ULTRASONIC WELDING PROCESS AND EQUIPMENT
FOR CONSTRUCTION OF ELECTRON-TUBE MOUNTS

Fifth Quarterly Progress Report
For the Period
July 1 through September 30, 1963

Contract No. DA-36-039-sc86741
Order No. 19063-PP-62-81-81

Placed by
Industrial Preparedness Directorate
United States Army Electronics
Materiel Agency

AEROPROJECTS INCORPORATED
West Chester, Pennsylvania
ULTRASONIC WELDING PROCESS AND EQUIPMENT
FOR CONSTRUCTION OF ELECTRON-TUBE MOUNTS

Fifth Quarterly Progress Report
For the Period
July 1 through September 30, 1963

The object of this program is to design and construct prototype welding equipments and their associated accessories to perform by ultrasonic techniques the welding operations required in the assembly of electron tubes under Specifications SCS-114A and SCIPPR-15.

Contract No. DA-36-039-sc86741
Order No. 19063-PP-62-81-81

Report Prepared by: Rosenberg

Report Approved by: James
ABSTRACT

Shock and vibration tests of fine- and heavy-wire weld specimens were completed by Chatham, and tensile-shear strength tests were performed by Aeroprojects. Equipment was procured for ultrasonically welding a broad range of electron-tube types, and tooling was designed and fabricated for welding the Type 6080WB electron-tube mount.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>11</td>
</tr>
<tr>
<td>PURPOSES</td>
<td>1</td>
</tr>
<tr>
<td><strong>NARRATIVE AND DATA</strong></td>
<td></td>
</tr>
<tr>
<td>WELD STUDY</td>
<td>2</td>
</tr>
<tr>
<td>Shock, Vibration, and Tensile-Strength Testing</td>
<td>2</td>
</tr>
<tr>
<td>1. Specimen Preparation and Handling</td>
<td>2</td>
</tr>
<tr>
<td>2. Test Procedure</td>
<td>2</td>
</tr>
<tr>
<td>3. Test Results</td>
<td>3</td>
</tr>
<tr>
<td>ULTRASONIC WELDING EQUIPMENT</td>
<td>4</td>
</tr>
<tr>
<td>1. Equipment Acceptance</td>
<td>4</td>
</tr>
<tr>
<td>2. Equipment Description</td>
<td>4</td>
</tr>
<tr>
<td>ELECTRON-TUBE STUDY</td>
<td>6</td>
</tr>
<tr>
<td>CONCLUSIONS</td>
<td>6</td>
</tr>
<tr>
<td>PROGRAM FOR THE NEXT REPORTING PERIOD</td>
<td>6</td>
</tr>
<tr>
<td>APPENDIX - TECHNICAL DISCUSSION WITH GENERAL ELECTRIC COMPANY</td>
<td></td>
</tr>
<tr>
<td>1. Personnel Visits During This Report Period</td>
<td>20</td>
</tr>
<tr>
<td>2. Technical Man-Hours Expended During This Report Period</td>
<td>21</td>
</tr>
<tr>
<td>PROJECT SCHEDULE</td>
<td>22</td>
</tr>
</tbody>
</table>

iii
### LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Specification for Weld Specimens and Test Planes</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>Shock and Vibration Fixture with Heavy Wire Weldments in Place.</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>Test Fixture in Place on Vibration Testing Machine</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>Test Fixture in Place on Shock Testing Machine</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>Ultrasonic Welding Equipment</td>
<td>9</td>
</tr>
<tr>
<td>6</td>
<td>Acceptance Test Specimens (&quot;SONOWELD&quot; Model W-1040-TSL)</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>Typical Acceptance Test Specimens (&quot;SONOWELD&quot; Model W-600-TSR)</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>Typical Acceptance Test Specimens (&quot;SONOWELD&quot; Model W-4000-FSR)</td>
<td>11</td>
</tr>
<tr>
<td>9</td>
<td>Tip: 3-Inch Spherical Radius (&quot;SONOWELD&quot; Model W-4000-FSR)</td>
<td>11</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Test Data on Heavy-Wire-to-Coupon Juncures</td>
<td>12</td>
</tr>
<tr>
<td>II</td>
<td>Test Data on Fine-Wire-to-Coupon Juncures</td>
<td>13</td>
</tr>
<tr>
<td>III</td>
<td>Coupon Base Metal Data</td>
<td>14</td>
</tr>
<tr>
<td>IV</td>
<td>Base Metal Data (Heavy Wire)</td>
<td>15</td>
</tr>
<tr>
<td>V</td>
<td>Base Metal Data (Fine Wire)</td>
<td>16</td>
</tr>
<tr>
<td>VI</td>
<td>Welder Performance Summary</td>
<td>17</td>
</tr>
</tbody>
</table>
The objectives of this Production Engineering Measure (PEM) are to:

1. Demonstrate the capability limits of ultrasonic welding to join combinations of metallic materials of interest to the electron-tube industry. This part of the work will be limited in that it will not continue exhaustive attempts to weld those combinations which might prove particularly difficult to join.

2. Analyze the welding requirements for three specific electron tubes. The three tube types selected are the Type 6080WB, 5814WB and 6205. These were selected by the U. S. Army Electronics Materiel Agency because they are widely used in military equipment, and have a record of failures due to improperly welded joints.

3. Prepare fixturing and tooling for the specific electron tubes, so that ultrasonic welding may be used in the manufacturing process.

4. Weld the parts required to assemble electron-tube mounts for the three tube types, and evaluate.

5. Build production ultrasonic welding equipment which will enable an electron-tube manufacturer to make the welded connections in a broad range of electron-tube types.

6. Install the ultrasonic welding equipment in a production company, and produce on a pilot basis with that company's personnel, a limited lot size of each of the three tubes for subsequent evaluation in accordance with applicable military specifications.
WELD STUDY

Shock, Vibration, and Tensile-Strength Testing

1. Specimen Preparation and Handling

A total of 27 fine- and heavy-wire specimens were welded for the purpose of evaluation by Chatham and Aeroprojects. Each specimen had specific dimensions (Figure 1) and contained three welds. There were two specimens (6 welds) for each successfully welded material and gage combination: one specimen for shock, and the other for vibration testing. Previously established preparation procedures and machine settings were employed in ultrasonically welding the entire series.

Four formerly weldable combinations, involving newly procured heavy-wire material, could not be satisfactorily welded; they were Nos. 40 (Re/Re), 41 (Re/SS), 49 (Ag/MS), and 52 (MS/Au). No reasons for the difference in weldability were observed via metallurgical investigation or contact with suppliers, and no attempt was made to determine suitable machine settings for the new material (see page 1, item 1). However, there is no reason to believe that these combinations cannot be satisfactorily welded if modest effort is given to an exploration of machine settings.

Because of breakage of some of the delicate wires (see Second Quarterly Progress Report) in the course of shipping, and loading into the test fixtures, the following 19 fine-wire welded combinations could not be environmentally tested:

Nos. 1A (Cu/Cu)  Nos. 20A (Mo/Ni)  Nos. 66A (SS/Ti)
2A (Cu/Au)  26A (Ni/Cu)  68A (Ta/Cu)
11A (Cu/W)  27A (Ni/Au)  75A (Ta/W)
12A (Au/Cu)  29A (Ni/Ni)  78A (Ti/Cu)
13A (Au/Au)  46A (Ag/Au)  89A (W/Ta)

Also, fewer tensile-shear test values could be obtained for some of the combinations because of wires broken too short in handling to fit the jaws of the Instron testing machine. However, the environmental tests performed were even more severe than had been planned, since all available specimens were inadvertently subjected by Chatham to both shock and vibration tests.

2. Test Procedure

a. A fixture (Figure 2) was constructed by Chatham for holding a group of test specimens at a time; the apparatus measured 8 inches by 9 inches and had a capacity of 40 coupons (120 welds).
The fixture, with the specimens in place, was clamped (Figure 3) to the table of a Vertical Vibrator, manufactured by International Pump and Machine Works (Livingston, New Jersey). The weldments were vibrated with simple harmonic motion for a total of 96 hours, i.e., 32 hours in each of the three positions X, Y, and Z (see Figure 1); the frequency was 25 + 2 cps with an amplitude of 0.0140 + 0.005-inch (total excursion 0.080 + 0.005-inch).

