Gage, Inch</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-105 Columbium</td>
<td>0.015</td>
<td>Wah Chang</td>
</tr>
<tr>
<td>B-66 Columbium</td>
<td>0.005</td>
<td>Westinghouse</td>
</tr>
<tr>
<td>B-66 Columbium</td>
<td>0.015</td>
<td>Westinghouse</td>
</tr>
<tr>
<td>Tungsten</td>
<td>0.010</td>
<td>Fansteel</td>
</tr>
<tr>
<td>Tungsten</td>
<td>0.020</td>
<td>Fansteel</td>
</tr>
<tr>
<td>Tungsten</td>
<td>0.060</td>
<td>Fansteel</td>
</tr>
<tr>
<td>Tungsten</td>
<td>0.100</td>
<td>Fansteel</td>
</tr>
</tbody>
</table>

The powder metallurgy tungsten was produced under the Bureau of Naval Weapons Refractory Metal Sheet Program, Contract NOw 60-0621-c. This material was supplied to us by Fansteel Metallurgical Corporation at the request of the Bureau of Naval Weapons, for use in connection with the performance of Contract NOw 63-0125-c and AF 33(600)-43026*.

Identity of all test specimens shall be subject to control with regard to sheet number, position on sheet, final rolling direction, etc.

The material received is identified as follows:

Powder Metallurgy Tungsten
(Received from Fansteel Metallurgical Corporation)

<table>
<thead>
<tr>
<th>Nominal Gage, (Inch)</th>
<th>Sheet Size (measured), (Inches)</th>
<th>Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.010</td>
<td>17-11/16 x 25-3/4</td>
<td>Lot A 5467 Sheet Plate 3</td>
</tr>
<tr>
<td>0.010</td>
<td>18-3/16 x 26</td>
<td>Lot A 5467 Sheet Plate 2</td>
</tr>
<tr>
<td>0.020</td>
<td>18-1/2 x 30-1/8</td>
<td>Lot A 5467 Sheet Plate 3-1</td>
</tr>
<tr>
<td>0.060</td>
<td>21-1/2 x 29</td>
<td>Lot A 5467 Sheet Plate 19</td>
</tr>
<tr>
<td>0.100</td>
<td>18-15/16 x 33-1/2</td>
<td>Lot A 5467 Sheet Plate 101</td>
</tr>
</tbody>
</table>

* Letter (T. F. Kearns, Head, Metals Branch, Materials Division, Department of the Navy, Bureau of Naval Weapons to H. L. McKaig, Vice President, Aeroprojects Incorporated) dated 29 April 1963.
Additional tungsten and Mo-0.5 Ti alloy sheets are on order.

The materials received to date are adequate to start the next phase of investigative work involving the application of power-force programming techniques to the ultrasonic welding of refractory metals and alloys.

Future Work

Power-force programming will be applied to the welding of refractory metals. Experiments will be designed with the view of establishing PFP patterns for the production of high-quality ultrasonic welds.
## DISTRIBUTION COPIES

<table>
<thead>
<tr>
<th>Number of Copies</th>
<th>Number of Copies</th>
<th>Recipient</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 and 1 repro</td>
<td>1</td>
<td>Chief, Bureau of Naval Weapons, Washington 25, D. C., Attention: DLI-31, RRMA-2h (6), PID-2 (1), NPR-531 (1), SP-27 (1), RMP-23 (1), DLI-31 (2)</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Commanding Officer, Naval Ordnance Test Station, China Lake, California, Attn: Code 55</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>U. S. Army Research Office, 3045 Columbia Pike, Arlington 4, Virginia, Attn: Mr. A. L. Tarr</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>Armed Services Tech. Info. Agency, Arlington Hall Station, Arlington 12, Virginia, Attn: Document Service Center (TIGSOP)</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>Office of Technical Service, Department of Commerce, Washington 25, D. C.</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Chief, Bureau of Ships, Department of the Navy, Washington 25, D. C., Attn: Code 634B</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Commanding General, Frankford Arsenal, Philadelphia 37, Pennsylvania, Attn: Mr. J. J. Power, Jr. (ORDBR-IMT)</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Army Ballistic Missile Agency, Redstone Arsenal, Huntsville, Alabama, Attn: Chief, Materials Branch, Development Operations Division</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Chief, Naval Research Laboratory, Department of the Navy, Washington 25, D. C., Attn: Mr. W. Pellini, Supt. Metallurgy Dept.</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Commanding Officer, Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland, Attn: Technical Library</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Chief, Office of Naval Research, Department of the Navy, Washington 25, D. C., Attn: Metallurgy Section</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Commanding Officer, Naval Air Engineering Center, Philadelphia 12, Pennsylvania, Attn: Metallurgy Division, AML</td>
</tr>
</tbody>
</table>
DISTRIBUTION LIST (Continued)

