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

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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

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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.

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Report Approved by: J Byron Jones

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.

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PURPOSES

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.

NARRATIVE AND DATA

WELD STUDY

Shock, Vibration, and Tensile-Strength Testing

1. Specimen Preparation and Handling

A total of 274 fine- and heavy-wire specimens was 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 15 fine-wire welded combinations could not be environmentally tested:

Nos. 1A (Cu/Cu)
2A (Cu/Au)
11A (Cu/W)
12A (Au/Cu)
13A (Au/Au)

Nos. 20A (Mo/Ni)
26A (Ni/Cu)
27A (Ni/Au)
29A (Ni/Ni)
46A (Ag/Au)

Nos. 66A (SS/Ti)
68A (Ta/Cu)
75A (Ta/W)
78A (Ti/Cu)
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).

* b. 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 0.040 ± 0.005-inch (total excursion 0.080 ± 0.005-inch).

* c. 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° (450 G) angular displacement.

* d. 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.

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* 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-1040-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-1040-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), 450 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 1541 pounds, with a standard deviation of 174 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-6858B. (This military specification is not applicable to Model W-1040-TSL, and the above performance data for this model have not been previously released.

2. Equipment Description

The Model W-1040-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-1040-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.

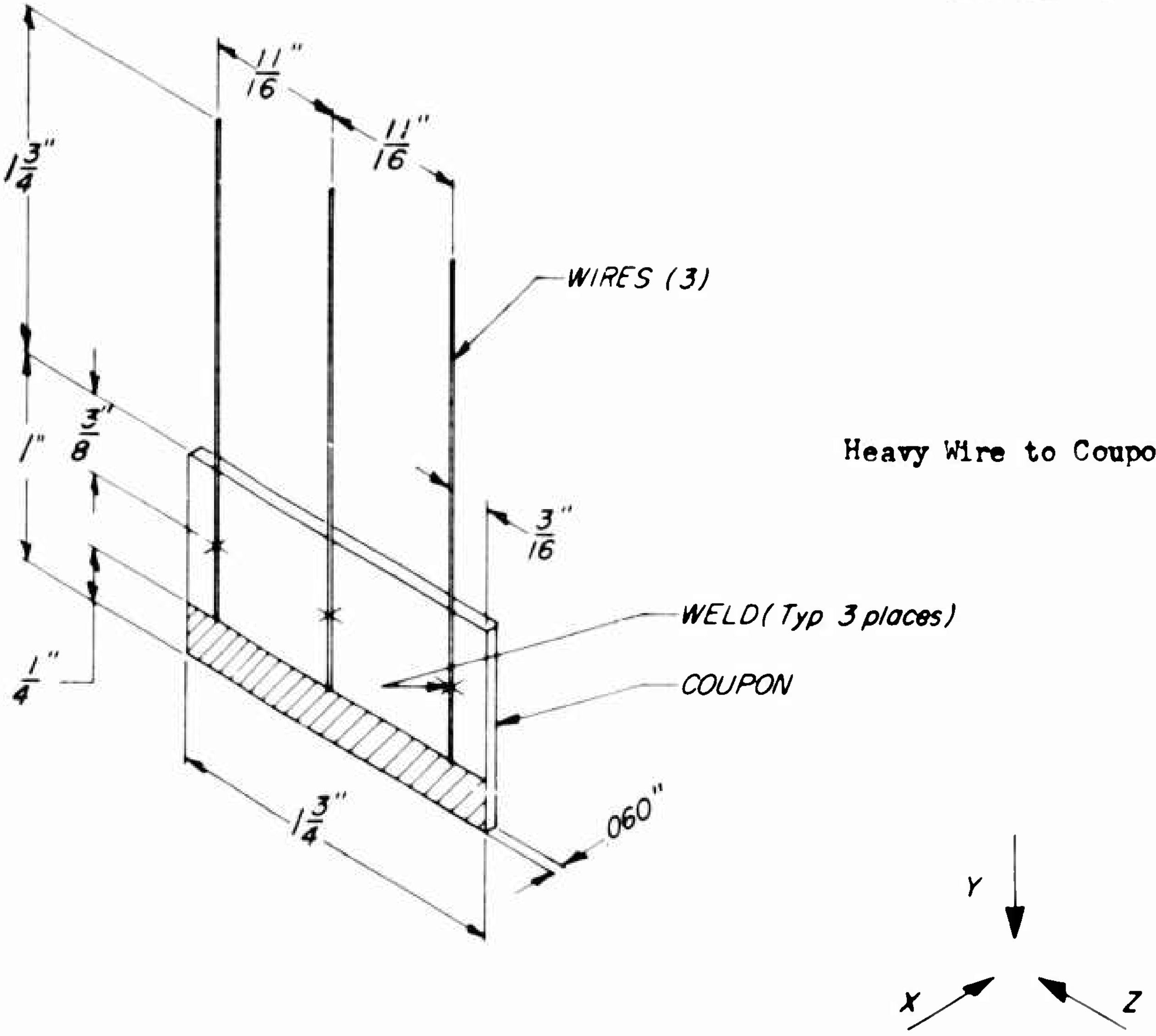
The USAEMA requested that a review be conducted of electron-tube mount data obtained, and that suggestions be formulated for increasing program effectiveness.