Next, for the shock tests, the fixture was clamped (Figure 4) to the table of a Navy flyweight shock machine, made by Taft-Pierce Manufacturing Company (Woonsocket, Rhode Island). Each weldment was subjected to seven hammer blows in each of the positions X, Y, and Z in any sequence, for a total per weld of 21 blows of 30° (500 G) angular displacement.

Subsequently, the weldments were tensile-shear tested at Aeroprojects, using a standard Model TT-C-L Instron testing machine.

3. Results

Except for the separation of one weld in each of the fine-wire combinations Nos. 53A (MS/Ni) and 74A (Ta/Ti), all welds tested survived both the shock and the vibration environments. This percentage of survival, after the unusually severe sequential testing, demonstrates that ultrasonic welds are exceptionally well suited for use in environments requiring such durability.

Direct evaluation could not be made of the effect of shock and vibration on weld strength, and the variability in results must be attributed either to the specific welding conditions or to wire degradation caused by handling. The two sets of tensile-shear strength data (in each of Tables I and II) were, of course, from different statistical populations (inasmuch as the strength tests of the basic welding study had not been preceded by shock and vibration testing). However, cogent evidence was found by a comparison of the values. Thus, for some combinations, joint efficiencies after shock and vibration were higher than the basic joint efficiencies. Furthermore, in some cases where the joint efficiencies were lower, the welds did not fail during tensile-shear testing; rather, the wire broke at the edge of the weld or at a distance from it. Base metal data for the coupon, heavy- and fine-wire materials used are given in Tables III, IV, and V.

* Tests conducted at room temperature, without special atmospheres.
**Model numbers unavailable.
ULTRASONIC WELDING EQUIPMENT

1. Equipment Acceptance

Subsequent to receipt of USAEMA approval to proceed with Phase II of the program, three ultrasonic welding machines (Figure 5) were procured from Sonobond Corporation, a subsidiary of Aeroprojects Incorporated: Model W-1000-TSL (100 watts), Model W-600-TSR (600 watts), and Model W-4000-FSR (4000 watts). Acceptance was made on the basis of satisfactory performance in accordance with Sonobond Factory Performance Standards.

The standard for Model W-1000-TSL involved the making of thirty (30) welds (Figure 6) between 0.010-inch diameter aluminum wire and 0.020-inch 2024-T3 clad aluminum, using a grooved sonotrode tip, a hardened-tool-steel flat anvil, and machine settings of 12 watts power, 1-pound clamping force, and a 0.3-second weld pulse time. All of the wires broke in tensile-shear between the weld and the testing jaws, rather than at the weld zone.

The Model W-600-TSR standard called for tensile-shear testing of eighty (80) welds (Figure 7), made between coupons of 0.020-inch 2024-T3 bare aluminum whose surface had been mechanically scraped. The flat anvil and the sonotrode tip were of hardened tool steel, and the tip had a 2-inch spherical radius. Machine settings used were maximum power (600 watts), 150 pounds clamping force, and 1.5 seconds weld pulse time. Weld shear strengths averaged 331.8 pounds, with a standard deviation of 30 pounds, as against the Manufacturer's Performance Standard of 280 pounds and 50 pounds, respectively.

Model W-4000-FSR was accepted after tensile-shear testing of welds made between coupons of scraped-surface 0.063-inch 2024-T3 bare aluminum alloy (Figure 8). The flat anvil and the sonotrode tip were of hardened-tool steel, and the tip had a 3-inch spherical radius. Machine settings were maximum power (4000 watts), 1100 pounds clamping force, and 1.5 seconds weld pulse time. Weld shear strengths averaged 1511 pounds, with a standard deviation of 171/2 pounds, as against the Manufacturer's Performance Standard of 1400 pounds and 300 pounds, respectively.

The test performance of the latter two models is summarized in Table VI. Note that the lower limit (90 percent) confidence interval of the Sonobond Factory Acceptance Standards is greater than the minimum average spot-weld strength required by MIL-W-5858B. (This military specification is not applicable to Model W-1000-TSL, and the above performance data for this model have not been previously released.

2. Equipment Description

The Model W-1000-TSL ultrasonic welder is suitable for electron-tube fine-wire welding applications. Mounted in a precision bearing arrangement, this light and compact transducer-coupling welding system assures...
repeatability of tip positioning during the welding cycle. The clamping force unit incorporates a spring system providing sensitive adjustment and permits use of a clamping force low enough for very fine work. The force settings are reproducible and can be controlled accurately throughout the range. The sonotrode can be actuated by hand, by means of a foot pedal, or by mechanical or pneumatic means. Welding tip and anvil are mechanically replaceable, to enable the accommodation of varying workpiece configurations. The ultrasonic power generator has a visual resonance indicator (for simplifying proper set-up), and an automatic control for adjusting frequency in accordance with transducer temperature changes. Step switch controls for power and weld pulse time prevent accidental changes and facilitate reproducible set-up procedures.

Because of its small size, the welding head is well suited to use with micropositioning devices. Figure 5 shows a Model W-1010-TSL equipped with a Model 201 Kulicke & Soffa Micropositioner. This unit has a platform on which specially designed anvils and work-positioning fixtures can be mounted. The positioning elements (consisting of three micrometer screw adjustments movable in each of the three planes x, y, and z) assist in accurate location of the workpiece with respect to the welding tip.

Model W-600-TSR is a versatile machine for general use in welding electron-tube mount assemblies. The welding head is a bench model for use in congested production line areas. Remote location of the power source is straightforward, since the interconnecting cables are light in weight and present no installation problems. The controls (located in the face of the power source) comprise an electronic timer (for the weld pulse time) and a step selector switch (for power levels). The clamping force is hydraulically applied, and the force regulator is in the welding head.

Model W-4000-FSR is a floor-mounted welding machine, for making welds in the larger electron tubes (the materials and gages of which require higher levels of ultrasonic energy), or for some smaller-tube applications requiring the making of a plurality of welds simultaneously. It has the required operating controls for power level, clamping force, and weld pulse time located on the face of the welder cabinet. Machine operation is possible without the necessity for ready access to the power package, so that the large power source is usually located remotely. Light weight inter-connecting cables are readily arrangeable for this purpose. Figure 9 shows a mechanically attachable tip for this model.

For manual operation of Models W-600-TSR and W-4000-FSR, the complete welding cycle is initiated by depressing a foot switch. The welding tip clamps the workpiece, and the ultrasonic welding pulse fires when the proper clamping force has been reached. The welding tip then retracts, and the circuitry resets for the next operation.
ELECTRON-TUBE STUDY

Tooling was designed and fabricated for production welding of the electron-tube mount assembly for Type 6080WB. Tooling details will be included in the next report.

The USAEMA requested that a review be conducted of electron-tube mount data obtained, and that suggestions be formulated for increasing program effectiveness.

CONCLUSIONS

Ultrasonic welds of fine- and heavy-wire combinations successfully survived both shock and vibration tests.

