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FINAL REPORT – PART I
(Contract No. 951069)

DETERMINATION OF THE EFFECTS OF A THERMAL STERILIZATION PROCESS ON THE MECHANICAL AND ELECTRICAL PROPERTIES OF SOLDERED AND WELDED JOINTS

Prepared for.
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

9 OCTOBER 1965

AEROSPACE GROUP

HUGHES

HUGHES AIRCRAFT COMPANY
CULVER CITY, CALIFORNIA

FINAL REPORT - PART I

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by

F. Z. Keister, Hughes Project Engineer

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For

Jet Propulsion Laboratory
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Approved: Smith

C. F. Smith, Manager
Materials Technology Department

Materials Technology Department
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Hughes Aircraft Company · Culver City, California

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The purpose of this investigation was to determine the effects of a thermal sterilization process on the mechanical and electrical properties of soldered and welded joints. An additional scope of work under this same contract was for the determination of the effects of thermal bake-out, heat sterilization, and ethylene oxide decontamination on the solderability of component leads.

This investigation involved the preparation and testing of 1362 soldered joints of 11 different types, including both stranded and solid conductors joined to connector cups and bifurcated terminals. A total of 834 cross-wire weld joints of 7 different material combinations were also prepared and tested. All solder and weld joint types were tested and examined before and after thermal sterilization. Testing consisted of:

a) Ultimate strength
b) Electrical resistance
c) Electrical testing during vibration
d) Ultimate strength after vibration
e) Stress-rupture strength
f) Metallurgical examination
g) Electron probe microanalysis

Based on a statistical analysis of the test results, it was concluded that there was no significant change in the ultimate strength or electrical resistance of either the soldered or welded joints due to the effects of a thermal sterilization process. Neither the metallurgical examination nor the electron probe microanalysis showed any degradation in metallurgical structure or in the extent of gold diffusion which could be attributed to thermal sterilization. However, the stress-rupture strength tests on the connector cup soldered joints pointed out that steady-state loads of only 10% of the ultimate strength of the joint were enough to cause short-term solder joint failures under thermal sterilization conditions.

Author

1. PURPOSE AND SCOPE

1.1 PURPOSE

The purpose of this investigation was to determine the effects of a thermal sterilization process on the mechanical and electrical properties of soldered and welded joints. An additional scope of work under this same contract was for the determination of the effects of thermal bake-out, heat sterilization, and ethylene oxide decontamination on the solderability of component leads.

This work was done for the Jet Propulsion Laboratory under Contract No. 951069 (subcontract under NASA Contract NAS 7-100). Mr. A. G. Fitak was the JPL Project Engineer on this program. During the final stages of this program, Mr. R. F. Holtze became the new JPL Project Engineer on this program, since Mr. Fitak was transferred to other duties.

This final report has been divided into three separate parts. Part I, which is this part, covers the thermal sterilization effects on solder and weld joints. Part II contains the weld schedule isoforce diagrams, raw data sheets, photomicrographs, and electron probe microanalysis charts for the solder and weld joints under Part I. Part III covers the solderability studies. It is therefore possible while reading the test results of Part I to turn to the applicable raw data sheet or photomicrograph in Part II and consult both pieces of information at the same time. Part III, being a separate study and not as lengthy as Part I, is all-inclusive with its own data sheets and photomicrographs included under the same cover.

1.2 SCOPE

Part I of this final report is a determination of the effects of a thermal sterilization process on the mechanical and electrical properties of soldered and welded joints. This involved the preparation and testing of 1362 soldered joints of 11 different types including both stranded and solid conductors joined to connector cups and bifurcated terminals. A total of 834 cross-wire weld joints of 7 different material combinations were prepared and tested. All of the different types of soldered and welded joints were tested and examined before and after thermal sterilization. Testing consisted of ultimate strength, electrical resistance, electrical testing during vibration, ultimate strength after vibration, and stress-rupture strength. In addition certain solder and weld joint types were submitted to electron probe microanalysis. All solder and weld joint types were examined metallographically and 48 photomicrographs were taken. The test results were analyzed statistically. Photographs were taken of each type of solder and weld joint specimen prior to testing and of each piece of test equipment used with at least one of each type of test specimen installed prior to test.

2. MATERIALS AND EQUIPMENT

2.1 MATERIALS FOR SOLDER JOINTS AND WELD JOINTS

The materials used in this program for the preparation of the solder joints and weld joints are listed in Table I. Vendor certifications were required for all materials. Incoming inspection for the materials listed in Table 1 was done by metallographic sectioning, tensile strength tests, spectrographic analysis, and magnified examination. Inspection was primarily aimed at correct plating thicknesses, proper base metal or alloy, and proper material dimensions.

Table II is a tabulation of the plating thickness measurements made on the materials listed in Table I. Certain of the materials were not plated and therefore are not included in Table II. The thickness measurements in Table II are averages of five readings with the minimum-maximum range given whenever possible.

2.2 RAW MATERIALS FOR SOLDERED JOINTS

2.2.1 Solvent for removal of flux residue - 1, 1, 1-Trichloroethane per Federal Specification O-T-620

2.2.2 Protective coating for connector cups and bifurcated terminals - Lonco Sealbrite No. 230-10.

2.2.3 Flux for tinning stranded conductors - Alpha No. 100 per MIL-F-14256 C, Type W.

2.2.4 Flux for tinning all gold plated and solder coated conductors - Alpha No. 611 per MIL-F-14256C, Type A.

2.2.5 Flux for tinning bare nickel conductors - Alpha No. 90 Stainless Steel Flux.

2.2.6 Cored solder for making all solder joints - Kester plastic rosin core solder, per QQ-S-571d, 0.032" diameter, Composition Sn63, Form W, Type R, Core P3.

Table I. List of materials for solder joints and weld joints.

1. Stranded conductor, #24 AWG, 19/36, per MIL-W-16870, Type E, silver plated, Teflon insulated.
* 2. Cinch connector cup per JPL 20045/200-E.
* 3. Bendix connector cup per JPL ZPH-2245-0300-B, JPL DS317, and MIL-C-26482C.
4. Bifurcated terminal, solder coated, per JPL DS167-7.
5. Bifurcated terminal, solder coated, per JPL DS167-3.
6. Bifurcated terminal, gold plated, per JPL DS99-7.
7. Conductor, copper, OFHC, 0.020" diam., gold plated per MIL-G-45204, Type I, Class 1.
8. Conductor, copper, OFHC, 0.020" diam., tin-lead coated, tin 10-70%, 0.0001" average min. thickness -0.001" average maximum thickness per Revision A to MIL-STD-1276. Preferred tin-lead alloy to be 63-37 or 60-40.
** 9. Conductor, Dumet, 0.020" diam., per MIL-STD-1276, Type D, gold plated per MIL-G-45204, Type I, Class 1.
10. Conductor, Kovar, 0.018" diam., per MIL-STD-1276, Type K, gold plated per MIL-G-45204, Type I, Class 1.
11. Conductor, Nickel, 0.025" diam., per MIL-STD-1276, Type N-2, gold plated per MIL-G-45204, Type I, Class 1.
12. Conductor, Nickel, bare, 0.025" diam., per MIL-N-46026.
13. Conductor, Nickel, bare, 0.016" diam., per MIL-N-46026.
14. Conductor, Nickel, 0.016" diam., per MIL-STD-1276, Type N-2, gold plated per MIL-G-45204, Type I, Class 1.
15. Conductor, Kovar, ribbon, per MIL-STD-1276, Type K, 0.005" x 0.016", gold plated per MIL-G-45204, Type I, Class 1.
16. Conductor, Nickel, Inco 200 ribbon, bare, 0.010" x 0.031" (rolled from wire & annealed).
17. Printed circuit board material, 0.062" thick, per MIL-P-13949C, Type FL-GE, glass-base epoxy laminate.

---

* Supplied by JPL

** Dumet wire supplied without a nickel strike between the copper sheath and the outer gold electroplate.

Table II. Plating thickness measurements.

Material	Type of Plating	Plating Thickness (micro-inches)
1. Stranded conductor, #24 AWG	Silver	80-110
2. Cinch connector cup	Gold	120-160
	Copper flash	310-400
3. Bendix connector cup	Gold	140-160
	Silver	220-320
	Copper strike	40-76
* 4. Bifurcated terminal DS 167-7	Solder	140-600
* 5. Bifurcated terminal DS 167-3	Solder	160-500
6. Bifurcated terminal DS 99-7	Gold	50-80
	Silver	200
	Silver strike	-
	Copper strike	47
7. Conductor, copper, 0.020" diam.	Gold	88
** 8. Conductor, copper, 0.020" diam.	Solder	220-320
9. Conductor, Dumet, 0.020" diam.	Gold	70-80
10. Conductor, Kovar, 0.018" diam.	Gold	100-130
11. Conductor, nickel, 0.025" diam.	Gold	84-90
12. Conductor, nickel, 0.016" diam.	Gold	88
13. Conductor, Kovar, 0.005" x 0.016"	Gold	100-120

*Terminals were centrifuged solder coated using an Electrovert "ACTA" Automatic Centrifugal Tinning Apparatus.

**Analysis showed the tin-lead composition of the solder plating to be 55%-65% tin with the balance lead.

2.2.7 Solder in solder pot for tinning conductors - Kester bar solder per QQ-S-571d, Type Sn 63-B-S.

2.3 EQUIPMENT FOR PREPARING SOLDERED JOINTS

2.3.1 Soldering iron used for making all soldered joints - Weller Model W-TCP (60 watts) thermally controlled soldering pencil with a Type PT-A6 600°F iron clad screwdriver tip.

2.3.2 Insulation stripper for stranded conductor wire - Pioneer Magnetics Thermal Stripper.

2.3.3 Suction method for removing excess solder from tinned connector cups - Zeva 70 watt soldering iron equipped with a Bazooka solder gobbler.

2.3.4 Solder pot for tinning conductors - Dee Melting Pot, Model 13.

2.4 EQUIPMENT FOR PREPARING WELDED JOINTS

2.4.1 Hughes Aircraft Company Model VTW-30B Stored Energy Power Supply (100 watt-seconds), Serial No. 30B-299, calibrated on 6-14-65.

2.4.2 Hughes Aircraft Company Model VTA-60 Welding Head, Serial Number 60A-364

2.4.3 RWMA-1 copper - cadmium alloy welding electrodes and RWMA-2 copper-chromium alloy welding electrodes.

2.5 TEST EQUIPMENT

The equipment used for conducting the various tests on the solder and weld joints is listed at the beginning of each section describing the applicable test procedure.

3. PREPARATION OF TEST SPECIMENS

3.1 BAKE-OUT OF CONDUCTORS

Conductor materials for solder and weld joints were baked-out prior to tinning and joining. The following conductor materials were baked-out at 200°C for 168 hours in an inert nitrogen atmosphere using a National Appliance Co. Vacuum Oven, Model 58402, Serial No. B59:

a) Gold plated copper wire
b) Gold plated Dumet wire
c) Gold plated Kovar wire
d) Gold plated nickel wire
e) Bare nickel wire
f) Gold plated Kovar foil

Originally these conductors were baked-out at 200°C for 168 hours in <u>air</u>; however the gold plated copper and gold plated Dumet wires turned black (severe oxidation) as a result of this bake-out schedule and were in an unsolderable condition. It was therefore decided to conduct all bake-outs in an inert atmosphere.

All solder coated copper wires and the leads of 1/4-watt axial lead resistors were baked-out at 150°C for 168 hours in an inert argon atmosphere using a National Appliance Co. Vacuum Oven, Model 58301, Serial No. C58.

The only wires <u>not baked-out</u> were the teflon insulated stranded conductors and the Inco 200 ribbon. None of the connector cups or bifurcated terminals were baked-out.

3.2 TINNING OF CONNECTOR CUPS

Prior to their use for solder joints, the Cinch and Bendix connector cups were tinned. Tinning was in accordance with JPL Interim Procedure "Procedure for Soldering Wire to Connector Pin Solder Cups." This procedure essentially calls out filling the cup cavity with solder using a soldering iron and then removing the excess solder by means of sucking or wicking. Suction (using a solder gobbler) was used to remove excess solder from the cup cavities. Flux residues were then removed by agitation in trichloroethane solvent. All connector cups were then dip coated with a protective coating of Lonco Sealbrite No. 230-10.

The solder coated bifurcated terminals were centrifuged solder coated by the vendor (Lyn-Tron, Inc.) but had not been protectively coated. Therefore these terminals were protectively dip coated with Sealbrite No. 230-10 at Hughes Aircraft Company.