CONCLUSIONS

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

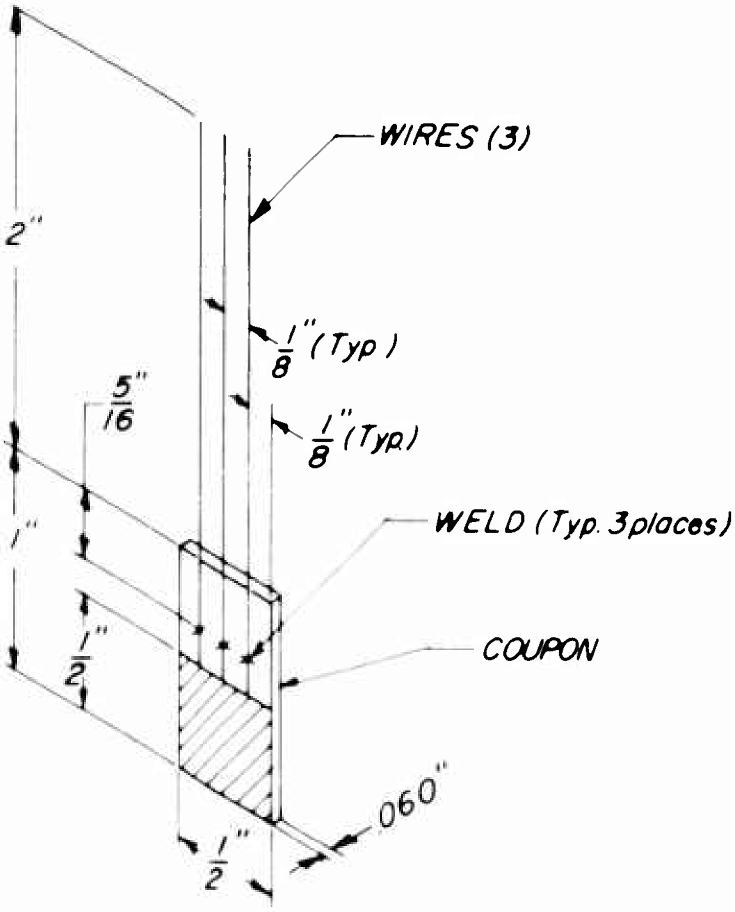
PROGRAM FOR THE NEXT REPORTING PERIOD

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.