PROGRAM FOR THE NEXT REPORTING PERIOD

Electron-tube mount assemblies for Type 6080WB will be constructed with appropriate ultrasonic welding equipment and associated production tooling. Data obtained during the program will be reviewed, and an engineering evaluation based on these data will be directed towards suggestions for improving the over-all program effectiveness.
SPECIFICATION FOR WELD SPECIMENS 
AND TEST PLANES
Figure 2

SHOCK AND VIBRATION FIXTURE WITH HEAVY WIRE WELDMENTS IN PLACE
(Size: 8 inches x 9 inches. Capacity: 40 coupons or 120 welds)

Figure 3

TEST FIXTURE IN PLACE ON VIBRATION TESTING MACHINE

Figure 4

TEST FIXTURE IN PLACE ON SHOCK TESTING MACHINE
Figure 5
ULTRASONIC WELDING EQUIPMENT
Figure 6

ACCEPTANCE TEST SPECIMENS
("SONOWELD" MODEL W-1040-TSL)

Figure 7

TYPICAL ACCEPTANCE TEST SPECIMENS
("SONOWELD" MODEL W-600-TSR)
Figure 8

TYPICAL ACCEPTANCE TEST SPECIMENS
("SONOWELD" MODEL W-4000-FSR)

Figure 9

SONOTRODE: TIP 3-INCH SPHERICAL RADIUS
("SONOWELD" MODEL W-4000-FSR)


<table>
<thead>
<tr>
<th>Weld Combinations Materials</th>
<th>Original Specimens (a)</th>
<th>Post-Shock and Vibration Specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average (c)</td>
<td>Joint Efficiency (Percent)</td>
</tr>
<tr>
<td>Copper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Copper</td>
<td>100+</td>
</tr>
<tr>
<td>2</td>
<td>Gold</td>
<td>100+</td>
</tr>
<tr>
<td>4</td>
<td>Nickel</td>
<td>100+</td>
</tr>
<tr>
<td>5</td>
<td>Rhenium</td>
<td>87</td>
</tr>
<tr>
<td>6</td>
<td>Silver</td>
<td>100+</td>
</tr>
<tr>
<td>9</td>
<td>Tantalum</td>
<td>91</td>
</tr>
<tr>
<td>10</td>
<td>Titanium</td>
<td>100+</td>
</tr>
<tr>
<td>Gold</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Copper</td>
<td>100+</td>
</tr>
<tr>
<td>13</td>
<td>Gold</td>
<td>100+</td>
</tr>
<tr>
<td>14</td>
<td>Nickel</td>
<td>95</td>
</tr>
<tr>
<td>15</td>
<td>Silver</td>
<td>100+</td>
</tr>
<tr>
<td>16</td>
<td>Mild Steel</td>
<td>97</td>
</tr>
<tr>
<td>Molybdenum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Molybdenum</td>
<td>86</td>
</tr>
<tr>
<td>20</td>
<td>&quot;A&quot; Nickel</td>
<td>100</td>
</tr>
<tr>
<td>22</td>
<td>St. Steel</td>
<td>60</td>
</tr>
<tr>
<td>23</td>
<td>Tantalum</td>
<td>100</td>
</tr>
<tr>
<td>&quot;A&quot; Nickel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Copper</td>
<td>91</td>
</tr>
<tr>
<td>27</td>
<td>Gold</td>
<td>100</td>
</tr>
<tr>
<td>28</td>
<td>Molybdenum</td>
<td>88</td>
</tr>
<tr>
<td>29</td>
<td>Nickel</td>
<td>99</td>
</tr>
<tr>
<td>30</td>
<td>Rhenium</td>
<td>100+</td>
</tr>
<tr>
<td>31</td>
<td>Silver</td>
<td>76</td>
</tr>
<tr>
<td>32</td>
<td>Mild Steel</td>
<td>100</td>
</tr>
<tr>
<td>33</td>
<td>St. Steel</td>
<td>92</td>
</tr>
<tr>
<td>34</td>
<td>Tantalum</td>
<td>94</td>
</tr>
<tr>
<td>35</td>
<td>Titanium</td>
<td>94</td>
</tr>
<tr>
<td>36</td>
<td>Tungsten</td>
<td>85</td>
</tr>
<tr>
<td>Rhenium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>&quot;A&quot; Nickel</td>
<td>78</td>
</tr>
<tr>
<td>42</td>
<td>Tantalum</td>
<td>100</td>
</tr>
<tr>
<td>Silver</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>Copper</td>
<td>95</td>
</tr>
<tr>
<td>46</td>
<td>Gold</td>
<td>100</td>
</tr>
</tbody>
</table>

*(a) Original Specimens are tested under standard conditions.*

*(b) Post-Shock and Vibration Specimens are tested after exposure to shock and vibration.*

*(c) Joint Efficiency is calculated as a percentage of the original specimen's performance.*

*(d) Variation is the standard deviation of the joint efficiency measurements.*
| Mild Steel | Copper | 51 | 96 | 0.10 | 91 | 0.15 | -5 |
| Gold | 100 | 0 | 100+ | 0.15 | - |
| "A" Nickel | 90 | 0.01 | 100+ | 0.02 | -10 |
| Silver | 93 | 0.14 | 100+ | 0.14 | -7 |
| Stainless Steel | Copper | 55 | 0.53 | 41 | 0.68 | -14 |
| Molybdenum | 93 | 0.16 | 59 | 0.25 | -34 |
| "A" Nickel | 97 | 0.01 | 65 | 0.33 | -32 |
| Rhenium | 100+ | 0.03 | 77 | 0.62 | -23 |
| Mild Steel | 100+ | 0 | 88 | 0.19 | -12 |
| St. Steel | 100+ | 0.05 | 92 | 0.05 | -8 |
| Tantalum | 100+ | 0.05 | 90 | 0.37 | -10 |
| Tungsten | 83 | 0.39 | 66 | 1.07 | -17 |
| Tantalum | "A" Nickel | 98 | 0.03 | 84 | 1.07 | -14 |
| Rhenium | 100 | 0.04 | 75 | 0.62 | -25 |
| St. Steel | 89 | 0.63 | 56* | 2.07 | -33 |
| Tantalum | 100 | 0.06 | 94 | 0.08 | -6 |
| Titanium | 73 | 0.43 | 89 | 0.50 | +16 |
| Tungsten | 72 | 0.50 | 77 | 0.58 | +5 |
| Titanium | Rhenium | 100 | 0.08 | 92 | 0.68 | -8 |
| St. Steel | 100+ | 0.01 | 97 | 0.05 | -3 |
| Molybdenum | 93 | 0.25 | 69 | 0.15 | -74 |
| "A" Nickel | 94 | 0.08 | 90 | 0.14 | -4 |
| Tantalum | 100 | 0.02 | 95 | 0.01 | -5 |
| Titanium | 100 | 0.02 | 100+ | 0.12 | 0 |
| Tungsten | 72 | 0.07 | 14 | 0.70 | -29 |
| Tungsten | "A" Nickel | 100+ | 0 | 14 | 0.89 | -54 |
| St. Steel | 93 | 0.10 | 100+ | 0.20 | +7 |
| Tantalum | 97 | 0.04 | 92 | 0.04 | -5 |
| Tungsten | 56 | 0.20 | 9** | 0.69 | -47 |

* One weld broke in shipment from Chatham Electronics to Aeroprojects.
As six welds were made for testing, these values are based on tensile-shear data from five welds.
** Five welds broke in shipment from Chatham Electronics to Aeroprojects. This value is for one weld.