3.3 TINNING OF CONDUCTORS

All conductor wires used in the preparation of solder joints were tinned prior to joining. Stranded conductors had the Teflon insulation stripped back for a distance of 5/32" - 3/16" using a Thermal Stripper. All wires used in the preparation of solder joints were precut to a length of 2" prior to tinning. Tinning of the conductor wires, stranded conductors, and resistor leads was done by first dip fluxing the end of the wire and then dipping the wire in a molten 63/37 solder pot at 500°F for 5 seconds. Alpha 611 activated rosin flux was used for all conductor wires except:

a) Stranded conductor - used Alpha 100 nonactivated rosin flux.

b) Bare nickel wire - used Alpha No. 90 stainless steel flux.

Flux residues remaining after tinning were removed by an agitated rinse in Trichloroethane, except for Alpha No. 90 flux residues which were removed by three successive hot water rinses followed by a distilled water rinse and a hot air dry.

None of conductors used in the preparation of welded joints were tinned prior to welding.

3.4 FABRICATION OF SOLDER JOINTS

Soldering of all solder joints was done in accordance with JPL Process Specification ZPE-1081-0002-A "Soldering of Electronic Equipment," dated 9 Dec., 1964 using a Weller Model No. W-TCP (60-watt) soldering iron with a PT-A6 600°F iron clad tip. A non-activated rosin cored solder (Sn 63-WRP3) was used for all joints. All solder joints were made by one operator who was certified for soldering per

NASA Electrical Assembly Specification MSFC-PROC-158B "Procedure for Soldering of High Reliability Electrical Connections."

Prior to making any solder joints, the soldering iron was tested to see if it would meet the temperature requirements of JPL Spec. ZPE-1081-0002-A. This specification states that "the temperature of the soldering iron shall be maintained within 475°F to 610°F during the soldering operation. The test results showed that during the soldering operation, the tip temperature is maintained between 530°F and 580°F using the PT-A6 tip.

Soldering techniques for specimen standardization were established by soldering samples of all joint types and material combinations and metallographically sectioning typical joints. Inspection of the metallographic mounts was done to insure that, as far as practical, all joints of one type are similar (e. g., same appearance, same mass of solder, etc.).

All solder joints were 100% inspected. No repairs were allowed. Only joints visually acceptable under 20X magnification were tested.

Flux residues from all solder joints were removed by 1, 1, 1-Trichloroethane.

The number and types of solder joints fabricated for this program are listed in Table III. Figures 1 and 2 are photographs showing all of the eleven types of solder joint specimens prepared for this program. The specimens in Figure 1 are labeled in accordance with the specimen identification used in Table III. This same identification code has been used throughout the entire program. The specimens in Figure 2 are of gold plated Kovar wire soldered to solder coated bifurcated terminals (identification 1. 3. 4).

Figures 3, 4, and 5 are close-up photographs of the eleven types of solder joint specimens. The ten specimens shown in Figures 3 and 4 have been photographed from two views. The solder joint specimens on the left show the side view and the specimens on the right show the top view of the same type of solder joint. The specimens in Figure 5 are 1/4-watt axial lead resistors soldered to solder coated bifurcated terminals. The terminals have been staked in a 1/16" thick glass-base

Table III. Fabrication of solder joints.

	Number of Specimens Fabricated
1.1 Stranded conductor (#24 AWG, Teflon insulated) to connector cup.	
1.1.1 CINCH connector cup per JPL Spec. 20045/200-E.	182
1.1.2 BENDIX connector cup per JPL Spec. ZPH 2245-0300-B, DS317	182
1.2 Stranded conductor (#24 AWG, Teflon insulated, per MIL-W-16878D, Type E) to solder coated bifurcated terminal per JPL DS 167-7	110
1.3 Solid conductors per 1.3.1, 1.3.2, 1.3.3, 1.3.4, 1.3.5, and 1.3.6 to solder coated bifurcated terminal per JPL DS 167-7	
*1.3.1 Copper, gold plated, OFHC, 0.020	114
**1.3.2 Copper, solder coated, OFHC, 0.020	110
*1.3.3 Dumet, gold plated, 0.020 per MIL-STD-1276, Type D	110
*1.3.4 Kovar, gold plated, 0.018 per MIL-STD-1276, Type K	110
*1.3.5 Nickel, gold plated, 0.025, per MIL-STD-1276, Type N-2	110
*1.3.6 Nickel, bare, 0.025, per MIL-N-46026	110
1.4 *Copper, gold plated, OFHC, 0.020 to gold plated bifurcated terminal per JPL DS 99-7	114
1.5 Components (1/4-watt axial lead resistors**) mounted between pairs of solder coated bifurcated terminals (JPL DS 167-3) on glass-epoxy circuit board per MIL-P-13949C, Type FL-GE, 0.062" thick	110
TOTAL =	1362

*Leads baked at 200°C for 168 hours in nitrogen.

**Solder coated leads baked at 150°C for 168 hours in argon.

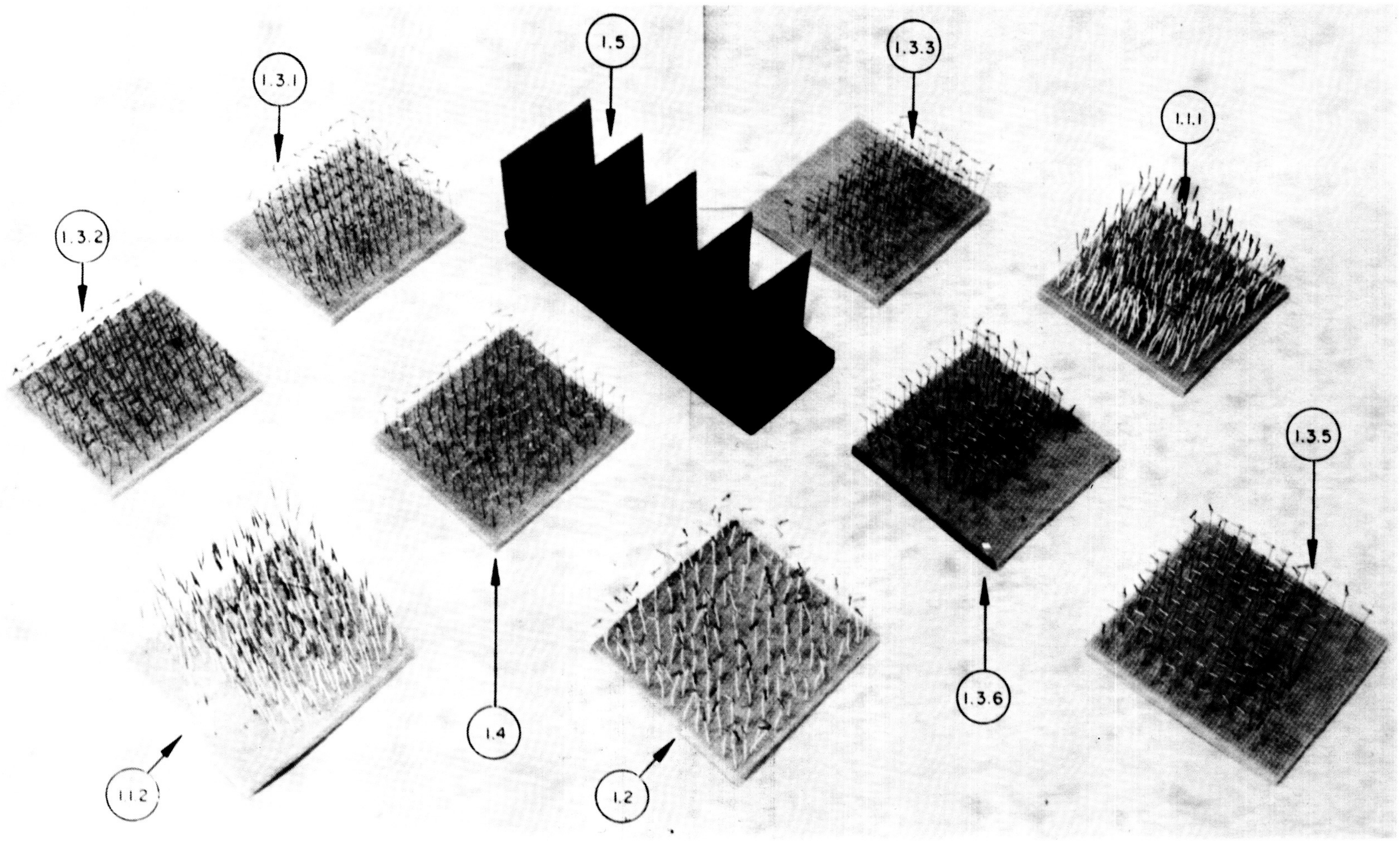


Figure 1. Photograph showing ten types of solder joint specimens (R104841).

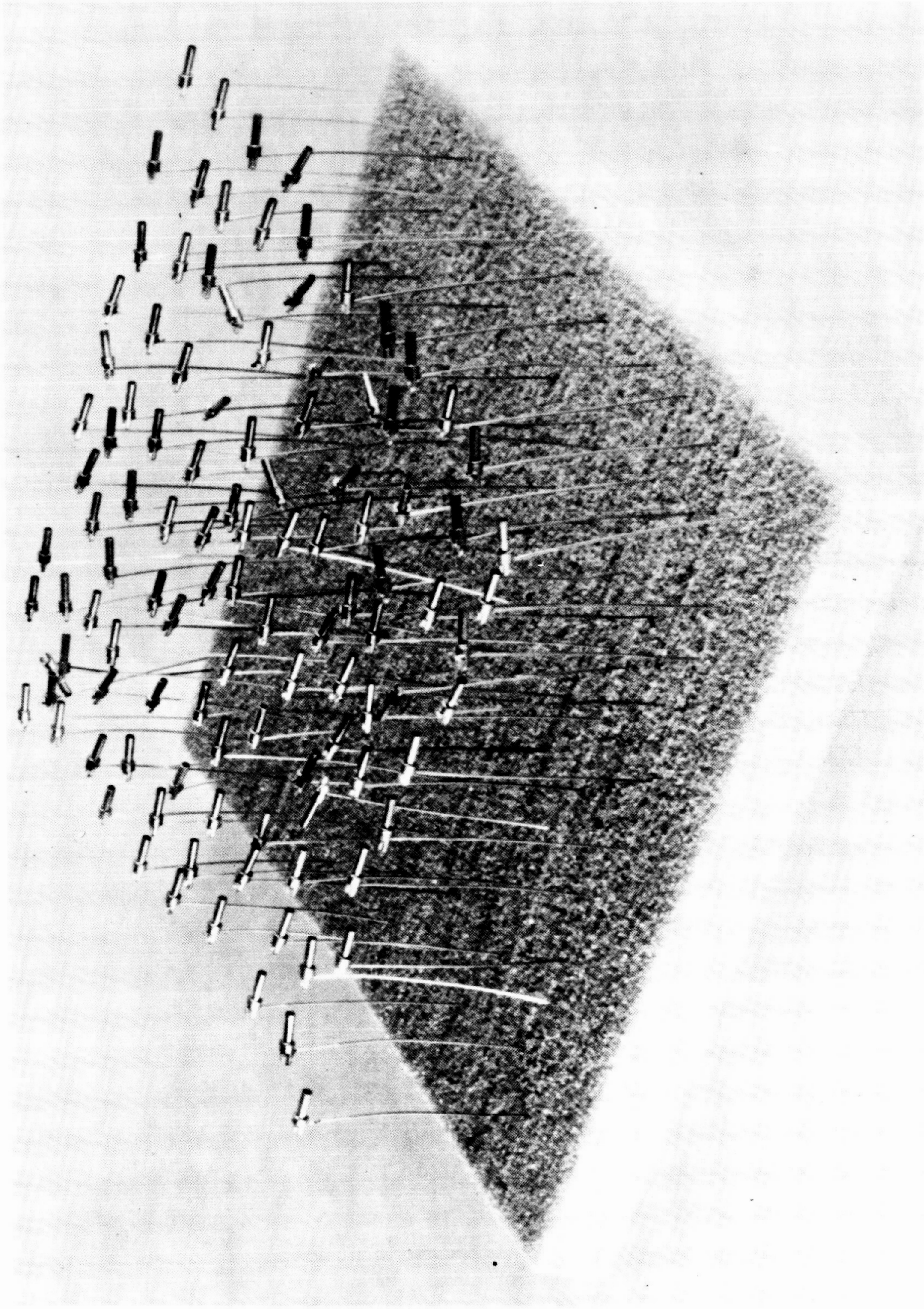


Figure 2. Photograph showing solder joint specimens of gold plated Kovar wire to solder coated bifurcated terminals (R105004).