1 Commanding Officer
Army Chemical Corps Command
Munitions Division
Army Chemical Center, Maryland
Attn: Mr. Joseph Trost

1 Commanding Officer
Engineering Res. & Dev. Lab.
Department of the Army
Fort Belvoir, Virginia
Attn: Metallurgical Dept.

1 Commander
Aeronautical Systems Division
Attn: Metals & Ceramics Laboratory (ASRCM)
Wright-Patterson Air Force Base, Ohio

1 Commander
Aeronautical Systems Division
Attn: Applications Lab. (ASRC) E
Wright-Patterson Air Force Base, Ohio

2 Commander
Aeronautical Systems Division
Attn: Manufacturing Technology Laboratory (ASRCT)

3 Scientific & Technical Info. Facility
(SAK/DL-419)
P. O. Box 5700
Bethesda, Maryland

1 The Arnold Engineering Company
P. O. Box C
Marengo, Illinois
Attn: Mr. Benjamin Falk

1 Atomic Energy Commission
Germantown, Maryland
Attn: Mr. J. Simmons, Div. of Reactor Development

2 Brookhaven National Laboratory
Information and Publication Service
Uptown, New York
Attn: Miss Mary Weismann, Document Section

1 U. S. Atomic Energy Commission
Attn: Technical Information Service
Oak Ridge, Tennessee

National Academy of Sciences
2101 Constitution Avenue, N. W.
Washington 25, D. C.
Attn: Dr. J. Lane, Metallurgist
Materials Advisory Board

Aerospace Industries Association
Technical Services Division
Shoreham Building
Washington 5, D. C.

Welding Research Council of the Engineering Foundation
345 East 47th Street
New York 17, New York

Battelle Memorial Institute
Defense Metals Information Center
Attn: Mr. C. S. DuMont
505 King Avenue
Columbus 1, Ohio

Battelle Memorial Institute
505 King Avenue
Columbus 1, Ohio
Attn: Mr. M. J. Rieppel
Chief, Metals Joining Division

Armour Research Foundation
Illinois Institute of Technology
Metals Research Dept.
3350 S. Federal Street
Chicago 16, Illinois
Attn: Dr. W. Rostoker

Renssalaer Polytechnic Institute
Department of Metallurgical Eng.
110 Eight Street
Troy, New York
Attn: Dr. Earnest Nippes
1 Ohio State University
   Department of Welding Engineering
   Columbus, Ohio
   Attn: Prof. R. B. McCauley

1 Massachusetts Institute of Technology
   Metallurgy Department
   Cambridge 39, Massachusetts
   Attn: Dr. Clyde Adams

3 Chemical Propulsion Information Agency
   The John Hopkins University
   Applied Physics Laboratory
   8621 Georgia Avenue
   Silver Spring, Maryland

1 University of California
   Los Alamos Scientific Laboratory
   Los Alamos, New Mexico
   Attn: Mr. J. R. Taub, Group Leader

1 Pratt & Whitney Division
   United Aircraft Corporation
   Connecticut Aircraft Nuclear
   Engines Laboratory
   Middletown, Connecticut
   Attn: Mr. L. M. Raring, Chief Metallurgist

1 The Martin Company
   Attn: Chief, Manufacturing Res. & Development Laboratory
   Denver 1, Colorado

1 Crucible Steel Company
   Titanium Division
   Midland, Pennsylvania
   Attn: Dr. Walter L. Finley

2 Mallory Sharon Titanium Corporation
   Niles, Ohio
   Attn: Dr. L. S. McCoy
   Dr. L. S. Busch

1 North American Aviation, Inc.
   Los Angeles Division
   International Airport
   Los Angeles, California
   Attn: Mr. H. D. Mason,
   Engineering Section

1 North American Aviation, Inc.
   Columbus Division
   1310 N. 5th Avenue
   Columbus, Ohio
   Attn: Mr. Paul Maynard, Chief of Materials