(a) Reported in Third Quarterly Progress Report
(b) Except as noted, these values are for six welds.
(c) Average Joint Efficiency (%) = \( \frac{\text{Weld Specimen Average Strength}}{\text{Strength of Base Wire}} \times 100 \)
(d) Variation = \( \frac{\text{Highest Shear-Strength Value} - \text{Lowest Shear-Strength Value}}{\text{Weld Specimen Average Strength}} \)
<table>
<thead>
<tr>
<th>Weld Combinations Materials</th>
<th>Original Specimens (a)</th>
<th>Post-Shock and Vibration Specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average (b) Joint Efficiency (Percent)</td>
<td>Variation (c)</td>
</tr>
<tr>
<td>Copper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3A</td>
<td>Copper</td>
<td>63</td>
</tr>
<tr>
<td>4A</td>
<td>Silver</td>
<td>94</td>
</tr>
<tr>
<td>6A</td>
<td>Molybdenum</td>
<td>86</td>
</tr>
<tr>
<td>7A</td>
<td>St. Steel</td>
<td>96</td>
</tr>
<tr>
<td>8A</td>
<td>Tantalum</td>
<td>96</td>
</tr>
<tr>
<td>10A</td>
<td>Titanium</td>
<td>96</td>
</tr>
<tr>
<td>Gold</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14A</td>
<td>&quot;A&quot; Nickel</td>
<td>90</td>
</tr>
<tr>
<td>15A</td>
<td>Silver</td>
<td>100*</td>
</tr>
<tr>
<td>16A</td>
<td>Molybdenum</td>
<td>81</td>
</tr>
<tr>
<td>17A</td>
<td>St. Steel</td>
<td>89</td>
</tr>
<tr>
<td>Molybdenum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19A</td>
<td>Molybdenum</td>
<td>15</td>
</tr>
<tr>
<td>24A</td>
<td>St. Steel</td>
<td>81</td>
</tr>
<tr>
<td>41A</td>
<td>Titanium</td>
<td>72</td>
</tr>
<tr>
<td>&quot;A&quot; Nickel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28A</td>
<td>Molybdenum</td>
<td>59</td>
</tr>
<tr>
<td>30A</td>
<td>Rhenium</td>
<td>100*</td>
</tr>
<tr>
<td>34A</td>
<td>Molybdenum</td>
<td>98</td>
</tr>
<tr>
<td>33A</td>
<td>St. Steel</td>
<td>96</td>
</tr>
<tr>
<td>34A</td>
<td>Tantalum</td>
<td>87</td>
</tr>
<tr>
<td>35A</td>
<td>Titanium</td>
<td>81</td>
</tr>
<tr>
<td>36A</td>
<td>Tungsten</td>
<td>94</td>
</tr>
<tr>
<td>Rhenium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>38A</td>
<td>Molybdenum</td>
<td>47</td>
</tr>
<tr>
<td>39A</td>
<td>&quot;A&quot; Nickel</td>
<td>92</td>
</tr>
<tr>
<td>41A</td>
<td>St. Steel</td>
<td>93</td>
</tr>
<tr>
<td>42A</td>
<td>Tantalum</td>
<td>87</td>
</tr>
<tr>
<td>43A</td>
<td>Titanium</td>
<td>84</td>
</tr>
<tr>
<td>Silver</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45A</td>
<td>Copper</td>
<td>100*</td>
</tr>
<tr>
<td>47A</td>
<td>&quot;A&quot; Nickel</td>
<td>92</td>
</tr>
<tr>
<td>48A</td>
<td>Silver</td>
<td>100</td>
</tr>
<tr>
<td>Alloy</td>
<td>Metal</td>
<td>J/Int Efficiency (%)</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>44A</td>
<td>Silver</td>
<td>0.08</td>
</tr>
<tr>
<td>49A</td>
<td>Mild Steel</td>
<td>0.59</td>
</tr>
<tr>
<td>50A</td>
<td>St. Steel</td>
<td>0.36</td>
</tr>
<tr>
<td><strong>Mild Steel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>51A</td>
<td>Copper</td>
<td>0.37</td>
</tr>
<tr>
<td>53A</td>
<td>&quot;A&quot; Nickel</td>
<td>0.01</td>
</tr>
<tr>
<td>55A</td>
<td>Mild Steel</td>
<td>0.35</td>
</tr>
<tr>
<td>56A</td>
<td>St. Steel</td>
<td>0.95</td>
</tr>
<tr>
<td><strong>Stainless St.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>59A</td>
<td>Molybdenum</td>
<td>0.08</td>
</tr>
<tr>
<td>60A</td>
<td>&quot;A&quot; Nickel</td>
<td>0.20</td>
</tr>
<tr>
<td>61A</td>
<td>Rhenium</td>
<td>0.86</td>
</tr>
<tr>
<td>64A</td>
<td>St. Steel</td>
<td>0.11</td>
</tr>
<tr>
<td>65A</td>
<td>Tantalum</td>
<td>0.08</td>
</tr>
<tr>
<td>67A</td>
<td>Tungsten</td>
<td>0.25</td>
</tr>
<tr>
<td><strong>Tantalum</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>69A</td>
<td>Molybdenum</td>
<td>0.06</td>
</tr>
<tr>
<td>70A</td>
<td>&quot;A&quot; Nickel</td>
<td>0.16</td>
</tr>
<tr>
<td>71A</td>
<td>Rhenium</td>
<td>0.39</td>
</tr>
<tr>
<td>72A</td>
<td>St. Steel</td>
<td>0.34</td>
</tr>
<tr>
<td>73A</td>
<td>Tantalum</td>
<td>0.30</td>
</tr>
<tr>
<td><strong>Titanium</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75A</td>
<td>Rhenium</td>
<td>0.25</td>
</tr>
<tr>
<td>77A</td>
<td>St. Steel</td>
<td>0.04</td>
</tr>
<tr>
<td>79A</td>
<td>Molybdenum</td>
<td>0.21</td>
</tr>
<tr>
<td>80A</td>
<td>&quot;A&quot; Nickel</td>
<td>0.13</td>
</tr>
<tr>
<td>81A</td>
<td>Tantalum</td>
<td>0.01</td>
</tr>
<tr>
<td>82A</td>
<td>Titanium</td>
<td>0.10</td>
</tr>
<tr>
<td>83A</td>
<td>Tungsten</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Tungsten</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>88A</td>
<td>St. Steel</td>
<td>0.06</td>
</tr>
<tr>
<td>90A</td>
<td>Titanium</td>
<td>1.36</td>
</tr>
</tbody>
</table>

(a) Reported in Third Quarterly Progress Report
(b) Average J/Int Efficiency (%) = \( \frac{\text{Weld Specimen Average Strength}}{\text{Strength of Base Wire}} \) x 100
(c) Variation = \( \frac{\text{Highest Shear-Strength Value} - \text{Lowest Shear-Strength Value}}{\text{Weld Specimen Average Strength}} \)
(d) These values are for six welds. The numbers in parentheses denote the number of welds remaining after pre- or post-handling breakage.
+ Higher average than unwelded wire.
<table>
<thead>
<tr>
<th>Metal</th>
<th>Gage, inch</th>
<th>Hardness, DPH (1)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>0.055</td>
<td>81.4</td>
<td></td>
</tr>
<tr>
<td>Gold</td>
<td>0.060</td>
<td>46.8</td>
<td></td>
</tr>
<tr>
<td>Molybdenum</td>
<td>0.058-0.065</td>
<td>269.4</td>
<td>Fansteel, as received</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>0.060</td>
<td>247.6</td>
<td>Fansteel, electroetched</td>
</tr>
<tr>
<td>Nickel</td>
<td>0.060</td>
<td>129.2</td>
<td></td>
</tr>
<tr>
<td>Rhenium</td>
<td>0.060-0.0625</td>
<td>396.0</td>
<td></td>
</tr>
<tr>
<td>Silver</td>
<td>0.060</td>
<td>149.0</td>
<td></td>
</tr>
<tr>
<td>Mild Steel</td>
<td>0.061-0.062</td>
<td>103.0</td>
<td>AISI 1010, annealed</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>0.060</td>
<td>165.8</td>
<td>AISI 304, annealed</td>
</tr>
<tr>
<td>Tantalum</td>
<td>0.060-0.063</td>
<td>104.8</td>
<td></td>
</tr>
<tr>
<td>Titanium</td>
<td>0.067-0.070</td>
<td>141.0</td>
<td></td>
</tr>
<tr>
<td>Tungsten</td>
<td>0.059-0.069</td>
<td>497.0</td>
<td>Fansteel, as received</td>
</tr>
</tbody>
</table>

(1) Checked on the surface of the plate.
Table IV
BASE METAL DATA (HEAVY WIRES)

<table>
<thead>
<tr>
<th>Metal</th>
<th>Gage (inch)</th>
<th>Average* Tensile Strength (pounds)</th>
<th>Hardness (DPH)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>0.064</td>
<td>114</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>Gold</td>
<td>0.050</td>
<td>53</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Molybdenum</td>
<td>0.061</td>
<td>386</td>
<td>231.8</td>
<td>Fansteel as received, stress relieved</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>0.050</td>
<td>285</td>
<td>231.8</td>
<td>Fansteel electroetched, stress relieved</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>0.060</td>
<td>540</td>
<td>281.4</td>
<td>Chatham Bright, as received</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>0.050</td>
<td>316</td>
<td>281.4</td>
<td>Chatham Bright, electropolished</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>0.060</td>
<td>243.8</td>
<td></td>
<td>Chatham Dull, as received</td>
</tr>
<tr>
<td>Nickel</td>
<td>0.060</td>
<td>159</td>
<td>78.4</td>
<td>Annealed</td>
</tr>
<tr>
<td>Rhenium</td>
<td>0.061</td>
<td>360</td>
<td>326.6</td>
<td>Annealed</td>
</tr>
<tr>
<td>Silver</td>
<td>0.060</td>
<td>76</td>
<td>45.8</td>
<td>Annealed</td>
</tr>
<tr>
<td>Mild Steel</td>
<td>0.0625</td>
<td>157</td>
<td>93.4</td>
<td>AISI 1010, annealed</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>0.0625</td>
<td>268</td>
<td>164.4</td>
<td>AISI 304, annealed</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>0.0625</td>
<td>819</td>
<td>536.0</td>
<td>AISI 302, spring temper</td>
</tr>
<tr>
<td>Tantalum</td>
<td>0.062</td>
<td>151</td>
<td>110.2</td>
<td>Annealed</td>
</tr>
<tr>
<td>Titanium</td>
<td>0.063</td>
<td>256</td>
<td>231.9</td>
<td>Annealed</td>
</tr>
<tr>
<td>Tungsten</td>
<td>0.060</td>
<td>660</td>
<td>460.0</td>
<td>As received</td>
</tr>
<tr>
<td>Tungsten</td>
<td>0.055-0.056</td>
<td>579</td>
<td>490.0</td>
<td>Electropolished</td>
</tr>
</tbody>
</table>