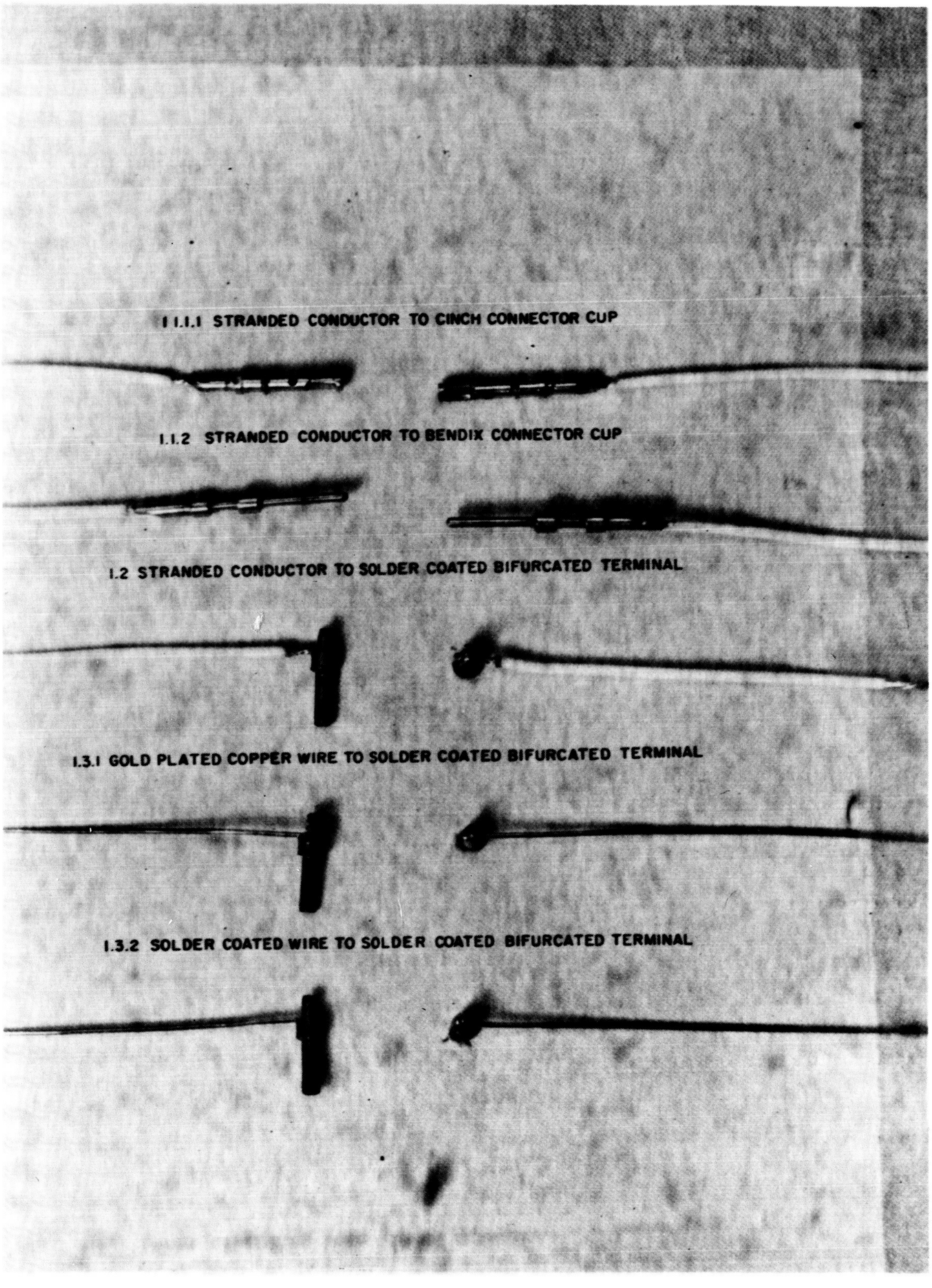


Figure 3. Photograph of five types of solder joints - 1.1.1, 1.1.2, 1.2, 1.3.1, 1.3.2 (R105350).

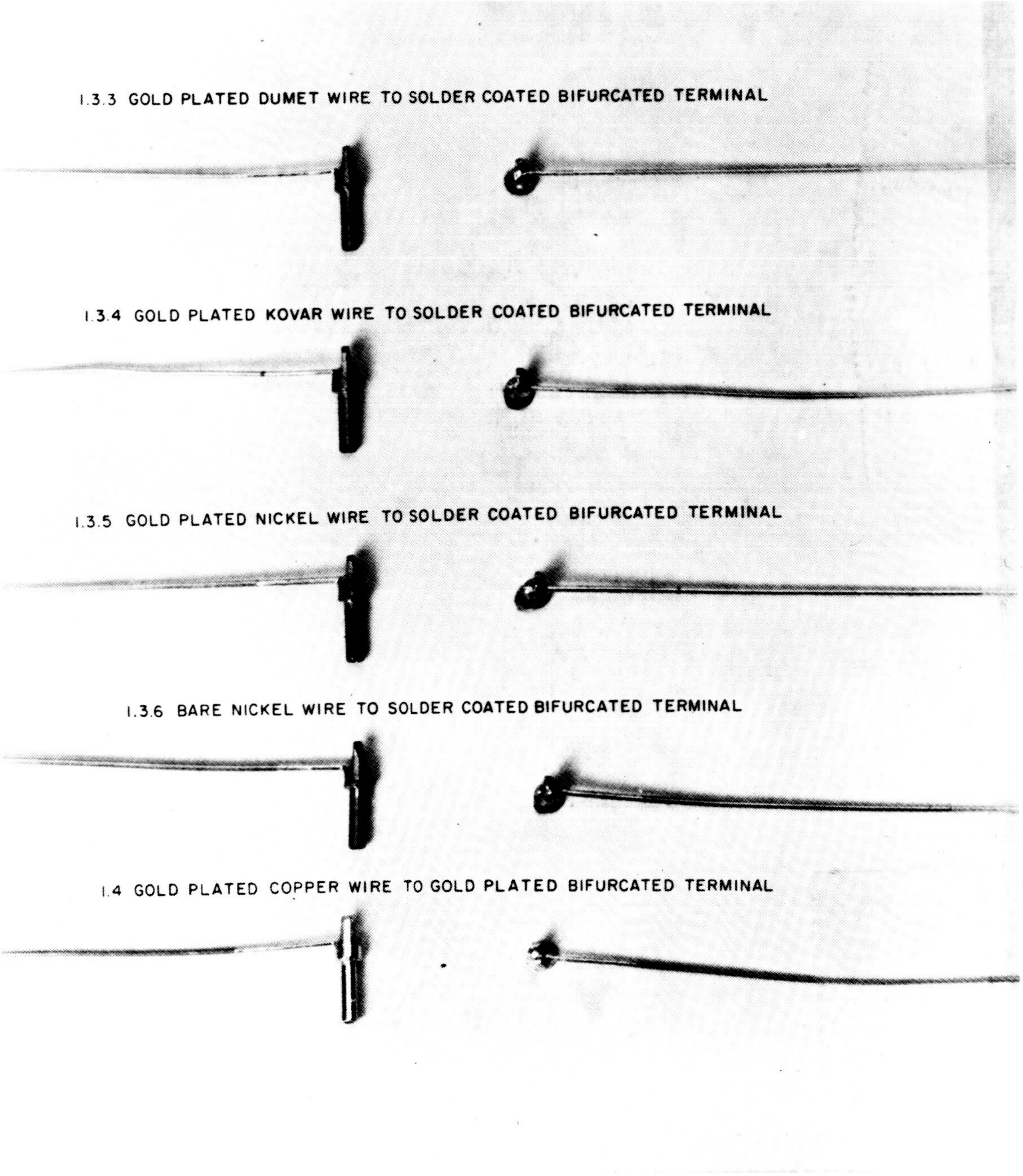


Figure 4. Photograph of five types of solder joints - 1.3.3, 1.3.4, 1.3.5, 1.3.6, 1.4 (R105349).

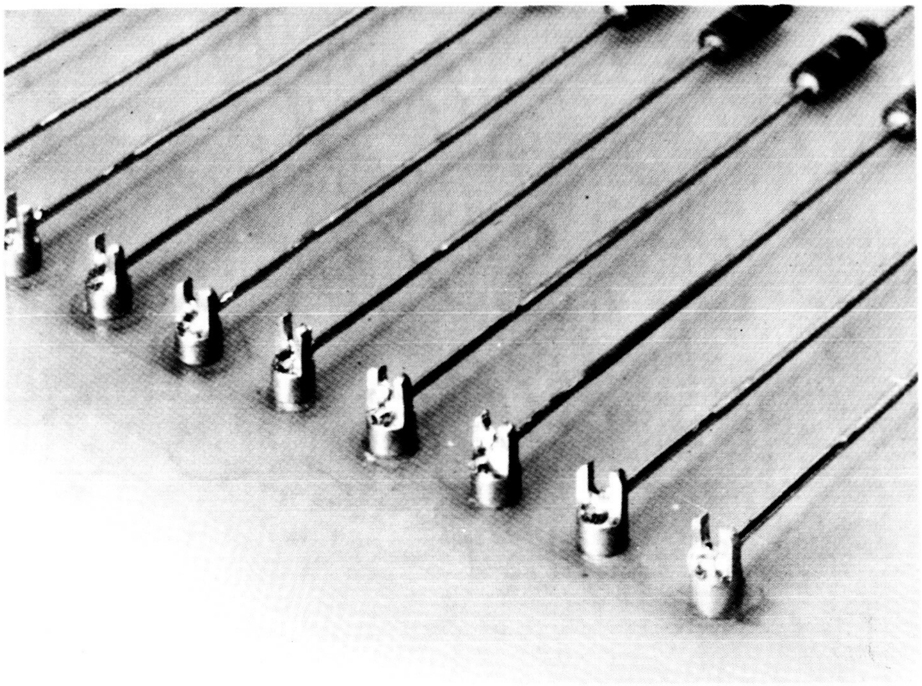


Figure 5. Solder joint specimens of 1/4-watt axial lead resistors soldered to solder-coated bifurcated terminals. Specimen No. 1.5 (R105005).

epoxy laminate printed circuit board and soldered to the gold plated etched circuit pad areas on the underside.

3.5 FABRICATION OF WELD JOINTS

The number and types of weld joints to be fabricated for this program are those listed in Table IV. Note that leads materials 1.1, 1.2, 1.3, 1.4, 1.5, and 2 are baked at 200°C for 168 hours in nitrogen. Lead material 1.6 was baked at 150°C for 168 hours in argon. In addition to the weld joints listed in Table IV, JPL welded ten (10) each of joint types 1.1 thru 1.6 as specified in Table IV using material baked-out and furnished by Hughes Aircraft Company. JPL did not prepare any weld joint specimens for joint 2. (Kovar foil to Kovar foil). All Hughes & JPL weld joints were made using material from the same spool of wire.

Table IV. Fabrication of welded joints.

	Number of Specimens Fabricated	
	Type A	Type B
1. Nickel (Inco 200) ribbon, 0.010 x 0.031		
*1.1 Nickel, bare, 0.016 per MIL-N-46026	90	20
*1.2 Nickel, gold plated, 0.016, per MIL-STD-1276, Type N-2	90	20
*1.3 Kovar, gold plated, 0.018, per MIL-STD-1276, Type K	90	20
*1.4 Dumet, gold plated, 0.020, per MIL-STD-1276, Type D	90	20
*1.5 Copper, gold plated, OFHC, 0.020	94	20
**1.6 Copper, solder coated, OFHC, 0.020	90	20
*2. Kovar, gold plated, 0.005 x 0.016, per MIL-STD-1276, Type K to itself	90	20
TOTALS	634	140
GRAND TOTAL = 774		

*Leads baked at 200°C for 168 hours in nitrogen.
**Solder coated leads baked at 150°C for 168 hours in argon.

The configuration of the weld joints is shown in the sketches (Types A and B) on Figure 6. The weld joint shown as Type A will be prepared in accordance with Figure 4 of JPL Spec. No. GPO-30995-GEN. Type B weld joint was used for electrical tests during vibration (before and after heating) and ultimate strength tests after vibration (before and after heating).