Heavy Wire to Coupon

▨ *Area available for clamping in test fixture.*



Fine Wire to Coupon

Figure 1

SPECIFICATION FOR WELD SPECIMENS
AND TEST PLANES

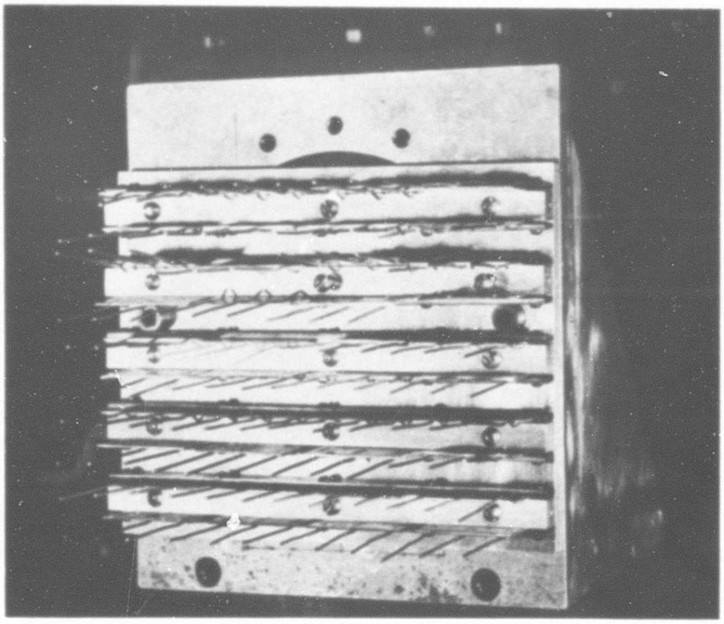


Figure 2

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

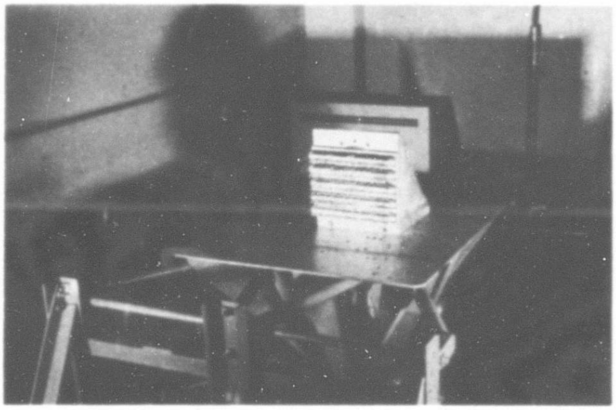


Figure 3

TEST FIXTURE IN PLACE ON
VIBRATION TESTING MACHINE

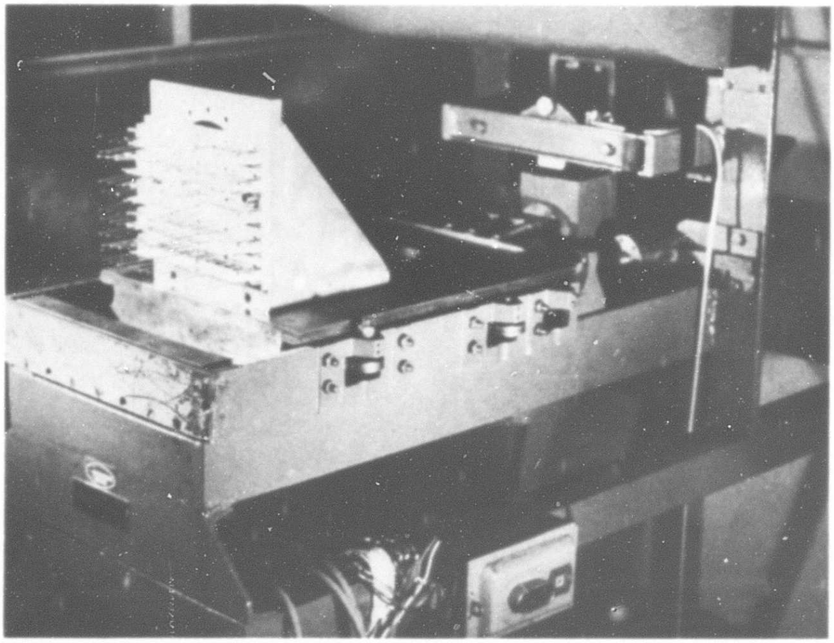
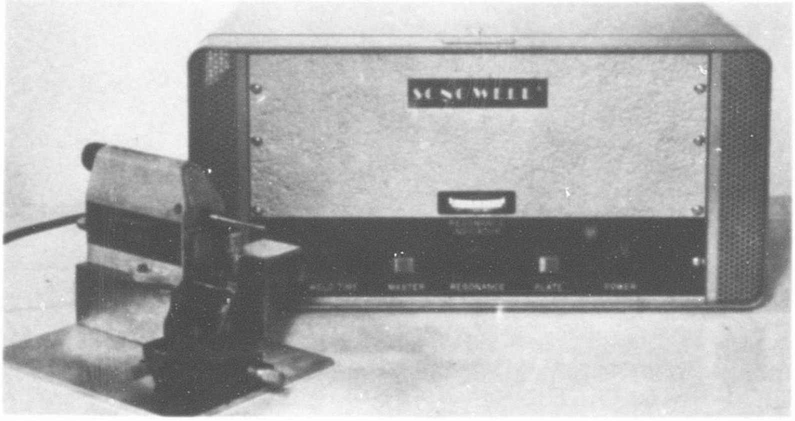
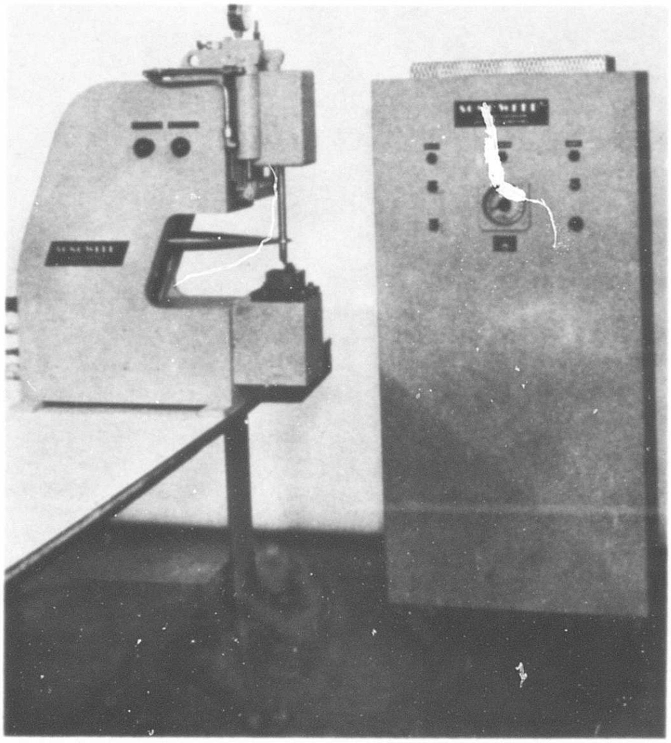