* Average of 3 specimens
1) Center of the wire.
2) On the area without porosity.
<table>
<thead>
<tr>
<th>Metal</th>
<th>Gage (inch)</th>
<th>Tensile Strength</th>
<th>Units</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>0.0005</td>
<td>6.15</td>
<td>Grams</td>
<td></td>
</tr>
<tr>
<td>Gold</td>
<td>0.0003</td>
<td>2.7</td>
<td>Grams</td>
<td></td>
</tr>
<tr>
<td>Molybdenum</td>
<td>0.0008</td>
<td>0.11</td>
<td>Pounds</td>
<td>Fansteel, as received</td>
</tr>
<tr>
<td>Nickel</td>
<td>0.0005</td>
<td>6.3</td>
<td>Grams</td>
<td></td>
</tr>
<tr>
<td>Rhenium</td>
<td>0.005</td>
<td>2.23</td>
<td>Pounds</td>
<td></td>
</tr>
<tr>
<td>Silver</td>
<td>0.0015</td>
<td>22.3</td>
<td>Grams</td>
<td></td>
</tr>
<tr>
<td>AISI 1010 Steel</td>
<td>0.0015</td>
<td>0.26</td>
<td>Pounds</td>
<td></td>
</tr>
<tr>
<td>AISI 304 Stainless</td>
<td>0.001</td>
<td>0.333</td>
<td>Pounds</td>
<td>AISI 302</td>
</tr>
<tr>
<td>Tantalum</td>
<td>0.003</td>
<td>0.48</td>
<td>Pounds</td>
<td></td>
</tr>
<tr>
<td>Titanium</td>
<td>0.001</td>
<td>52.5</td>
<td>Grams</td>
<td></td>
</tr>
<tr>
<td>Titanium</td>
<td>0.0003</td>
<td>16.3</td>
<td>Grams</td>
<td></td>
</tr>
<tr>
<td>Tungsten</td>
<td>0.0003</td>
<td>13.13</td>
<td>Grams</td>
<td>General Electric, as received</td>
</tr>
</tbody>
</table>

* Average of four specimens.
Table VI
WELDER PERFORMANCE SUMMARY

<table>
<thead>
<tr>
<th>SONOWELD Model No.</th>
<th>Test Material* Gage (Inch)</th>
<th>MIL-W-6858B</th>
<th>Sonobond Factory Performance Standard</th>
<th>Actual Welder Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Average</td>
<td>Minimum</td>
<td>Average</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>90% Confidence Interval</td>
</tr>
<tr>
<td>W-500-TSR</td>
<td>0.020</td>
<td>175</td>
<td>140</td>
<td>280</td>
</tr>
<tr>
<td>W-4000-FSR</td>
<td>0.063</td>
<td>840</td>
<td>670</td>
<td>1400</td>
</tr>
</tbody>
</table>

All spot strength values are in pounds.

* 2024-T3 bare aluminum.

** Note that this lower limit is greater than the average required by MIL-W-6858B.
APPENDIX

TECHNICAL DISCUSSION WITH GENERAL ELECTRIC COMPANY PERSONNEL

On December 11, 1961, a conference was held in Cleveland, Ohio, with technical personnel of General Electric Company's Lamp and Components Department, for purposes of discussing the metallurgical properties of and current fabrication techniques for molybdenum and tungsten. Those present were:

**General Electric Company**

- Dr. Howard T. Green, Manager, Sheet Section
- Charles W. Irish, Marketing Section
- John Petro, Manager, Wire Section
- H. Kuebrich, Manager, Wrought Products Engineering
- J. Burton, Engineering

**Aeroprojects-Sonobond**

- J. Koziarski, Director, Welding Laboratory
- J. Peterson, Engineering

A. Molybdenum and Mo-0.5 Ti

General Electric Company experienced difficulty in procuring molybdenum and Mo-0.5 Ti sheet and wire that exhibited uniform properties and was free of surface contamination. Poor quality material was usually traceable to heating in non-protective atmospheres during fabrication and processing. At present, General Electric fabricates its own sheet and wire, from molybdenum and tungsten ingots supplied by a prime producer, with rigid specifications and inspection to insure clean and sound ingot material. The Mo and Mo-0.5 Ti sheet is produced from powder-metallurgy and electron-beam-melted stock, and the Mo wire from powder-metallurgy material only.

General Electric has found that material with surface contamination may bend satisfactorily but still be brittle, with the brittleness apparently caused by molybdenum carbides rather than by molybdenum. Ordinary bend tests are generally inadequate for measuring the ductility of Mo and Mo-0.5 Ti, and General Electric uses a cupping test (Erichsen) instead.
B. **Tungsten**

General Electric currently produces tungsten wire, foil, and sheet from powder-metallurgy material only. According to Mr. Kuebrich, tungsten embrittlement is occasioned chiefly by metallic impurities (such as nickel, chromium, silicon, calcium, and iron) rather than by interstitial elements.

It was agreed that ductility could be improved by removing material from the surface of wire and sheet. Adding rhenium to tungsten also increases ductility, but General Electric was not able to confirm the data of Hahn et al.* A tungsten alloy wire (with 3 percent rhenium) is now used for heater elements, because the rhenium decreases oxidation rate and increases electrical resistivity by about 17 percent; however, the rhenium increases the wire's strain rate sensitivity (i.e., with an increase in strain rate, there is a rapid increase in yield strength with a corresponding decrease in elongation).

---

<table>
<thead>
<tr>
<th>Date</th>
<th>Visit</th>
<th>Purpose of Visit</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/2/63</td>
<td>Mr. Shienbloom, USAEMA, visited Aeroprojects, West Chester, Pennsylvania</td>
<td>Review data and program progress to release activity on Phase II</td>
</tr>
<tr>
<td>8/13/63</td>
<td>Mr. W. N. Rosenberg visited Messrs. B. F. Steiger and N. Helmstetter, Chatham Electronics, Livingston, New Jersey</td>
<td>Review ultrasonic welding of electron tubes.</td>
</tr>
</tbody>
</table>
# TECHNICAL MAN-HOURS

## EXPENDED DURING THIS REPORT PERIOD

<table>
<thead>
<tr>
<th>Name</th>
<th>Project Position</th>
<th>Hours Expended This Report Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>W. N. Rosenberg</td>
<td>Project Supervisor</td>
<td>64</td>
</tr>
<tr>
<td>J. Koziarski</td>
<td>Director Welding Lab</td>
<td>24</td>
</tr>
<tr>
<td>J. G. Thomas</td>
<td>Metallurgist</td>
<td>72</td>
</tr>
<tr>
<td>A. L. Fuchs</td>
<td>Chief Design Engineer</td>
<td>1/2</td>
</tr>
<tr>
<td>C. DePrisco</td>
<td>Chief Electronics Engineer</td>
<td>4</td>
</tr>
<tr>
<td>W. B. Devine</td>
<td>Director of Publications</td>
<td>42</td>
</tr>
<tr>
<td>N. Maropis</td>
<td>Physicist</td>
<td>10</td>
</tr>
</tbody>
</table>

**TOTAL** 216-1/2
Note 1: 30-day period for approval by U. S. Army Electronics Material Agency to proceed with equipment construction.