Weld joints were made in accordance with JPL Spec. No. GPO-30995-GEN "General Specification for the Design and Fabrication of Resistance Welded Electrical Connections." Welding will be done using a Hughes Model VTW-30B Stored Energy Power Supply (100 watt-seconds) with a Hughes VTA-60 weld head. This unit is a capacitance discharge resistance welder having a force fired head with controllable welding energy. The weld electrode material was dependent upon the materials being joined. Weld schedule determination was by the isoforce diagram method whereby weld energy (watt-sec.) is plotted against weld breaking strength for constant clamping forces. All welding was done by one certified operator.

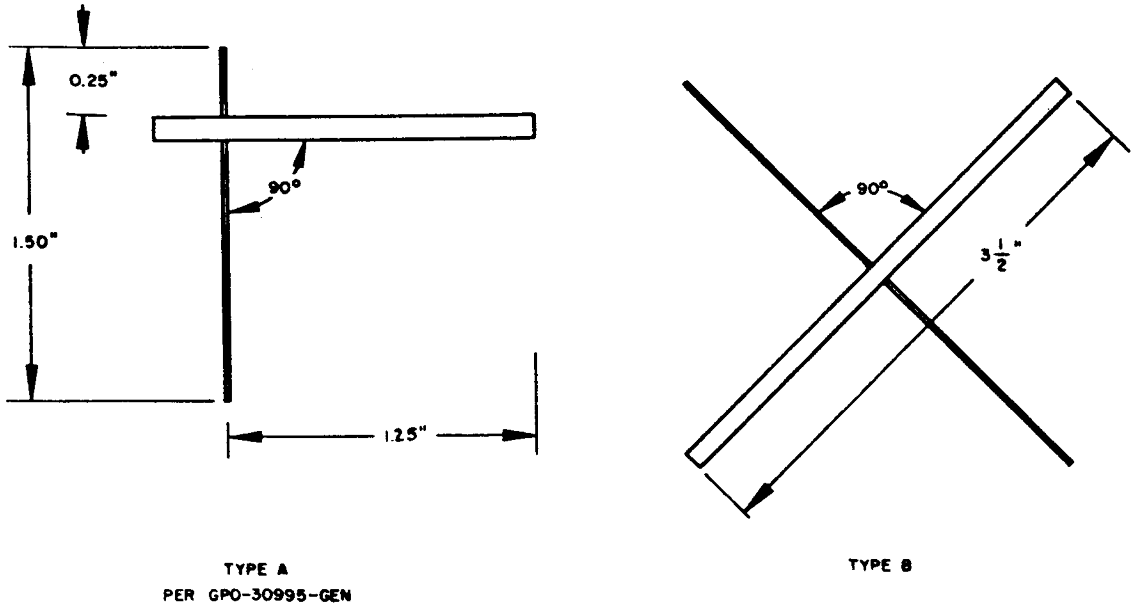


Figure 6. Weld joint configurations.

Typical specimens of all weld joint types were metallographically sectioned and examined for internal defects and specimen standardization. All weld joints were 100% inspected at 20X magnification. Weld schedule verification was per paragraph 3. 3. 6 of JPL Spec. GPO-30995-GEN.

In order to prepare weld joints per JPL specification No. GPO-30995-GEN it was necessary to first establish optimum schedules. This required from 100 to 200 weld joints of each type to be prepared and pulled apart while varying parameters such as weld energy, electrode force, electrode material, and polarity and observing percent setdown, percent lead deformation, interface spitting, mean pull strength, etc. Six weld specimens for each joint type were also metallographically examined per paragraph 3. 3. 5 of JPL Spec. GPO-30995-GEN for weld schedule defects. Weld schedule verification was done by preparing fifty (50) weld joints of Type A in Figure 6 for pull testing. Forty (40) of these fifty (50) weld joints were used to obtain ultimate strength data for another testing portion of this program. Those weld joints giving the most trouble were:

1. 1 Bare nickel to Inco 200 ribbon
1. 3 Gold plated Kovar to Inco 200 ribbon
2. 0 Gold plated Kovar ribbon to itself.

Attachment 1 in Part II of this final report contains an isoforce diagram for each of the seven types of weld joints. All pertinent data regarding determination of weld schedules has been included on the isoforce diagrams.

Table V is a summation of weld schedule data showing the various weld schedules established by Hughes and JPL for the weld joints. All JPL weld joints were fabricated using a Weldmatic Model 1065 power supply with electrodes having 0.050" tip diameters.

Figure 7 is a photograph showing all of the weld joint specimens (Type A and Type B) prepared for this program. The Type A specimens are on the lower bench top and the Type B specimens are on the upper shelf. The identification numbers for the specimens are coded in accordance with Table IV. The Type B specimens of one type are shown

Table V. Weld schedules for weld joint specimens as prepared by Hughes Aircraft Company and Jet Propulsion Laboratory.

Joint Type	Material	Electrode Pressure (lbs)		Weld Energy (watt-sec.)		Upper Electrode		Upper Electrode Polarity		Lower Electrode		Lower Electrode Polarity	
		HAC	JPL	HAC	JPL	HAC	JPL	HAC	JPL	HAC	JPL	HAC	JPL
1.1	Bare nickel wire to Inco ribbon	9	8	21	6	RWMA 2	RWMA 2	-	+	RWMA 2	RWMA 2	-	+
1.2	Gold plated nickel wire to Inco ribbon	6	8	15	6	RWMA 1	RWMA 2	-	-	RWMA 2	RWMA 2	+	+
1.3	Gold plated Kovar wire to Inco ribbon	11	8	10	4	RWMA 2	RWMA 2	-	-	RWMA 2	RWMA 2	+	+
1.4	Gold plated Dumet wire to Inco ribbon	6	8	17	6	RWMA 1	RWMA 2	-	-	RWMA 2	RWMA 2	+	+
1.5	Gold plated copper wire to Inco ribbon	8	8	33	10	RWMA 1	RWMA 2	-	-	RWMA 2	MOLY.	+	+
1.6	Solder coated copper wire to Inco ribbon	7	8	28	10	RWMA 1	RWMA 2	-	-	RWMA 2	RWMA 2	+	+
2	Gold plated Kovar foil to itself	6	-	6	-	RWMA 2	-	-	-	RWMA 2	-	+	-

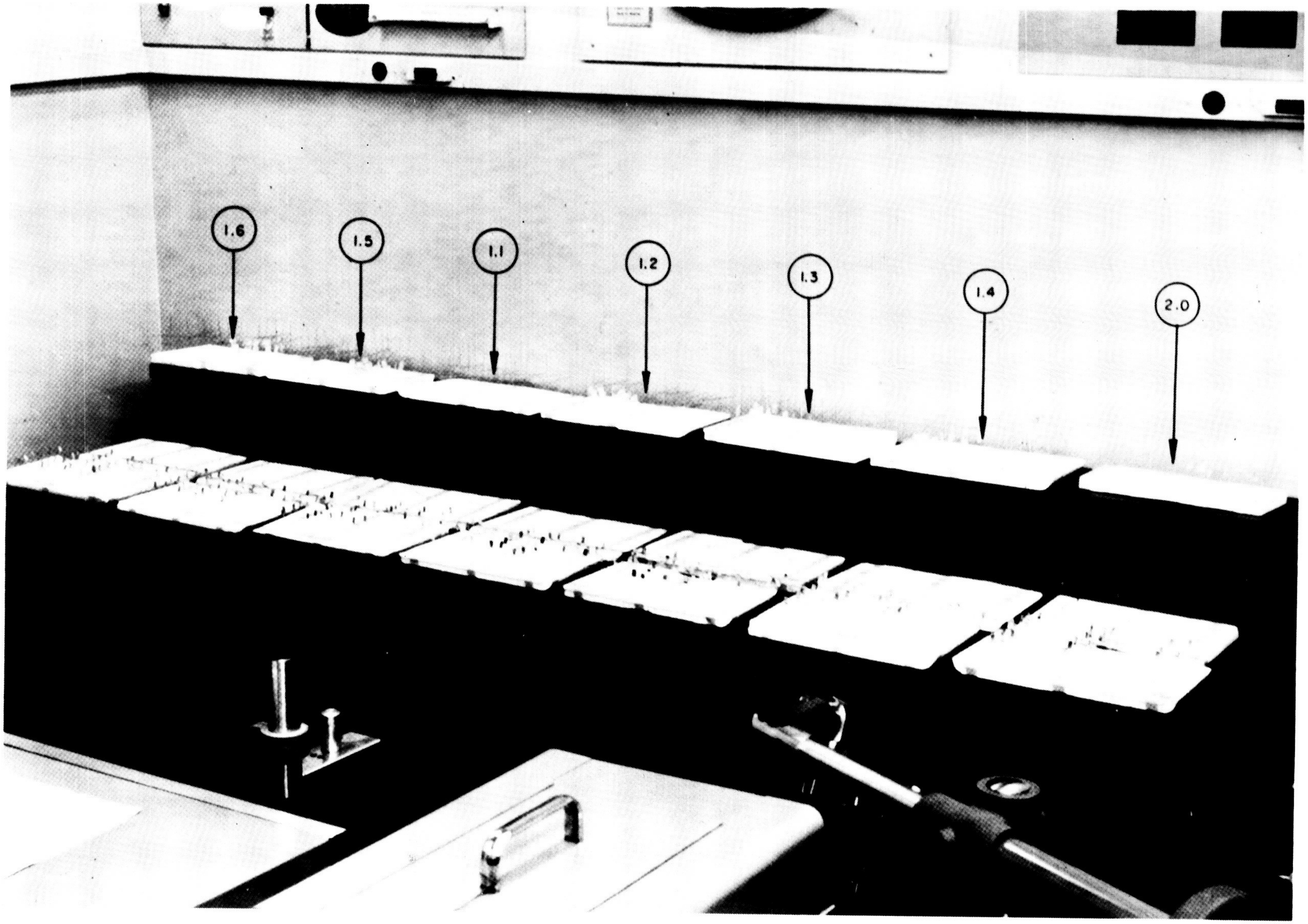


Figure 7. Photograph of all seven types of weld-joint specimens (R105346).

directly above the Type A specimens of that same type. Note that certain weld joint specimens have already been labeled with small tags. All specimens were eventually labeled, either before or after destructive testing.

Figure 8 is a photograph showing two each of the seven types of weld joint specimens, all of which were fabricated per configuration A of Figure 6. The weld joints on the left show the Inco ribbon on the bottom and the weld joints on the right show the Inco ribbon on the top. Weld joint 2.0 (Kovar foil to Kovar foil) of course has the same material on the top and bottom.

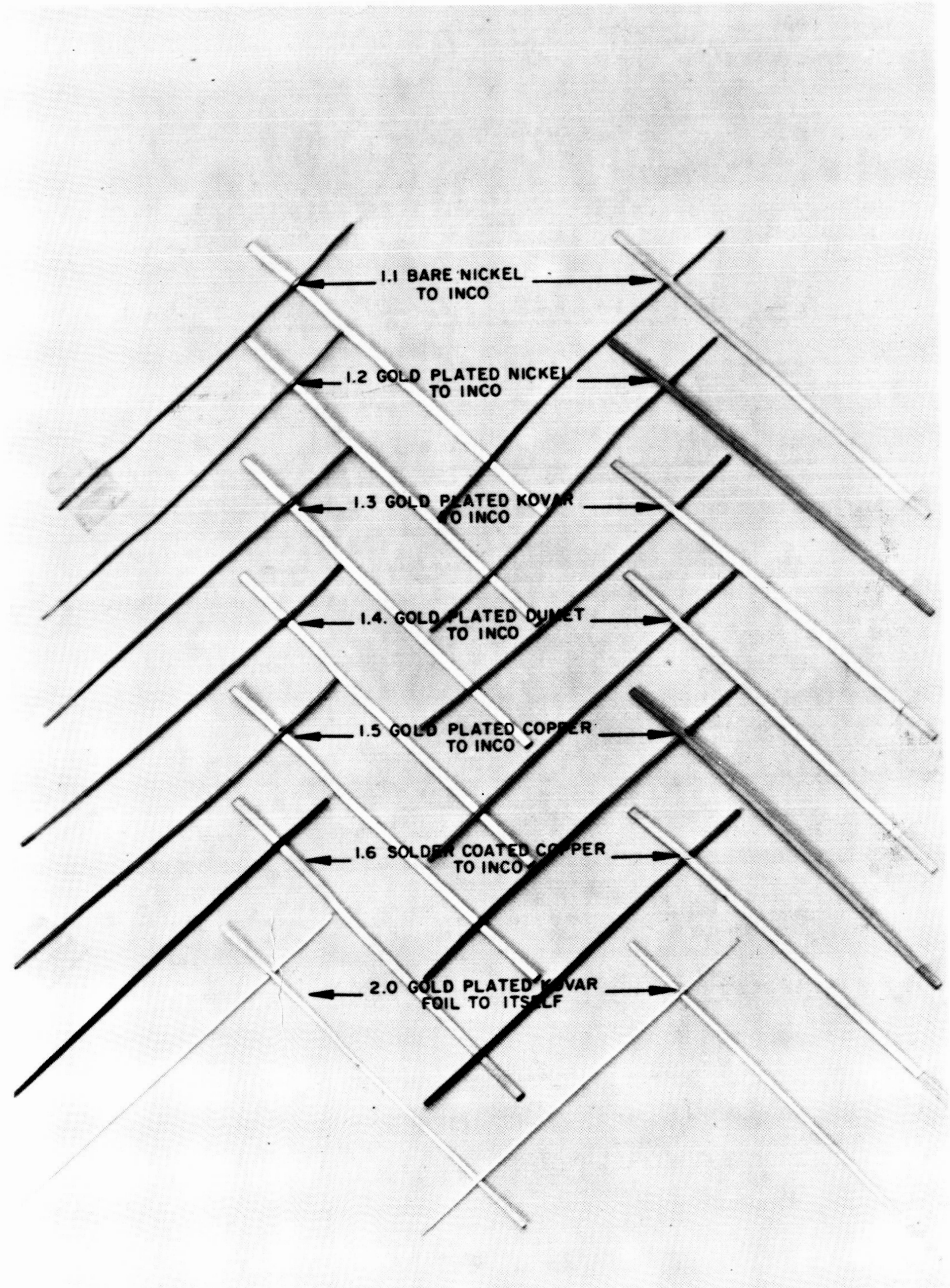


Figure 8. Photograph of the seven types of weld-joint specimens (R105348).