Figure 4

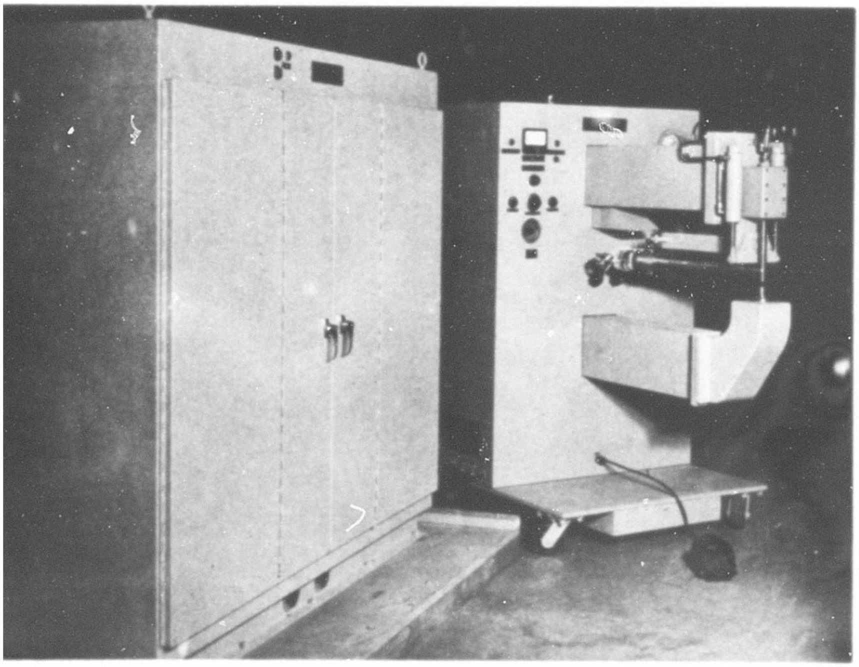
TEST FIXTURE IN PLACE ON
SHOCK TESTING MACHINE