Schedule allows 30-day period for approval of equipment prior to electron-tube manufacture.
<table>
<thead>
<tr>
<th>No. of Copies</th>
<th>Distribution Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Advisory Group on Electron Devices</td>
</tr>
<tr>
<td></td>
<td>346 Broadway - 8th Floor</td>
</tr>
<tr>
<td></td>
<td>New York 13, New York</td>
</tr>
<tr>
<td>1</td>
<td>Commander</td>
</tr>
<tr>
<td></td>
<td>Aeronautical Systems Division</td>
</tr>
<tr>
<td></td>
<td>Wright-Patterson Air Force Base</td>
</tr>
<tr>
<td></td>
<td>Dayton, Ohio</td>
</tr>
<tr>
<td>2</td>
<td>Commanding General</td>
</tr>
<tr>
<td></td>
<td>U. S. Army Electronics Material Agency</td>
</tr>
<tr>
<td></td>
<td>225 South 18th Street</td>
</tr>
<tr>
<td></td>
<td>Philadelphia 3, Pennsylvania</td>
</tr>
<tr>
<td></td>
<td>Attn: SELMA-R2b</td>
</tr>
<tr>
<td>1</td>
<td>Commanding Officer</td>
</tr>
<tr>
<td></td>
<td>Los Angeles Procurement District</td>
</tr>
<tr>
<td></td>
<td>U. S. Army</td>
</tr>
<tr>
<td></td>
<td>55 South Grand Avenue</td>
</tr>
<tr>
<td></td>
<td>Pasadena 2, California</td>
</tr>
<tr>
<td></td>
<td>Attn: Chief, Industrial Preparedness Division</td>
</tr>
<tr>
<td>1</td>
<td>Commanding Officer</td>
</tr>
<tr>
<td></td>
<td>U. S. Army Electronics Materiel Support Agency</td>
</tr>
<tr>
<td></td>
<td>Fort Monmouth, New Jersey</td>
</tr>
<tr>
<td></td>
<td>Attn: SELMS-PFE</td>
</tr>
<tr>
<td>Commanding Officer</td>
<td>U. S. Army Electronics R&amp;D Agency</td>
</tr>
<tr>
<td></td>
<td>Fort Monmouth, New Jersey</td>
</tr>
<tr>
<td></td>
<td>Attn: Chief, Tube Techniques Branch</td>
</tr>
<tr>
<td></td>
<td>Chief, General Tubes Branch</td>
</tr>
<tr>
<td></td>
<td>Chief, Gaseous Electronics Section, Bldg. S-53</td>
</tr>
<tr>
<td>10</td>
<td>Defense Documentation Center</td>
</tr>
<tr>
<td></td>
<td>Cameron Station</td>
</tr>
<tr>
<td></td>
<td>Alexandria, Virginia, 22314</td>
</tr>
<tr>
<td></td>
<td>Attn: TISIA-1</td>
</tr>
<tr>
<td>1</td>
<td>Canadian Liaison Officer</td>
</tr>
<tr>
<td></td>
<td>Army Material Command</td>
</tr>
<tr>
<td></td>
<td>Tempo 7, Room 1067</td>
</tr>
<tr>
<td></td>
<td>Washington 25, D. C.</td>
</tr>
<tr>
<td></td>
<td>Chief, Bureau of Ships</td>
</tr>
<tr>
<td></td>
<td>Department of the Navy</td>
</tr>
<tr>
<td></td>
<td>Washington 25, D. C.</td>
</tr>
<tr>
<td></td>
<td>Amperex Electronic Corporation</td>
</tr>
<tr>
<td></td>
<td>230 Duffy Avenue</td>
</tr>
<tr>
<td></td>
<td>Hicksville, L. I., New York</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. Alex Mitchell</td>
</tr>
<tr>
<td></td>
<td>Bell Telephone Laboratories</td>
</tr>
<tr>
<td></td>
<td>Technical Reports Center</td>
</tr>
<tr>
<td></td>
<td>Whippany, New Jersey</td>
</tr>
<tr>
<td></td>
<td>Attn: Miss Nan Farley</td>
</tr>
<tr>
<td></td>
<td>The Bendix Corporation</td>
</tr>
<tr>
<td></td>
<td>Red Bank Division</td>
</tr>
<tr>
<td></td>
<td>Eatontown, New Jersey</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. Joseph F. Bozzelli</td>
</tr>
<tr>
<td></td>
<td>Bomac Laboratories, Inc.</td>
</tr>
<tr>
<td></td>
<td>Salem Road</td>
</tr>
<tr>
<td></td>
<td>Beverly, Massachusetts</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. Richard S. Briggs</td>
</tr>
<tr>
<td></td>
<td>Burroughs Corporation</td>
</tr>
<tr>
<td></td>
<td>Electronic Tube Division</td>
</tr>
<tr>
<td></td>
<td>P. O. Box 1226</td>
</tr>
<tr>
<td></td>
<td>Plainfield, New Jersey</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. Roger Wolfe</td>
</tr>
<tr>
<td></td>
<td>Allen B. DuMont Laboratories, Inc.</td>
</tr>
<tr>
<td></td>
<td>750 Bloomfield Avenue</td>
</tr>
<tr>
<td></td>
<td>Clifton, New Jersey</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. Robert Deutsch</td>
</tr>
<tr>
<td></td>
<td>Edgerton, Gereshhausen &amp; Grier, Inc.</td>
</tr>
<tr>
<td></td>
<td>160 Brookline Avenue</td>
</tr>
<tr>
<td></td>
<td>Boston 15, Massachusetts</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. S. Goldberg</td>
</tr>
<tr>
<td></td>
<td>Eitel-McCullough, Inc.</td>
</tr>
<tr>
<td></td>
<td>301 Industrial Way</td>
</tr>
<tr>
<td></td>
<td>San Carlos, California</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. H. M. Bailey</td>
</tr>
</tbody>
</table>
## DISTRIBUTION LIST (Continued)