4. TEST PROCEDURES

4.1 GENERAL TEST INFORMATION

Testing of solder and weld joints was in accordance with Table VI. A more detailed breakdown of the number of joints for testing is given in Table VII.

Table VIII shows a flow diagram of the test sequence and the number of soldered and welded joints which were submitted to each particular test. The numbers (1 through 13) in the circles above the testing blocks refer back to that particular test outlined in Table VI.

All solder and weld joints were separately identified by special labels and code numbers. This was especially important during the electrical resistance tests so that the same joint could be identified and electrically tested before and after heat sterilization. After testing, all joints (separately identified) were bagged for delivery to JPL. Joints which were destroyed by virtue of ultimate strength tests had their mating members taped back together, so that JPL can, if necessary, refer back to this particular specimen at a later date.

Photographs of each type of test equipment used with a typical joint type installed were taken prior to testing.

Calibration data, where applicable, for the test equipment used was recorded in order to allow traceability of test result data to the original recordation made during testing.

Separate data sheets were used for each particular type of test. A typical data sheet is shown in Figure 9. Original raw data sheets for all tests conducted during this program have been included in Part II, Attachment 2, to this final report.

4.2 DRY HEAT STERILIZATION TEST PROCEDURES

A National Appliance Co. Vacuum Oven, Model 58402 (Serial No. B59), was used to accomplish the dry heat sterilization cycling in the following portions of the program:

(1) Ultimate strength testing.

(2) Metallographic examination.

Table VI. Test outline.

Tests	Number of Specimens
1. Ultimate strength before heating	1. 40 each of all joints
2. Ultimate strength after heating	2. 40 each of all joints
3. Metallurgical examination before heating	3. 5 each of all joints and 1 each of the JPL welded joints
4. Metallurgical examination after heating	4. 5 each of all joints and 1 each of the JPL welded joints
5. Electrical resistance before heating	5. 40 each of all joints except 1.5
6. Electrical resistance after heating	6. 40 each of all joints except 1.5
7. Electrical test during vibration before heating	7. 10 each of all joints and 4 each of the JPL welded joints
8. Electrical test during vibration after heating	8. 10 each of all joints and 4 each of the JPL welded joints
9. Ultimate strength after vibration before heating	9. 10 each of all joints and 4 each of the JPL welded joints
10. Ultimate strength after vibration after heating	10. 10 each of all joints and 4 each of the JPL welded joints
11. Stress-rupture strength for heat sterilization time and temperature and for the sterilization time period at room temperature	11. 72 each of joints 1.1.1 and 1.1.2
12. Electron probe micro-analysis for gold diffusion before heating	12. 2 each of soldered joints 1.3.1 and 1.4 and welded joint 1.5
13. Electron probe micro-analysis for gold diffusion after heating	13. 2 each of soldered joints 1.3.1 and 1.4 and welded joint 1.5

Table VII. Number of joints for testing.

1. ULTIMATE STRENGTH TEST

1100 solder joints (100 each of 11 types)
748 weld joints (100 each of 7 types + 48 JPL welds)
1848 joints

2. METALLURGICAL EXAMINATION

110 solder joints (10 each of 11 types)
82 weld joints (10 each of 7 types + 12 JPL welds)
192 joints

3. ELECTRICAL RESISTANCE TEST

800 solder joints (40 each of 10 types tested 2 times)
560 weld joints (40 each of 7 types tested 2 times)
1360 joints

4. HEAT STERILIZATION

A.	440 solder joints (40 each of 11 types) 280 weld joints (40 each of 7 types)	BEFORE ULTIMATE STRENGTH
B.	55 solder joints (5 each of 11 types) 41 weld joints (5 each of 7 types plus 6 JPL welds)	BEFORE METALLURGICAL
C.	110 solder joints(10 each of 11 types) 94 weld joints (10 each of 7 types plus 24 JPL welds)	BEFORE VIBRATION
D.	72 solder joints (36 each of 2 types)	STRESS-RUPTURE
E.	4 solder joints (2 each of 2 types) 2 weld joints (2 each of 1 type)	ELECTRON MICRO-PROBE

1098 joints

5. ELECTRICAL TEST DURING VIBRATION

220 solder joints (10 each of 11 types tested 2 times)
188 weld joints (10 each of 7 types tested 2 times + 24 JPL welds tested 2 times)
408 joints

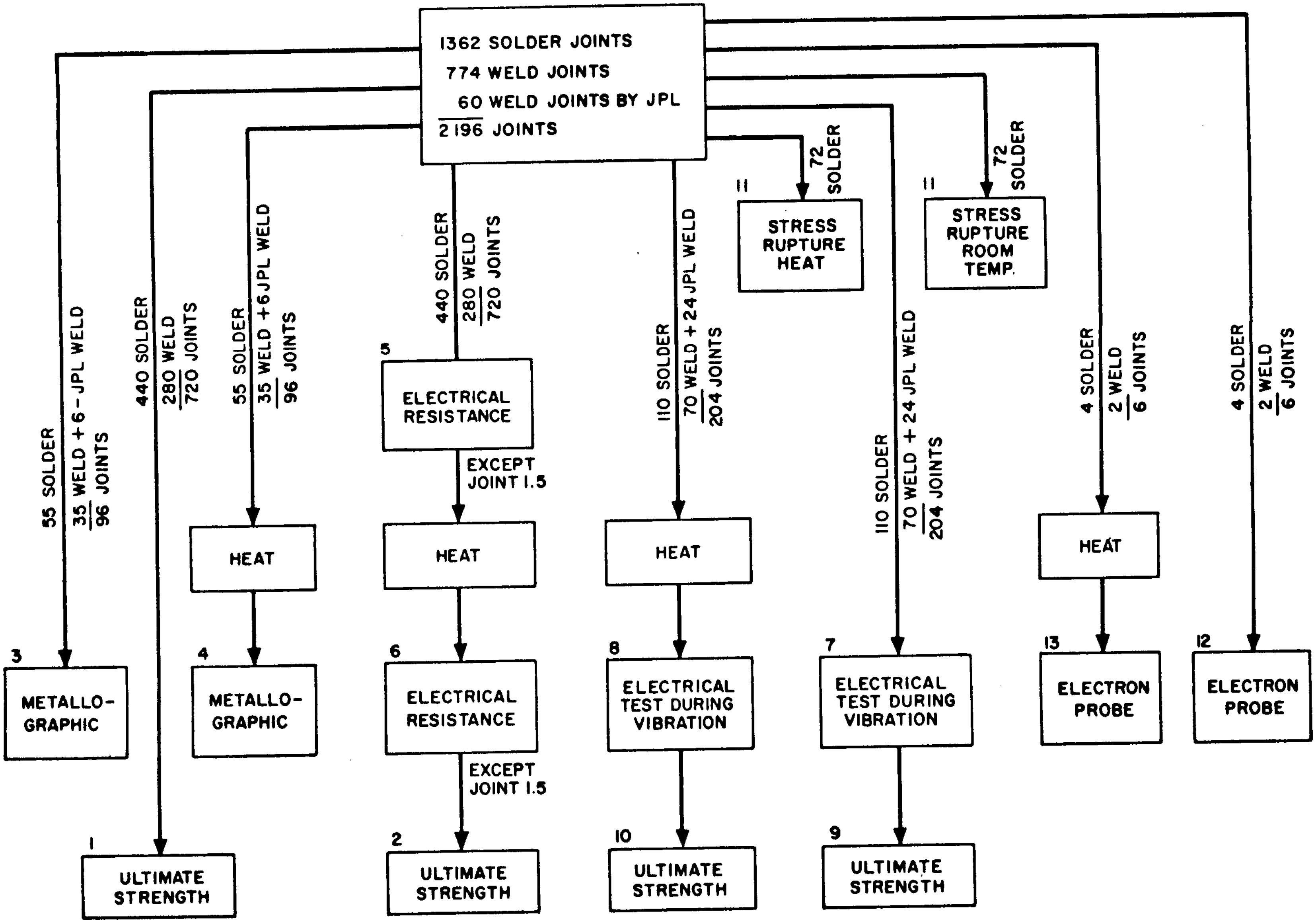
6. STRESS RUPTURE

144 solder joints (72 each of 2 types)

7. ELECTRON PROBE MICRO-ANALYSIS

8 solder joints (4 each of 2 types)
4 weld joints (4 each of 1 type)

Table VIII. Flow diagram of soldered and welded joints for testing.



TEST Ultimate Strength DATE July 12, 1965

TYPE OF JOINT: Solder Joint

MATERIAL: Gold plated copper to solder coated bifurcated terminal per 1.3.1

TEST PERFORMED BY: D. L. Teter

SPECIMEN NUMBER	STRENGTH (pounds)		RESISTANCE (microhms)	
	Ⓐ BEFORE HEAT	Ⓑ AFTER HEAT	Ⓒ BEFORE HEAT	Ⓓ AFTER HEAT
1	16.3	16.3		
2	16.4	16.4		
3	16.3	16.1		
.	.	.		
.	.	.		
.	.	.		
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.	.	.		
.	.	.		
.	.	.		
.	.	.		
.	.	.		
.	.	.		
.	.	.		
.	.	.		
40	15.9	15.8		

Figure 9. Typical data sheet for recording test results on solder and weld joints.

(3) Vibration testing.

(4) Electron probe microanalysis.

During heat cycling specimens were mounted in such a manner that the space between them precluded any synergistic effects that might occur. Only specimens of good quality and workmanship were selected for testing and all necessary steps were taken to assure maximum cleanliness of samples prior to test.

To achieve the purity of nitrogen atmosphere required in the test chamber during the heat exposure, a mechanical vacuum pump and nitrogen source (bottled commercial grade nitrogen) was used. Using an appropriately mounted thermocouple, a record was made of temperature as a function of time during the entire cycle.

Heat sterilization of solder joint specimens for stress-rupture testing was carried out in a large Conrad Temperature-Altitude Chamber Model No. FH8-3-3 (Serial No. 7268). This chamber is capable of being evacuated and backfilled with nitrogen. Automatic recording devices were used to keep a constant record of the time-temperature data. Periodic sampling and analysis of the atmosphere within the test chamber was performed to insure that no air leakage has occurred.

All dry heat cycling will be carried out in accordance with JPL Specification XSO-30275-TST-A "Environmental Test Specification Compatibility Test for Planetary Dry Heat Sterilization Requirements" dated 24 May 1963. The thermal sterilization compatibility test conditions are 145°C ±2°C for 36 hours in a dry nitrogen environment. This test is performed three (3) times with stabilization to room conditions between heating cycles.