MODEL W-1040-TSL



MODEL W-600-TSR



MODEL W-4000-FSR

Figure 5

ULTRASONIC WELDING EQUIPMENT

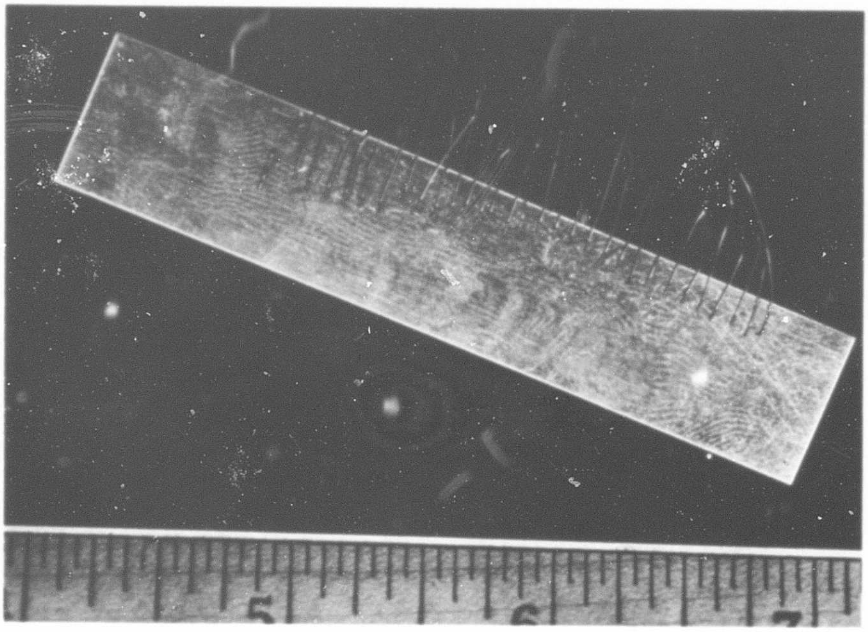


Figure 6

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

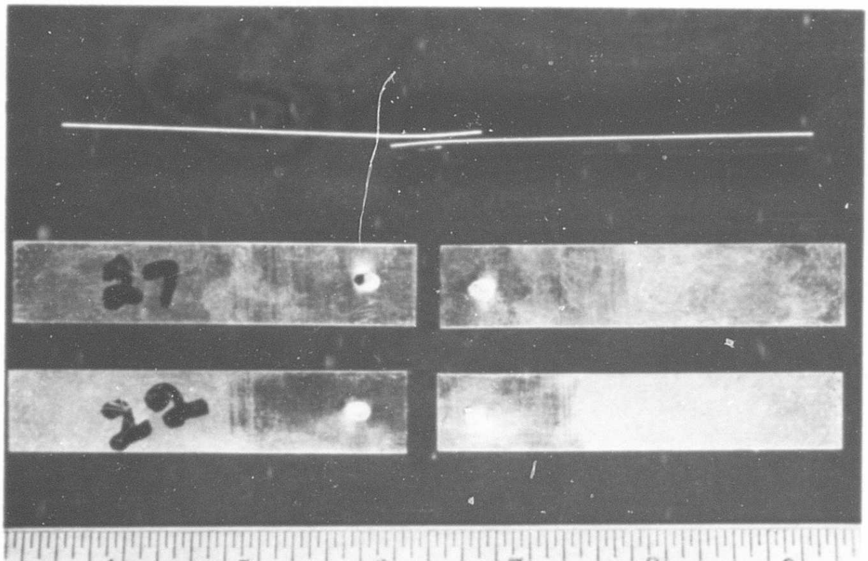


Figure 7

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

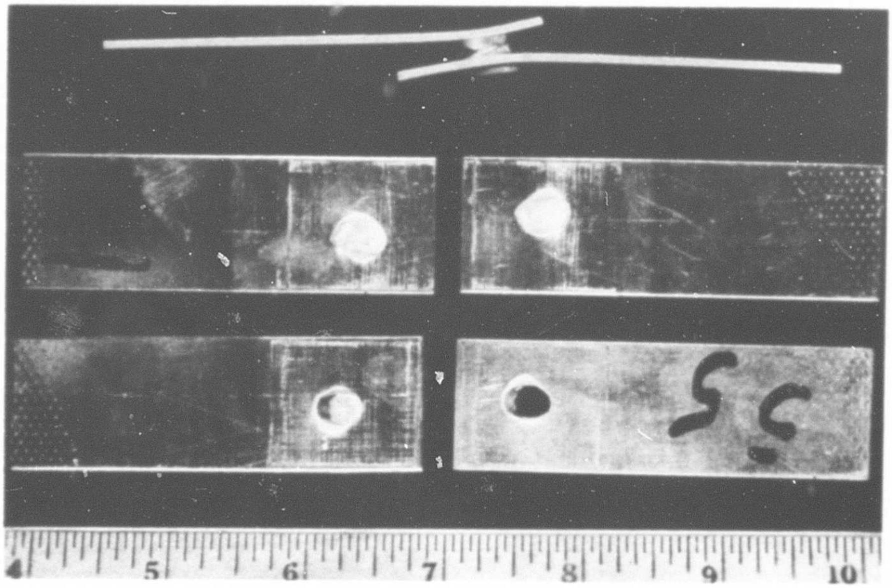


Figure 8

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

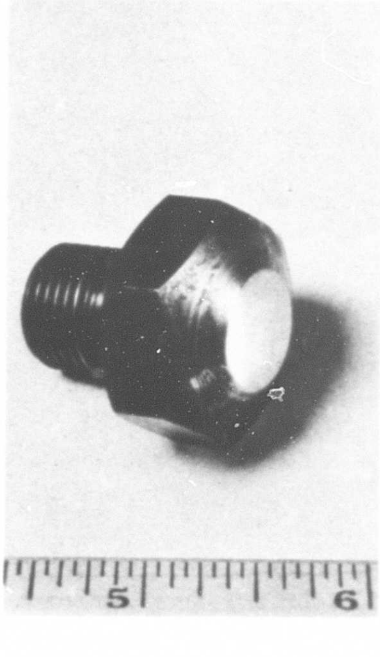


Figure 9

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

Table I

TEST RESULTS OF HEAVY-WIRE-TO-COUPON JUNCTURES

Weld Combinations Materials			Original Specimens(a)		Post-Shock and Vibration Specimens		
Coupon	Combination No.	Wire	Average (c) Joint Efficiency (Percent)	Variation(d)	Average(c) Joint Efficiency (Percent)(b)	Variation(d)	Joint Efficiency Difference
Copper	1	Copper	100+	0.10	100	0.03	0
	2	Gold	100+	0.02	96	0.12	-4
	4	Nickel	100+	0.09	100+	0.02	0
	5	Rhenium	87	0.15	85	0.37	-2
	6	Silver	100+	0.05	96	0.33	-4
	9	Tantalum	91	0.32	76	0.83	-15
	10	Titanium	100+	0.95	81	0.68	-19
Gold	12	Copper	100+	0	100+	0.18	0
	13	Gold	100+	0.02	100	0.02	0
	14	Nickel	95	0.223	100+	0.01	+5
	15	Silver	100+	0	99	0.15	-1
	16	Mild Steel	97	0.03	97	0.24	0
Molybdenum	19	Molybdenum	86	0.10	64*	0.60	-22
	20	"A" Nickel	100	0.01	67	0.93	-33
	22	St. Steel	40	0.44	100	0.48	+60
	23	Tantalum	100	0.05	66*	1.38	-34
"A" Nickel	26	Copper	91	0.003	89	0.19	-2
	27	Gold	100	0.02	94	0.12	-6
	28	Molybdenum	88	0.22	87	0.42	-1
	29	Nickel	99	0.06	89	0.12	-10
	30	Rhenium	100+	0.06	65*	1.53	-35
	31	Silver	76	0.09	66	0.14	-10
	32	Mild Steel	100	0.03	100+	0.04	0
	33	St. Steel	92	0.06	91	0.35	-1
	34	Tantalum	94	0.04	95	0.06	+1
	35	Titanium	94	0.05	98	0.15	+4
	36	Tungsten	85	0.13	42	0.30	-43
Rhenium	39	"A" Nickel	78	0.22	81	0.60	+3
	42	Tantalum	100	0.04	88	0.41	-12
Silver	45	Copper	95	0.01	98	0.19	+3