1 Westinghouse Electric Corporation
   Research Laboratories
   Beaulah Road, Churchill Boro
   Pittsburgh 35, Pennsylvania
   Attn: Chief, Metals Joining Section

1 Gulton Industries, Inc.
   212 Durham Avenue
   Metuchen, New Jersey
   Attn: Director, Research & Dev.

1 Circo Ultrasonic Corporation
   Attn: Mr. B. Carlin, Vice-President
   51 Terminal Avenue
   Clark, New Jersey

1 The Budd Company
   Defense Division
   2450 Hunting Park Avenue
   Philadelphia 32, Pennsylvania
   Attn: Chief, Metallurgy Dept.

1 Sciaky Brothers, Inc.
   5915 W. 67th Street
   Chicago 38, Illinois
   Attn: Mr. W. J. Farrell, Chief Applications Engineer

1 Climax Molybdenum Company
   1100 Woodrow Wilson Avenue
   Detroit 3, Michigan
   Attn: Mr. A. J. Herzig
**DISTRIBUTION LIST (Continued)**

<table>
<thead>
<tr>
<th>1</th>
<th>Universal-Cyclops Steel Corporation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Refractomet Division</td>
</tr>
<tr>
<td></td>
<td>Bridgeville, Pennsylvania</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. O. Mueller, Mgr.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1</th>
<th>General Electric Company</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Applied Research Operations</td>
</tr>
<tr>
<td></td>
<td>Flight Propulsion Laboratory</td>
</tr>
<tr>
<td></td>
<td>Dept.</td>
</tr>
<tr>
<td></td>
<td>Cincinnati 15, Ohio</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. Louis F. Jahnke, Mgr.</td>
</tr>
<tr>
<td></td>
<td>Metallurgical Engineering</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1</th>
<th>General Electric Company</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Missile and Ordnance Systems</td>
</tr>
<tr>
<td></td>
<td>Dept.</td>
</tr>
<tr>
<td></td>
<td>3750 D Street</td>
</tr>
<tr>
<td></td>
<td>Philadelphia 24, Pennsylvania</td>
</tr>
<tr>
<td></td>
<td>Attn: Aerosciences Laboratory</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1</th>
<th>Boeing Airplane Company</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P. O. Box 3707</td>
</tr>
<tr>
<td></td>
<td>Seattle 3L, Washington</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. John T. Stacey, Senior Group Engineer, Aerospace Div.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2</th>
<th>Republic Aviation Corporation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Farmingdale, Long Island, New York</td>
</tr>
<tr>
<td></td>
<td>Attn: Dr. S. Korman, Chief, Materials Dev., R.A.C.</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. T. F. Imholtz, Manufacturing Research</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1</th>
<th>Lockheed Aircraft Corporation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Burbank, California</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. E. Green, Mgr., Production Engineering Dept.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1</th>
<th>Lockheed Aircraft Corporation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Missiles and Space Division</td>
</tr>
<tr>
<td></td>
<td>Sunnyvale, California</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. Alfred Peterson, Mgr., Production Eng. Dept., 83-31</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1</th>
<th>Aerojet General Corporation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Solid Rocket Plant</td>
</tr>
<tr>
<td></td>
<td>Sacramento, California</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. Alan V. Levy</td>
</tr>
<tr>
<td></td>
<td>Head, Materials R&amp;D Dept. (4610)</td>
</tr>
</tbody>
</table>
DISTRIBUTION LIST (Concluded)

1 Commanding Officer
Picatinny Arsenal
Dover, New Jersey
Attn: Mr. George Van Syckle
Building 65, TAAC

1 Massachusetts Institute of Technology
Department of Aeronautics and Astronautics
Instrumentation Laboratory
Cambridge 39, Massachusetts
Attn: Miss Betty Robinson
Ass’t. Librarian

1 Delco Remy Division
General Motors Corporation
Anderson, Indiana
Attn: Mr. J. R. West, Piress Dept.

1 Inspector of Naval Material
10 North 8th Street
Reading, Pennsylvania

1 Branson Instruments, Incorporated
37 Brown House Road
Stamford, Connecticut

1 P. R. Mallory and Company, Inc.
Indianapolis 6, Indiana
Attn: Mr. A. S. Doty, Director,
Technical Services Laboratories