In stress-rupture testing, however, a single 108 hour exposure was used since the three 36 hour exposure cycles per the specification would be extremely difficult to accomplish with the test configuration to be used. The test rig cannot be conveniently removed from the chamber once exposure has begun and the large mass of the chamber would require excessively long cooling periods before room temperature is achieved.

A flow diagram for heat sterilization was previously given in Table VIII. Heat sterilization of solder joint 1.5 (components between pairs of bifurcated terminals) was done with the joint still mounted on the printed wiring board. After heat cycling the terminal was removed from the printed wiring board for further testing. To facilitate removal from the circuit board without damage to the solder joint, the bifurcated terminal was not staked, but was soldered directly to the gold plated etched circuit pad (see Figure 5). Removal was accomplished by clipping the leads from the resistor bodies and quickly de-soldering the terminals from the etched pads using heat sinks in order not to disturb the solder joint between the component lead and the tines of the bifurcated terminal.

Figure 10 is a photograph showing the vacuum oven used for the dry heat sterilization tests with the weld joints inside the vacuum oven in separate Petri dishes. Figure 11 is a close-up of this vacuum oven with the solder joint specimens inside. Also shown in Figure 11 are certain of the solderability specimens.

4.3 ULTIMATE STRENGTH TEST PROCEDURES

4.3.1 Equipment

4.3.1.1 Hunter Spring Tensile Tester, Model TJH (Serial No. 175) equipped with a Hunter Mechanical Force Gage, Model D-50-T

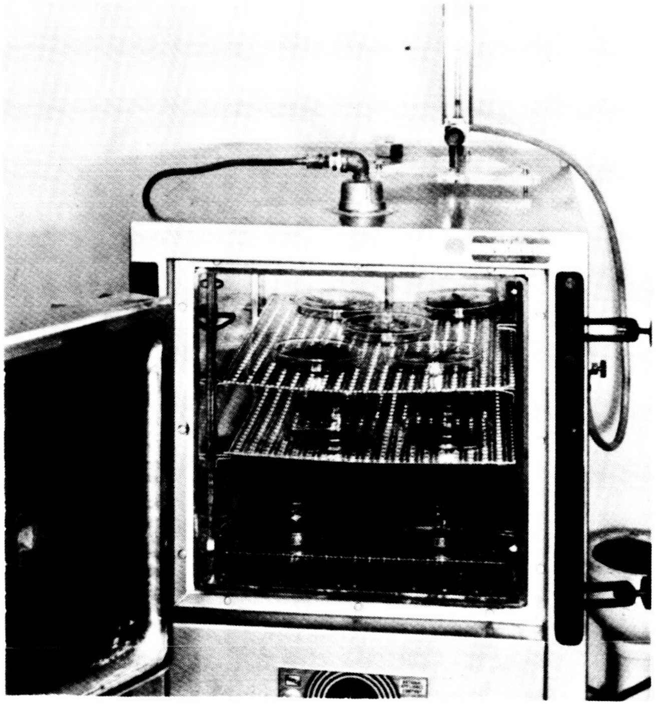


Figure 10. Vacuum oven used for dry heat sterilization tests with weld joints inside (R105391).

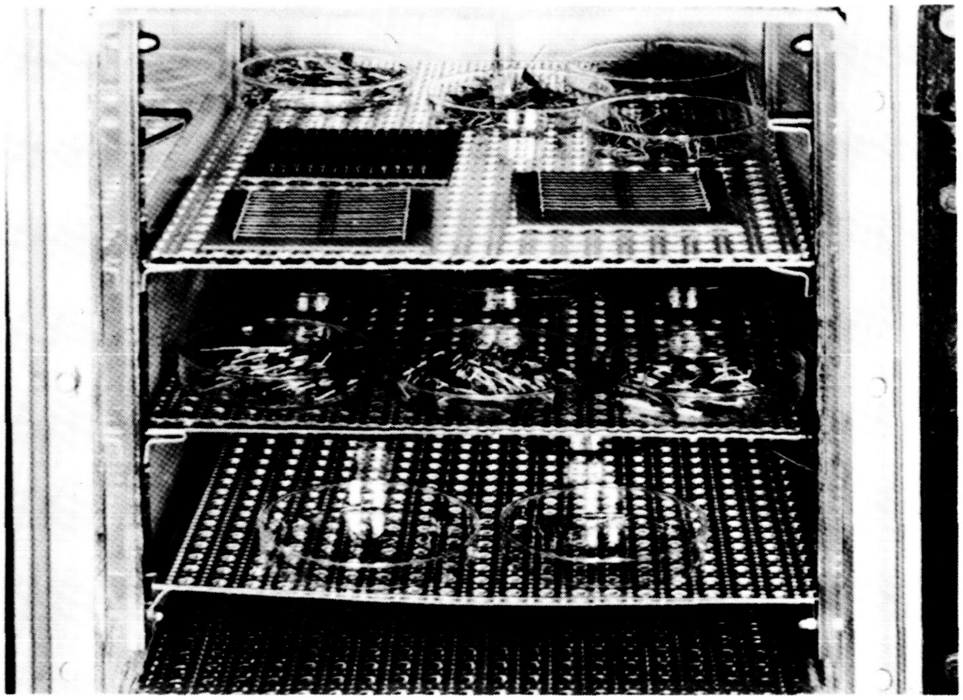


Figure 11. Inside of vacuum oven showing solder joint specimens ready for dry heat sterilization (R105259).

(Serial No. 261). Calibrated on 26 April 1965. This tensile tester was used for all ultimate strength tests on solder joints.

4.3.1.2 Hunter Spring Tensile Tester, Model TJH (Serial No. 190) equipped with a Hunter Mechanical Force Gage, Model D-50-T (Serial No. 365). Calibrated on 17 March 1965. This tensile tester was used for all ultimate strength tests on welded joints.

4.3.2 Procedures

All ultimate strength tests on solder joints were made by one technician using one tensile tester and all ultimate strength tests on welded joints were made by one technician using one tensile tester. Ultimate strength tests of both solder and weld joints were done at room temperature and were in accordance with Tables VI and VIII. A total of 1100 solder joints and 748 weld joints were tested for ultimate strength. Weld joints and solder joints of similar types were clamped as nearly alike as possible using the same tensile tester jaw attachments and were pulled at the same rate (i. e., identical air pressure).

Weld joints were all pulled in the torsion-shear mode as shown in Figure 12 and as required in JPL Spec. GPO-30995-GEN. Figure 13 is a close-up photograph of weld joint 1. 3 being pulled apart. These same jaw attachments were used for all weld joints.

Solder joints to connector cups and to bifurcated terminals were tested for ultimate strength in the direction of pull shown in the sketches on Figure 12. Special jaw attachments for the Hunter Tensile Tester made it possible to the grasp the many different joint configurations. Figure 14 shows the Hunter Tensile Tester with solder joint 1. 1. 1 (stranded conductor to CINCH connector cup) in position ready for ultimate strength testing. Figure 15 is a close-up of the jaws of the Tensile Tester showing solder joint 1. 3. 3 (Dumet wire to bifurcated terminal) in position for ultimate strength testing.

After ultimate strength testing of the solder and weld joints, the specimen halves were taped together and labeled accordingly. All strength values were recorded in pounds on separate Raw Data Sheets. These data sheets contained the strength values before and after thermal sterilization for each joint type. In addition each tested joint was examined for the failure mode and this was also recorded on the applicable data sheet. All labeled joints were placed in plastic bags and saved for later submittal to JPL.

4. 4 ELECTRICAL RESISTANCE TEST PROCEDURES

4. 4. 1 Equipment

4. 4. 1. 1 Hewlett Packard Model 425A D. C. MicroVolt - Ammeter, Serial No. 399-01060. Calibrated on 18 June 1965.

4. 4. 1. 2 Daystrom Model 931 D. C. Milliammeter, Serial No. 28020. Calibrated on 18 May 1965.

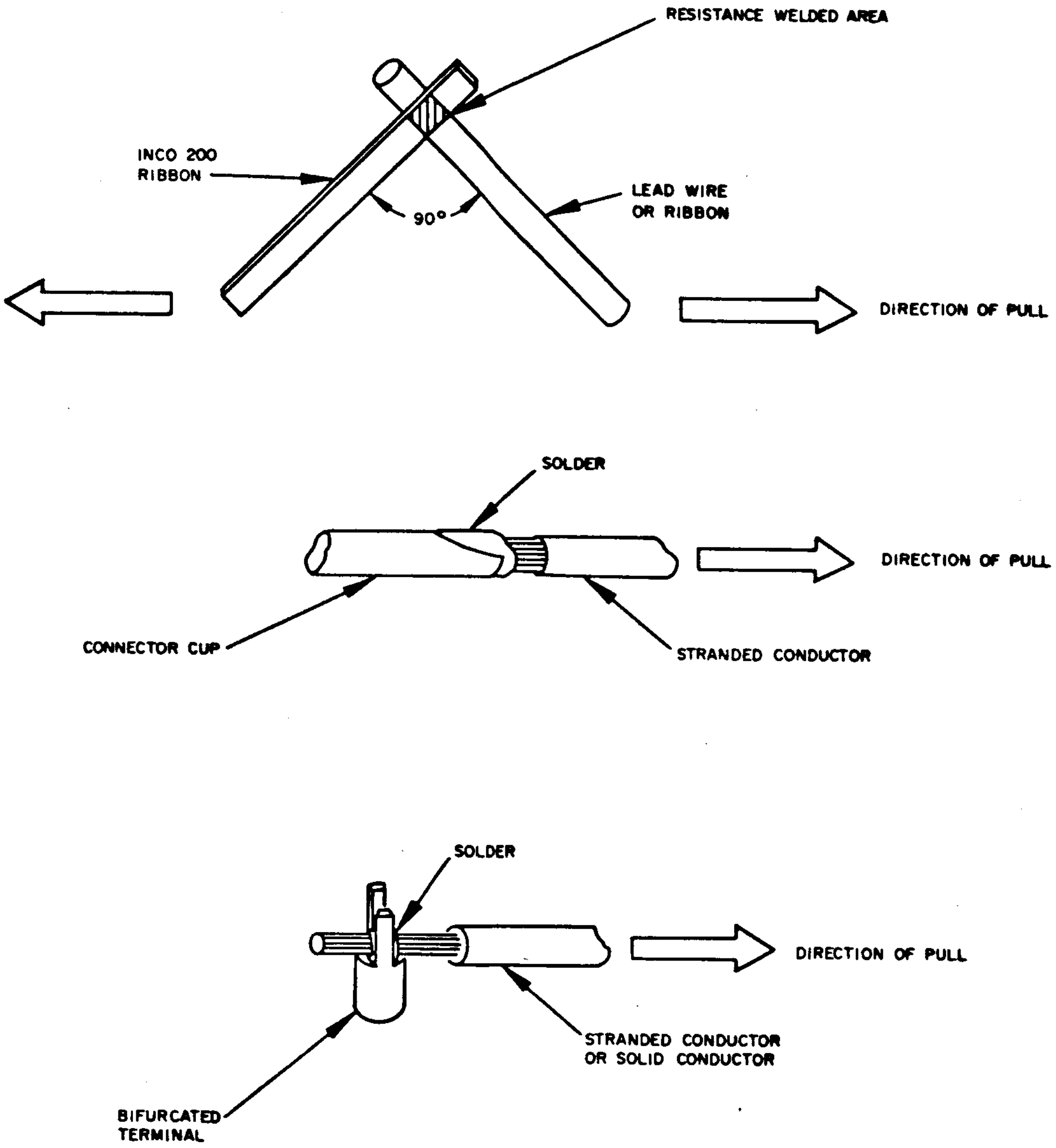


Figure 12. Ultimate strength tests on soldered and welded joints.