	[illegible]	[illegible]	[illegible]	0.01	[illegible]	0.19	+3
	46	Gold	100	0	100+	0.15	0
	47	"A" Nickel	90	0.01	100+	0.02	+10
	48	Silver	93	0.14	100+	0.14	+7
Mild Steel	51	Copper	96	0.10	91	0.15	-5
	53	"A" Nickel	73	0.06	93	0.16	+20
	55	Mild Steel	100	0.03	100	0.04	0
	56	St. Steel	95	0.02	100+	0.07	+5
Stainless Steel	57	Copper	55	0.53	41	0.68	-14
	59	Molybdenum	93	0.16	59	0.25	-34
	60	"A" Nickel	97	0.01	65	0.33	-32
	61	Rhenium	100+	0.03	77	0.62	-23
	63	Mild Steel	100+	0	88	0.19	-12
	64	St. Steel	100+	0.05	92	0.05	-8
	65	Tantalum	100+	0.05	90	0.37	-10
	67	Tungsten	83	0.39	66	1.07	-17
Tantalum	70	"A" Nickel	98	0.03	84	1.07	-14
	71	Rhenium	100	0.04	75	0.62	-25
	72	St. Steel	89	0.63	56*	2.07	-33
	73	Tantalum	100	0.06	94	0.08	-6
	74	Titanium	73	0.43	89	0.60	+16
	75	Tungsten	72	0.50	77	0.58	+5
Titanium	76	Rhenium	100	0.08	92	0.68	-8
	77	St. Steel	100+	0.01	97	0.05	-3
	79	Molybdenum	93	0.25	69	0.45	-24
	80	"A" Nickel	94	0.08	90	0.14	-4
	81	Tantalum	100	0.02	95	0.01	-5
	82	Titanium	100	0.02	100+	0.12	0
	83	Tungsten	72	0.07	43	0.70	-29
Tungsten	86	"A" Nickel	100+	0	46	0.89	-54
	88	St. Steel	93	0.10	100+	0.20	+7
	89	Tantalum	97	0.04	92	0.04	-5
	91	Tungsten	56	0.20	9**	-	-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.

\+ Higher average than unwelded wire.

(c) Average Joint Efficiency (%) = $\frac{\text{Weld Specimen Average Strength}}{\text{Strength of Base Wire}} \times 100$

(d) Variation = $\frac{\text{Highest Shear-Strength Value - Lowest Shear-Strength Value}}{\text{Weld Specimen Average Strength}}$

Table II

TEST RESULTS OF FINE-WIRE-TO-COUPON JUNCTURES

Weld Combinations Materials			Original Specimens(a)		Post-Shock and Vibration Specimens		
Coupon	Combination No.	Wire	Average(b) Joint Efficiency (Percent)	Variation(c)	Average(b) Joint Efficiency (Percent)(d)	Variation(c)	Joint Efficiency Difference
Copper	3A	Molybdenum	63	0	35(4)	0.9	-28
	4A	"A" Nickel	95	0.05	56(3)	0.43	-39
	6A	Silver	94	0.12	48(4)	0.34	-46
	7A	Mild Steel	86	0.49	65(3)	1.06	-21
	8A	St. Steel	96	0.05	90	0.32	-6
	9A	Tantalum	96	0.14	93	0.18	-3
	10A	Titanium	96	0.12	88	0.22	-8
Gold	14A	"A" Nickel	90	0.08	87(5)	0.05	-3
	15A	Silver	100+	0.01	48	1.1	-52
	16A	Mild Steel	81	0.45	68(2)	0.87	-13
	17A	St. Steel	89	0.12	67(5)	0.51	-22
Molybdenum	19A	Molybdenum	15	1.17	23(1)		+8
	22A	St. Steel	81	0.26	85	0.26	+4
	24A	Titanium	72	0.27	49(1)		-23
"A" Nickel	28A	Molybdenum	59	0	45(3)	0.88	-14
	30A	Rhenium	100+	0.19	28(1)		-72
	32A	Mild Steel	98	0.08	27(1)		-71
	33A	St. Steel	96	0.09	78	0.4	-18
	34A	Tantalum	87	0.21	90	0.35	+3
	35A	Titanium	81	0.26	68(3)	0.82	-13
	36A	Tungsten	94	0.16	77(3)	0.04	-17
Rhenium	38A	Molybdenum	47	0.23	27(2)	1.08	-20
	39A	"A" Nickel	92	0.10	83(1)		-9
	41A	St. Steel	93	0.06	15(2)	1.24	-78
	42A	Tantalum	87	0.05	54(4)	0.37	-33
	43A	Titanium	84	0.23	61(1)		-23
Silver	45A	Copper	100+	0.03	51(4)	1.30	-49
	47A	"A" Nickel	92	0.43	68(2)	0.23	-24
	48A	Silver	100	0.08	59(4)	0.33	-41

	48A	Silver	100	0.08	59(4)	0.33	-41
	49A	Mild Steel	72	0.59	13(1)		-59
	50A	St. Steel	86	0.36	84	0.34	-2
Mild Steel	51A	Copper	75	0.37	10(2)	1.8	-65
	53A	"A" Nickel	92	0.01	90(4)	0.05	-2
	55A	Mild Steel	83	0.35	62(3)	0.81	-21
	56A	St. Steel	70	0.95	90(5)	0.35	+20
Stainless St.	59A	Molybdenum	57	0.08	48	0.41	-9
	60A	"A" Nickel	94	0.20	51(1)		-43
	61A	Rhenium	83	0.86	87(4)	0.61	+4
	64A	St. Steel	79	0.11	87	0.17	+8
	65A	Tantalum	100+	0.08	44	1.5	-56
	67A	Tungsten	84	0.25	40(1)		-44
Tantalum	69A	Molybdenum	62	0.06	45(5)	0.52	-17
	70A	"A" Nickel	92	0.16	92(1)		0
	71A	Rhenium	64	0.39	29(3)	0.55	-35
	72A	St. Steel	88	0.34	97	0.05	+9
	73A	Tantalum	89	0.30	39(4)	1.2	-50
Titanium	76A	Rhenium	100+	0.25	99	0.53	-1
	77A	St. Steel	100+	0.04	35(2)	0	-65
	79A	Molybdenum	64	0.21	45(4)	0.20	-19
	80A	"A" Nickel	95	0.13	92(1)		-3
	81A	Tantalum	100+	0.01	53(5)	0.26	-47
	82A	Titanium	98	0.10	75(4)	0.49	-23
	83A	Tungsten	97	0	10(2)	0.52	-87
Tungsten	88A	St. Steel	76	0.06	54(2)	0.92	-22
	90A	Titanium	45	1.36	44(4)	1.5	-1