<table>
<thead>
<tr>
<th>No. of Copies</th>
<th>No. of Copies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td><strong>1</strong></td>
</tr>
<tr>
<td>Electronic Enterprises, Inc.</td>
<td>Lionel Electronic Laboratories, Inc.</td>
</tr>
<tr>
<td>65-67 Seventh Avenue</td>
<td>1226 Flushing Avenue</td>
</tr>
<tr>
<td>Newark, New Jersey</td>
<td>Brooklyn 37, New York</td>
</tr>
<tr>
<td>Attn: Mr. Richard Bloemeke</td>
<td></td>
</tr>
<tr>
<td><strong>1</strong></td>
<td><strong>1</strong></td>
</tr>
<tr>
<td>Electronic Tube &amp; Instrument Div.</td>
<td>Litton Engineering Laboratories</td>
</tr>
<tr>
<td>1200 East Mermaid Lane</td>
<td>P. O. Box 949</td>
</tr>
<tr>
<td>Philadelphia, Pennsylvania</td>
<td>Grass Valley, California</td>
</tr>
<tr>
<td>Attn: Mr. S. Pearlman</td>
<td>Attn: Mr. Charles V. Litton</td>
</tr>
<tr>
<td><strong>1</strong></td>
<td><strong>1</strong></td>
</tr>
<tr>
<td>Electrons, Inc.</td>
<td>Litton Industries</td>
</tr>
<tr>
<td>127 Sussex Avenue</td>
<td>Electron Tube Division</td>
</tr>
<tr>
<td>Newark, New Jersey</td>
<td>San Carlos, California</td>
</tr>
<tr>
<td>Attn: Mr. E. K. Smith</td>
<td>Attn: Mr. B. D. Kumpfer</td>
</tr>
<tr>
<td><strong>1</strong></td>
<td><strong>1</strong></td>
</tr>
<tr>
<td>General Electric Company</td>
<td>Machlett Laboratories, Inc.</td>
</tr>
<tr>
<td>316 East Ninth Street</td>
<td>1063 Hope Street</td>
</tr>
<tr>
<td>Owensboro, Kentucky</td>
<td>Springdale, Connecticut</td>
</tr>
<tr>
<td>Attn: Mr. W. T. Millis</td>
<td>Attn: T. H. Rogers</td>
</tr>
<tr>
<td><strong>1</strong></td>
<td><strong>1</strong></td>
</tr>
<tr>
<td>Gulton Industries, Inc.</td>
<td>Metcom, Inc.</td>
</tr>
<tr>
<td>212 Durham Avenue</td>
<td>76 Lafayette Street</td>
</tr>
<tr>
<td>Metuchen, New Jersey</td>
<td>Salem, Massachusetts</td>
</tr>
<tr>
<td>Attn: Mr. Daniel Abrams</td>
<td>Attn: Mr. Richard Broderick</td>
</tr>
<tr>
<td><strong>1</strong></td>
<td><strong>1</strong></td>
</tr>
<tr>
<td>Huggins Laboratories</td>
<td>Microwave Associates, Inc.</td>
</tr>
<tr>
<td>999 East Argues Avenue</td>
<td>South Street</td>
</tr>
<tr>
<td>Sunnyvale, California</td>
<td>Burlington, Massachusetts</td>
</tr>
<tr>
<td>Attn: Mr. R. A. Huggins</td>
<td>Attn: Dr. L. Gould</td>
</tr>
<tr>
<td><strong>1</strong></td>
<td><strong>1</strong></td>
</tr>
<tr>
<td>Hughes Aircraft</td>
<td>Microwave Electronics Corporation</td>
</tr>
<tr>
<td>Vacuum Tube Products</td>
<td>4061 Transport Street</td>
</tr>
<tr>
<td>2020 Short Street</td>
<td>Palo Alto, California</td>
</tr>
<tr>
<td>Oceanside, California</td>
<td>Attn: Dr. Stanley Kaisel</td>
</tr>
<tr>
<td>Attn: Mr. James Sutherland</td>
<td></td>
</tr>
<tr>
<td><strong>1</strong></td>
<td><strong>1</strong></td>
</tr>
<tr>
<td>International Telephone &amp; Telegraph Corporation</td>
<td>Ohio State University</td>
</tr>
<tr>
<td>Components Division</td>
<td>Department of Metallurgy</td>
</tr>
<tr>
<td>P. O. Box 212</td>
<td>Columbus, Ohio</td>
</tr>
<tr>
<td>Clifton, New Jersey</td>
<td>Attn: Mr. Frederick J. Fraikor</td>
</tr>
<tr>
<td>Attn: Mr. G. G. Ferry</td>
<td></td>
</tr>
<tr>
<td><strong>1</strong></td>
<td><strong>1</strong></td>
</tr>
<tr>
<td>PEK Laboratories, Inc.</td>
<td>PEK Laboratories, Inc.</td>
</tr>
<tr>
<td>4024 Transport Street</td>
<td>4024 Transport Street</td>
</tr>
<tr>
<td>Palo Alto, California</td>
<td>Palo Alto, California</td>
</tr>
<tr>
<td>Attn: Mr. H. H. Eaves</td>
<td>Attn: Mr. H. H. Eaves</td>
</tr>
<tr>
<td>No. of Copies</td>
<td>No. of Copies</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Penta Laboratories, Inc.</td>
<td>Sperry Electronic Tube Division</td>
</tr>
<tr>
<td>312 North Nopal Street</td>
<td>Sperry Rand</td>
</tr>
<tr>
<td>Santa Barbara, California</td>
<td>Gainesville, Florida</td>
</tr>
<tr>
<td>Attn: Mr. R. L. Norton</td>
<td>Attn: Mr. John Whitford</td>
</tr>
<tr>
<td>1</td>
<td>Sylvania Electric Products, Inc.</td>
</tr>
<tr>
<td>Philco Corporation</td>
<td>Emporium, Pennsylvania</td>
</tr>
<tr>
<td>Lansdale Division</td>
<td>Attn: Mr. Vincent Grubbe</td>
</tr>
<tr>
<td>Church Road</td>
<td></td>
</tr>
<tr>
<td>Attn: Mr. F. Mayock</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Tucor, Inc.</td>
</tr>
<tr>
<td>Polarad Electronics Corporation</td>
<td>59 Danbury Road</td>
</tr>
<tr>
<td>43-20 Thirty-fourth Street</td>
<td>Wilton, Connecticut</td>
</tr>
<tr>
<td>Long Island City 1, New York</td>
<td>Attn: Mr. R. White</td>
</tr>
<tr>
<td>Attn: Dr. D. L. Jaffe</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Tung-Sol Electric, Inc.</td>
</tr>
<tr>
<td>Radio Corporation of America</td>
<td>Chatham Electronics Division</td>
</tr>
<tr>
<td>Electron Tube Division</td>
<td>630 W. Mt Pleasant Ave.</td>
</tr>
<tr>
<td>415 South Fifth Street</td>
<td>Livingston, New Jersey</td>
</tr>
<tr>
<td>Harrison, New Jersey</td>
<td>Attn: Mr. Ben Steiger</td>
</tr>
<tr>
<td>Attn: Mr. Clarence West</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>United Electronics Company</td>
</tr>
<tr>
<td>Radio Corporation of America</td>
<td>42 Spring Street</td>
</tr>
<tr>
<td>Electron Tube Division</td>
<td>Newark, New Jersey</td>
</tr>
<tr>
<td>415 South Fifth Street</td>
<td>Attn: Dr. John Beers</td>
</tr>
<tr>
<td>Harrison, New Jersey</td>
<td></td>
</tr>
<tr>
<td>Attn: Mr. Clarence West</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Varian Associates</td>
</tr>
<tr>
<td>Raytheon Company</td>
<td>611 Hansen Way</td>
</tr>
<tr>
<td>Industrial Components Division</td>
<td>Palo Alto, California</td>
</tr>
<tr>
<td>55 Chapel Street</td>
<td>Attn: Dr. Richard Nelson</td>
</tr>
<tr>
<td>Newton 58, Massachusetts</td>
<td></td>
</tr>
<tr>
<td>Attn: Mr. Paul R. Keeler</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>The Victoreen Instrument Company</td>
</tr>
<tr>
<td>S.P.D. Laboratories, Inc.</td>
<td>5806 Hough Avenue</td>
</tr>
<tr>
<td>800 Rahway Avenue</td>
<td>Cleveland 3, Ohio</td>
</tr>
<tr>
<td>Union, New Jersey</td>
<td>Attn: Mr. Ben Olson</td>
</tr>
<tr>
<td>Attn: Dr. Joseph Saloom</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Watkins-Johnson Company</td>
</tr>
<tr>
<td>Sonatone Corporation</td>
<td>3333 Hillview Avenue</td>
</tr>
<tr>
<td>Box 200</td>
<td>Palo Alto, California</td>
</tr>
<tr>
<td>Elmsford, New York</td>
<td>Attn: Dr. Rolf Peter</td>
</tr>
<tr>
<td>Attn: Dr. L. G. Hector</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Westinghouse Electric Corporation</td>
</tr>
<tr>
<td>Electronic Tube Division</td>
<td>Box 284</td>
</tr>
<tr>
<td>Elmira, New York</td>
<td>Elmira, New York</td>
</tr>
<tr>
<td>Attn: Mr. B. W. Sauter</td>
<td></td>
</tr>
<tr>
<td>No. of Copies</td>
<td>No. of Copies</td>
</tr>
<tr>
<td>---------------</td>