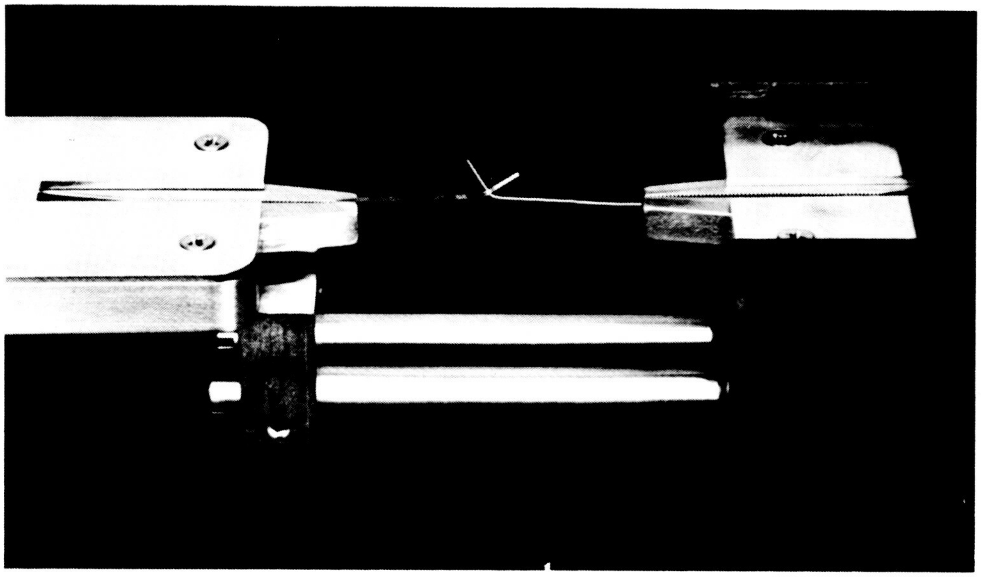


Figure 13. Weld joint being tested for ultimate strength in tensile tester (R105347).

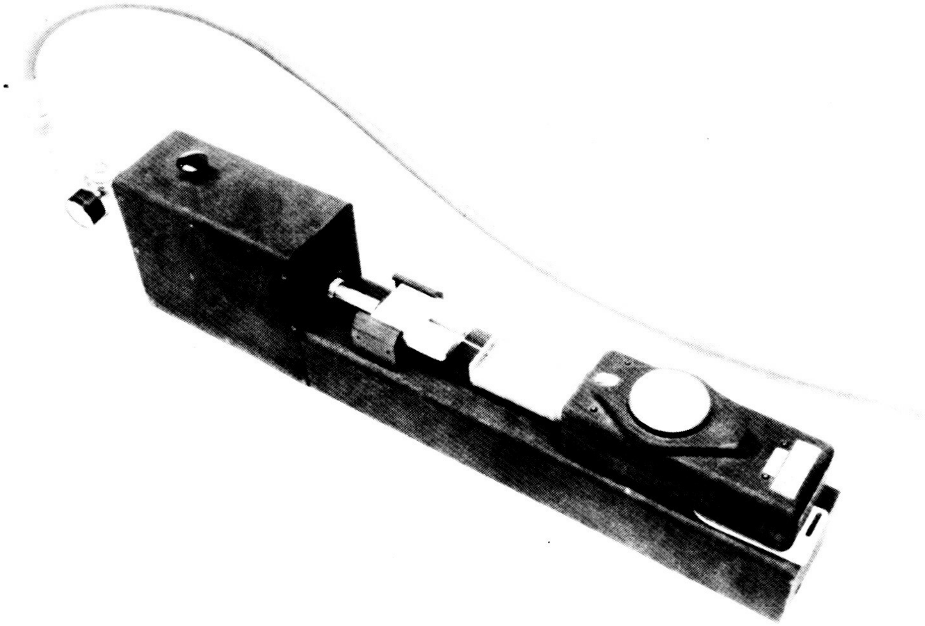


Figure 14. Hunter tensile tester with solder joint 1. 1. 1 in position for ultimate strength testing (R104840).

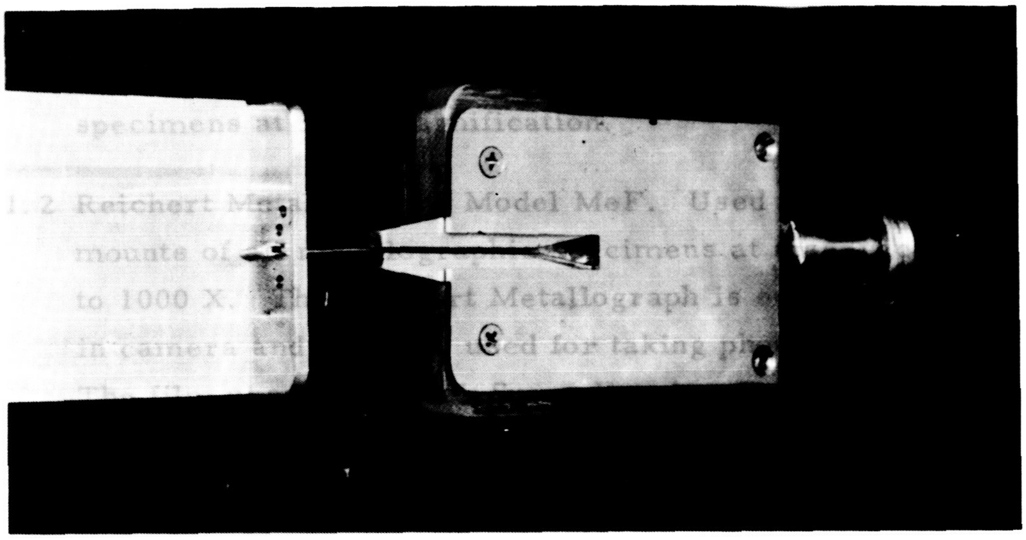


Figure 15. Solder joint 1.3.3 mounted in jaws of tensile tester ready for ultimate strength testing (R105341).

4.4.1.3 Kepco Model SM-36-5M Voltage Regulated D.C. Power Supply, Serial No. C-28791.

4.4.1.4 Ohmite No. 0528 Rheostat, Series A.

4.4.1.5 Various Hughes-designed test fixtures for clamping solder and weld joints during electrical resistance tests.

4.4.2 Procedures

Electrical resistance tests of soldered and welded joints before and after heating were done in accordance with the schedules shown in Tables VI and VIII. A total of 800 resistance tests on soldered joints and 560 resistance tests on welded joints were made. Solder joint 1.5 was not given the electrical resistance test since it must remain mounted in the printed wiring board during thermal sterilization without being separated from the body of the 1/4-watt resistor. For purposes of a final statistical analysis of the test results, each individual joint was separately identified and tested for electrical resistance before and after heating. All electrical resistance tests were made by one technician.

The solder joint configuration for resistance testing was per Figure 12. The welded joint configuration for resistance testing was per Type A on Figure 6.

Electrical resistance tests on solder joints were done using the upper test setup shown in Figure 16. Electrical resistance tests on welded joints will be done using the lower test setup shown in Figure 16. Special clips were used to insure that all joints of one type are tested in an identical manner. Precautions were taken to insure that contact resistance was minimized, so that only the resistance of the soldered or welded joint would be read. The test set-up shown in Figure 16 essentially consists of applying a current of 1 ampere dc through the joint and measuring the resultant voltage drop - which is equal to the joint resistance.

Figure 17 is a photograph of the electrical test set-up used for resistance measurements of both soldered and welded joints. All measurements were made after 1 minute of 1 ampere current flow. Readings were then recorded on the applicable Raw Data Sheets.

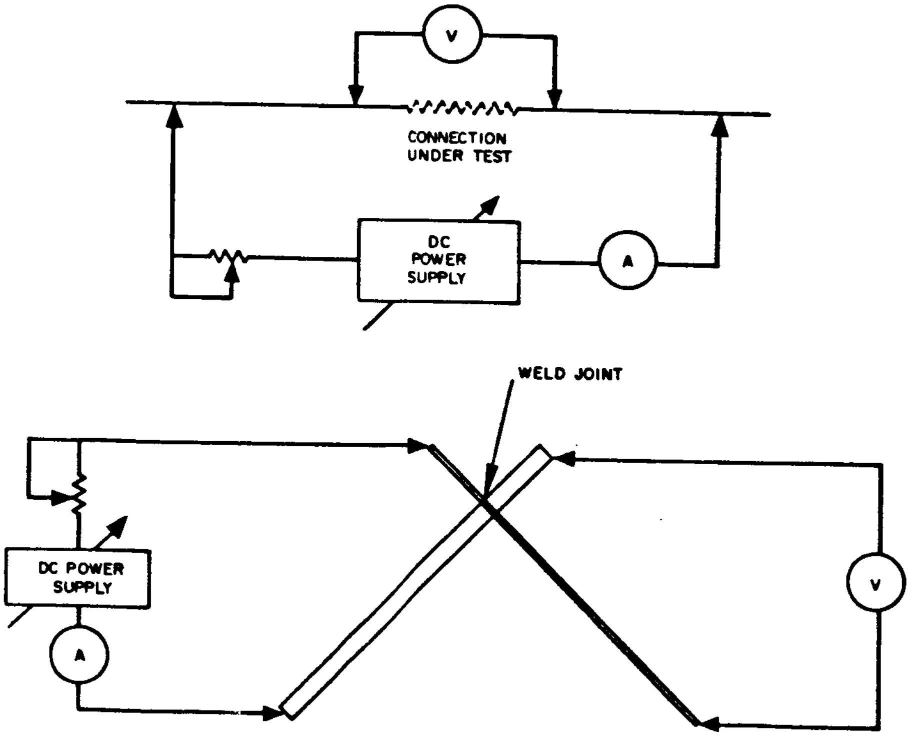


Figure 16. Test setup for electrical resistance (i. e., voltage drop) tests of soldered and welded joints.

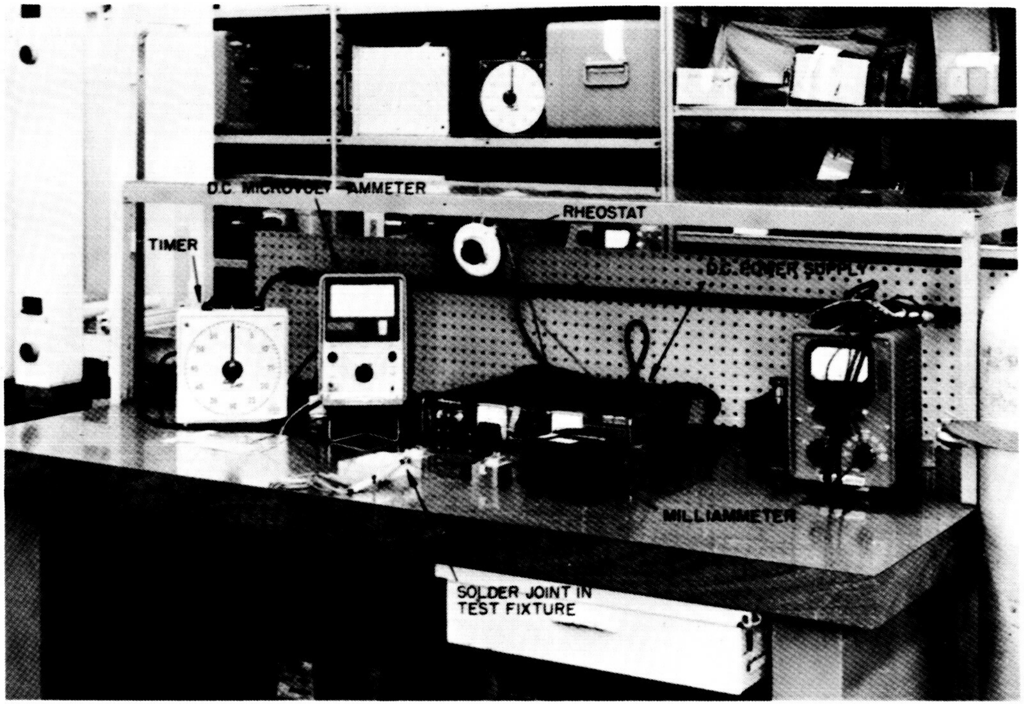


Figure 17. Test set-up for electrical resistance measurements of soldered and welded joints (R105342).

Figure 18 is a close-up photograph of a solder joint (gold plated Dumet wire to solder coated bifurcated terminal) being tested for electrical resistance. A 200 gram weight was used, where applicable, for uniform contact pressure.

Figure 19 is a close-up photograph of a different type of solder joint (stranded conductor to Bendix connector cup) being tested for electrical resistance. The voltage probes are the two inside contacts and the current probes are the two outside contacts.

Figure 20 is a close-up photograph of a weld joint (gold plated Kovar to Inco) being tested for electrical resistance.

4.5 STRESS-RUPTURE STRENGTH TEST PROCEDURES

4.5.1 Equipment

4.5.1.1 Conrad Temperature - Altitude Chamber, Model No. FH 8-3-3, Serial No. 7268. Calibrated on 14 May 1965. This chamber is equipped with a Honeywell Electronik temperature recorder which was last calibrated on 14 July 1965.