(a) Reported in Third Quarterly Progress Report

(b) $\text{Average Joint Efficiency (\%)} = \dfrac{\text{Weld Specimen Average Strength}}{\text{Strength of Base Wire}} \times 100$

(c) $\text{Variation} = \dfrac{\text{Highest Shear-Strength Value} - \text{Lowest Shear-Strength Value}}{\text{Weld Specimen Average Strength}}$

(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 III

COUPON BASE METAL DATA

Metal	Gage, inch	Hardness, DPH (1)	Notes
Copper	0.055	81.4	
Gold	0.060	46.8	
Molybdenum	0.058-0.065	269.4	Fansteel, as received
Molybdenum	0.060	247.6	Fansteel, electroetched
Nickel	0.060	129.2	
Rhenium	0.060-0.0625	396.0	
Silver	0.060	49.0	
Mild Steel	0.061-0.062	103.0	AISI 1010, annealed
Stainless Steel	0.060	165.8	AISI 304, annealed
Tantalum	0.060-0.063	104.8	
Titanium	0.067-0.070	141.0	
Tungsten	0.059-0.069	497.0	Fansteel, as received

(1) Checked on the surface of the plate.

Table IV

BASE METAL DATA (HEAVY WIRES)

Metal	Gage (inch)	Average* Tensile Strength (pounds)	Hardness (DPH)	Notes
Copper	0.064	114	58	
Gold	0.050	53	36	
Molybdenum	0.061	386	231.8[1]	Fansteel as received, stress relieved
Molybdenum	0.050	285	231.8[1]	Fansteel electroetched, stress relieved
Molybdenum	0.060	540	281.4[1]	Chatham Bright, as received
Molybdenum	0.050	316	281.4[1]	Chatham Bright, electropolished
Molybdenum	0.060		243.8[1]	Chatham Dull, as received
Nickel	0.060	159	78.4	Annealed
Rhenium	0.061	360	326.6[2]	Annealed
Silver	0.060	76	45.8	Annealed
Mild Steel	0.0625	157	93.4	AISI 1010, annealed
Stainless Steel	0.0625	268	164.4	AISI 304, annealed
Stainless Steel	0.0625	819	536.0	AISI 302, spring temper
Tantalum	0.062	151	110.2	Annealed
Titanium	0.063	256	231.8	Annealed
Tungsten	0.060	660	460.0[1]	As received
Tungsten	0.055- 0.056	579	490.0[1]	Electropolished

* Average of 3 specimens

1) Center of the wire.

2) On the area without porosity.

Table V

BASE METAL DATA (FINE WIRE)

Metal	Gage (inch)	Tensile Strength		Notes
		Average*	Units	
Copper	0.0005	6.15	Grams	
Gold	0.0003	2.7	Grams	
Molybdenum	0.0008	0.11	Pounds	Fansteel, as received
Nickel	0.0005	6.3	Grams	
Rhenium	0.005	2.23	Pounds	
Silver	0.0015	22.3	Grams	
AISI 1010 Steel	0.0015	0.26	Pounds	
AISI 304 Stainless Steel	0.001	0.333	Pounds	AISI 302
Tantalum	0.003	0.48	Pounds	
Titanium	0.001	52.5	Grams	
Tungsten	0.0003	16.3	Grams	
Tungsten	0.0003	13.13	Grams	General Electric, as received

* Average of four specimens.

Table VI

WELDER PERFORMANCE SUMMARY

	Test	MIL-W-6858B		Sonobond Factory Performance Standard			Actual Welder Performance	
SONOWELD Model No.	Material* Gage (Inch)	Average	Minimum	Minimum Average	Maximum Standard Deviation	Lower Limit** 90% Confidence Interval	Average	Standard Deviation
W-600-TSR	0.020	175	140	280	50	197.5	331.8	30
W-4000-FSR	0.063	840	670	1400	300	905	1541	174

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, 1962, 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 the oxygen and nitrogen which are responsible for most surface contamination. Accordingly, 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).

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* Hahn, G. T., Gilbert, A., and Jaffee, R. I., "The Effects of Solutes on the Ductile-to-Brittle Transition in Refractory Metals", DMIC Memorandum 155, Defense Metals Information Center, Battelle Memorial Institute, June 28, 1962.