<td>---------------</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>U. S. Army Ordnance</strong>&lt;br&gt;Frankford Arsenal&lt;br&gt;Bridge &amp; Tacony Streets&lt;br&gt;Philadelphia, Pennsylvania&lt;br&gt;Attn: Mr. Frank Hussey&lt;br&gt;Metal Joining Section 1323, 64-1</td>
<td><strong>Raytheon Manufacturing Company</strong>&lt;br&gt;Chelmsford Street&lt;br&gt;Lowell, Massachusetts&lt;br&gt;Attention: Mr. W. W. Robinson</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Battelle Memorial Institute</strong>&lt;br&gt;505 King Avenue&lt;br&gt;Columbus 1, Ohio&lt;br&gt;Attn: Mr. C. M. Jackson</td>
<td><strong>Sprague Electric Company</strong>&lt;br&gt;87 Marshall Street&lt;br&gt;North Adams, Massachusetts&lt;br&gt;Attention: Mr. W. Bell</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Westinghouse Electric Corporation</strong>&lt;br&gt;Youngwood, Pennsylvania&lt;br&gt;Attention: Mr. Ozzie Jaeger</td>
<td><strong>Texas Instruments, Inc.</strong>&lt;br&gt;Semiconductor Components Division&lt;br&gt;Post Office Box 5012&lt;br&gt;Dallas 22, Texas&lt;br&gt;Attention: Semiconductor Library</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Clevite Transistor</strong>&lt;br&gt;A Division of Clevite Corporation&lt;br&gt;200 Smith Street&lt;br&gt;Waltham 54, Massachusetts&lt;br&gt;Attention: Mr. Sam Rubinovitz</td>
<td><strong>Transitron Electronic Corporation</strong>&lt;br&gt;168-182 Albion Street&lt;br&gt;Wakefield, Massachusetts&lt;br&gt;Attention: Dr. D. Bakalar</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Rome Air Development Center</strong>&lt;br&gt;Griffiss Air Force Base, New York&lt;br&gt;Attention: Mr. L. Gubbins, RASGR</td>
<td><strong>Western Electric Company</strong>&lt;br&gt;Marion and Vine Streets&lt;br&gt;Laureldale, Pennsylvania&lt;br&gt;Attention: Mr. Robert Moore</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Hamilton Standard Division</strong>&lt;br&gt;United Aircraft Corporation&lt;br&gt;Windsor Locks, Connecticut&lt;br&gt;Attn: Mr. John Dudenhoefefer Project Director</td>
<td><strong>Delco Radio Division</strong>&lt;br&gt;Kokomo, Indiana&lt;br&gt;Attention: Dr. F. E. Jaumot, Jr.</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Mr. C. W. Irish</strong>&lt;br&gt;Marketing Sector&lt;br&gt;Lamp Metals &amp; Components Dept.&lt;br&gt;General Electric Company&lt;br&gt;21800 Tungsten Road&lt;br&gt;Cleveland 17, Ohio</td>
<td><strong>Bendix Corporation</strong>&lt;br&gt;Semiconductor Division&lt;br&gt;Holmdel, New Jersey&lt;br&gt;Attention: Dr. Robert Meijer</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Radio Corporation of America</strong>&lt;br&gt;Somerville, New Jersey&lt;br&gt;Attention: Mr. R. Wicks</td>
<td><strong>Motorola, Inc.</strong>&lt;br&gt;5005 East McDowell Road&lt;br&gt;Phoenix, Arizona&lt;br&gt;Attention: Mr. James LaRue</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Sprague Electric Company</strong>&lt;br&gt;87 Marshall Street&lt;br&gt;North Adams, Massachusetts&lt;br&gt;Attention: Mr. W. Bell</td>
<td><strong>Pacific Semiconductors, Inc.</strong>&lt;br&gt;14520 S. Aviation Blvd.&lt;br&gt;Lawndale, California&lt;br&gt;Attention: Dr. H. Q. North</td>
</tr>
<tr>
<td>No. of Copies</td>
<td>No. of Copies</td>
</tr>
<tr>
<td>---------------</td>
<td>---------------</td>
</tr>
<tr>
<td>1</td>
<td>General Electric Company</td>
</tr>
<tr>
<td></td>
<td>Electronic Park</td>
</tr>
<tr>
<td></td>
<td>Syracuse, New York</td>
</tr>
<tr>
<td></td>
<td>Attention: Mr. T. F. Kendall</td>
</tr>
<tr>
<td></td>
<td>Bldg. 7, Room 152</td>
</tr>
<tr>
<td>1</td>
<td>Bureau of Weapons</td>
</tr>
<tr>
<td></td>
<td>Department of the Navy</td>
</tr>
<tr>
<td></td>
<td>Washington 25, D. C.</td>
</tr>
<tr>
<td></td>
<td>Attention: Mr. Roy G. Gustafson</td>
</tr>
<tr>
<td></td>
<td>RRMA-2U, Materials Div.</td>
</tr>
<tr>
<td>1</td>
<td>The Rembar Company, Inc.</td>
</tr>
<tr>
<td></td>
<td>67 Main Street</td>
</tr>
<tr>
<td></td>
<td>Dobbs Ferry, New York</td>
</tr>
<tr>
<td></td>
<td>Attention: Mr. E. Dietz</td>
</tr>
<tr>
<td>1</td>
<td>Fairchild Semiconductor Corp.</td>
</tr>
<tr>
<td></td>
<td>5145 Whisman Road</td>
</tr>
<tr>
<td></td>
<td>Mountain View, California</td>
</tr>
<tr>
<td></td>
<td>Attention: Mr. Ralph Lee</td>
</tr>
<tr>
<td>1</td>
<td>Radio Corporation of America</td>
</tr>
<tr>
<td></td>
<td>Electronic Components and Devices</td>
</tr>
<tr>
<td></td>
<td>Lancaster, Pennsylvania</td>
</tr>
<tr>
<td></td>
<td>Attention: Mr. Edward L. Romero</td>
</tr>
<tr>
<td>1</td>
<td>General Electric Company</td>
</tr>
<tr>
<td></td>
<td>Schenectady, New York</td>
</tr>
<tr>
<td></td>
<td>Attn: Dr. Harold R. Day</td>
</tr>
<tr>
<td></td>
<td>Building 5, Room 323</td>
</tr>
<tr>
<td>1</td>
<td>Arinc Research Company</td>
</tr>
<tr>
<td></td>
<td>1700 'K' Street - NW</td>
</tr>
<tr>
<td></td>
<td>Washington, D. C. - 20006</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. Robert Reed</td>
</tr>
<tr>
<td>1</td>
<td>Sylvania Electric Products, Inc.</td>
</tr>
<tr>
<td></td>
<td>Div. of General Telephone Corp.</td>
</tr>
<tr>
<td></td>
<td>Sylvania Lighting Products Div.</td>
</tr>
<tr>
<td></td>
<td>60 Boston Street</td>
</tr>
<tr>
<td></td>
<td>Salem, Massachusetts</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. Rufus L. Briggs,</td>
</tr>
<tr>
<td></td>
<td>Project Eng.-3C</td>
</tr>
<tr>
<td>1</td>
<td>ITT Industrial Laboratories</td>
</tr>
<tr>
<td></td>
<td>3700 East Pontiac</td>
</tr>
<tr>
<td></td>
<td>Fort Wayne, Indiana</td>
</tr>
<tr>
<td></td>
<td>Attn: M. F. Toohig</td>
</tr>
<tr>
<td></td>
<td>Manager, Tubes and Sensors</td>
</tr>
<tr>
<td>1</td>
<td>Thermo Electron Engr. Corp.</td>
</tr>
<tr>
<td></td>
<td>85 First Avenue</td>
</tr>
<tr>
<td></td>
<td>Waltham, Massachusetts</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. T. Johnson</td>
</tr>
<tr>
<td>1</td>
<td>Raytheon Company</td>
</tr>
<tr>
<td></td>
<td>Second Avenue</td>
</tr>
<tr>
<td></td>
<td>Waltham, Massachusetts</td>
</tr>
<tr>
<td></td>
<td>Attn: Dr. Colin Bowness</td>
</tr>
<tr>
<td>1</td>
<td>Raytheon Company</td>
</tr>
<tr>
<td></td>
<td>Route 128</td>
</tr>
<tr>
<td></td>
<td>Burlington, Massachusetts</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. George Freedman</td>
</tr>
<tr>
<td>1</td>
<td>Ferrotec Company</td>
</tr>
<tr>
<td></td>
<td>417 California St.</td>
</tr>
<tr>
<td></td>
<td>Newton, Massachusetts</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. Paul Rutledge</td>
</tr>
<tr>
<td>1</td>
<td>IIT Research Institute</td>
</tr>
<tr>
<td></td>
<td>10 W. 35th Street</td>
</tr>
<tr>
<td></td>
<td>Chicago 16, Illinois</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. S. Y. Alum</td>
</tr>
</tbody>
</table>