VISITS DURING THIS REPORT PERIOD

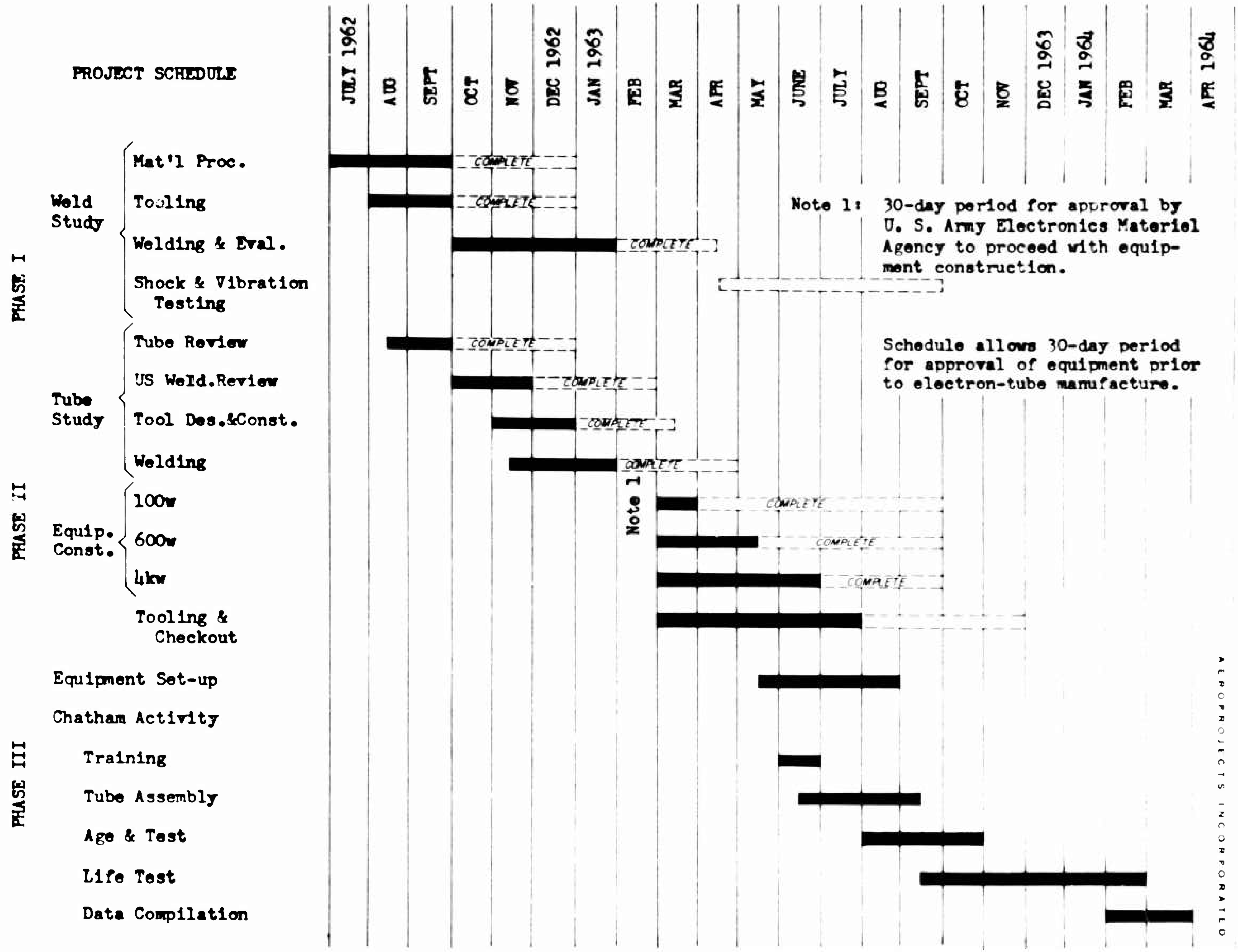
Date	Visit	Purpose of Visit
7/2/63	Mr. Shienbloom, USAEMA, visited Aeroprojects, West Chester, Pennsylvania	Review data and program progress to release activity on Phase II
8/13/63	Mr. W. N. Rosenberg visited Messrs. B. F. Steiger and N. Helmstetter, Chatham Electronics, Livingston, New Jersey	Review ultrasonic welding of electron tubes.
9/11/63	Mr. W. N. Rosenberg visited Messrs. B. F. Steiger and N. Helmstetter, Chatham Electronics, Livingston, New Jersey.	Review program progress and scope.
9/25/63	Mr. W. N. Rosenberg visited Mr. H. Shienbloom, U.S. Army Electronics Materiel Agency, 225 S. Eighteenth Street, Philadelphia, Pennsylvania	Review program progress and scope.

TECHNICAL MAN-HOURS

EXPENDED DURING THIS REPORT PERIOD

Name	Project Position	Hours Expended This Report Period
W. N. Rosenberg	Project Supervisor	64
J. Koziarski	Director Welding Lab	24
J. G. Thomas	Metallurgist	72
A. L. Fuchs	Chief Design Engineer	1/2
C. DePrisco	Chief Electronics Engineer	4
W. B. Devine	Director of Publications	42
N. Maropis	Physicist	10
	TOTAL	216-1/2

PROJECT SCHEDULE



Note 1: 30-day period for approval by U. S. Army Electronics Materiel Agency to proceed with equipment construction.

Schedule allows 30-day period for approval of equipment prior to electron-tube manufacture.

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