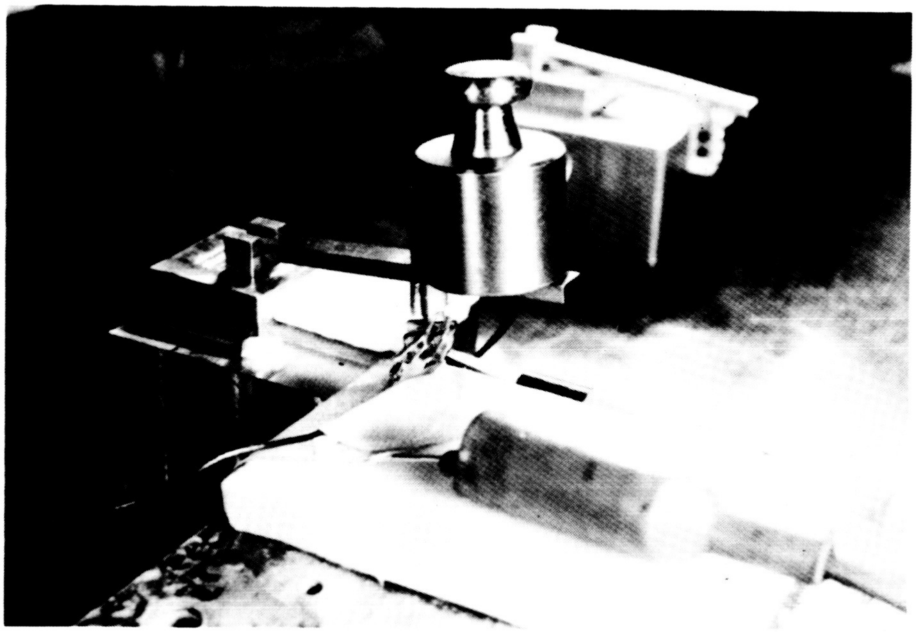


Figure 18. Solder joint (wire to bifurcated terminal) in test fixture for electrical resistance measurement (R105343).

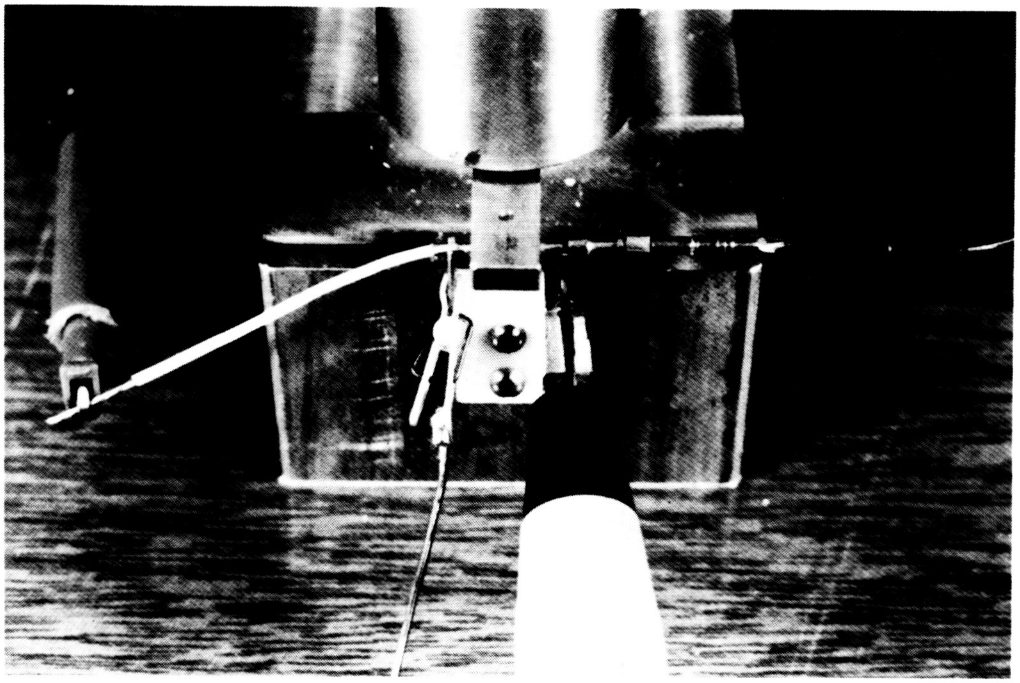


Figure 19. Solder joint (stranded conductor to connector cup) in test fixture for electrical resistance measurement (R105344).

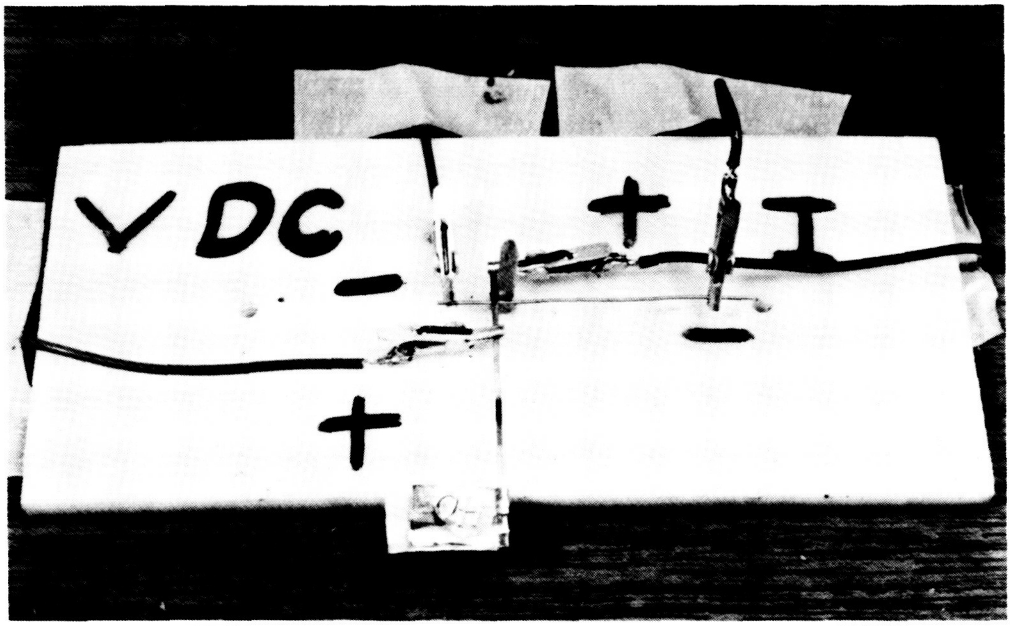


Figure 20. Weld joint in test fixture for electrical resistance measurement (R105345).

4.5.1.2 Hughes Aircraft Company specially designed stress-rupture test fixtures. Two test fixtures were constructed. Each test fixture consisted of the following:

a) One specimen rack capable of holding 9 solder joints.
b) Nine Unimax Precision Microswitches, Type 20GMXW-1, SPDT, 15 amps at 125 vac.
c) Nine buckets each loaded with shot to provide dead weights.
d) Nine panel-mounted Aero Instruments Type 61134-1 Running Time Meters (120 v, 60 ~) each with a neon indicator light.

4.5.2 Procedures

Stress-rupture strength was determined under conditions of actual heat sterilization (i.e., 145°C for 108 hours in a nitrogen atmosphere) and also at room temperature for 108 hours. Stress-rupture tests were performed on solder joints 1.1.1 and 1.1.2 (stranded conductor to CINCH and BENDIX connector cups) in accordance with the schedule given in Tables VI and VIII. A total of 144 solder joints (72 each of joints 1.1.1 and 1.1.2) were tested for stress-rupture strength. In addition two small ink marks were made on each solder joint prior to stress-rupture loading. Any change in axial position of these marks during or after the 108 hours of testing would show evidence of creep in the solder joint.

Testing was done by suspending weights from joint specimens within the test chamber so they will be under constant tensile load. The time to rupture (at a particular stress loading) was recorded. Figure 21 is a diagram of the stress-rupture test setup for a single soldered specimen. When the joint fails, the microswitch will close. Closing of the microswitch stops the time meter and turns off the neon light. The weights were selected so as to cause those joints of questionable strength to fail within the 108 hours of testing, provided that their stress-rupture strength is degraded by thermal sterilization. Since 9 joints were tested simultaneously, the initial selection of weight

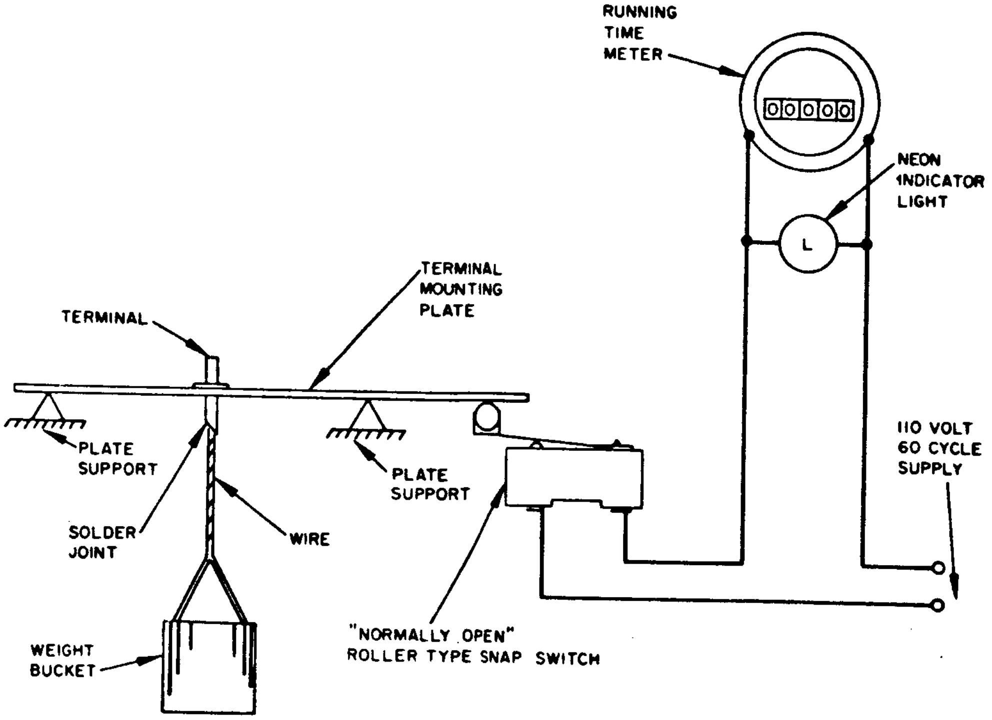


Figure 21. Diagram of stress-rupture test setup.

loadings was from 10% to 90% of the ultimate strength of the solder joints being tested--approximately 15 pounds. After the 108 hour testing period. the joint was examined for the failure mode and for any indication of creep. Each joint was then labeled and bagged. The time meter readings were recorded on the applicable Raw Data Sheets.

Stress-rupture tests at room temperature conditions for both the Cinch and Bendix connector cup solder joints were connected using weights ranging from 10% to 90% of the ultimate strength of the joints. However during stress-rupture testing under sterilization time and temperature conditions, all of the Cinch connector cup solder joints failed even at the 10% loading. All failures occurred within 5.2 hours after the start of testing. The majority of joints failed within 1 hour after the 145°C temperature was reached, whereas identical joints would last the full 108 hours at 25°C.

New stress loadings were therefore adopted for the remaining stress-rupture tests at sterilization time and temperature conditions for the Bendix connector cup solder joints. These new loadings are shown in Table IX and were designed to insure that some joints would fail and some joints would not fail after the 108 hours at 145°C in a nitrogen atmosphere. The ultimate strength of these joints is approximately 15 pounds.

Table IX. Old and new stress-rupture test loadings.

Specimen Number	Old Loads (lbs)	% Ultimate Strength	New Loads (lbs)	% Ultimate Strength	Alternate New Loads (lbs)	% Ultimate Strength
1	1.625	10.7	0.15	1	0.30	2
2	3.125	20.8	0.30	2	0.45	3
3	4.625	30.7	0.45	3	0.60	4
4	6.125	40.7	0.60	4	0.75	5
5	7.625	50.7	0.75	5	1.125	7.5
6	9.125	60.6	1.50	10	1.50	10
7	10.500	70.0	2.25	15	2.25	15
8	12.063	80.4	3.00	20	3.00	20
9	13.563	90.3	3.75	25	3.75	25

Figure 22 is a photograph of the stress-rupture test set-up under room temperature conditions. Nine Cinch connector cup solder joints are shown under test. The front three joints have already failed as indicated by the weight buckets having fallen to the floor.

Figure 23 is a close-up photograph showing a Bendix connector cup solder joint suspended from the specimen rack. The metal cross-piece (not the joint itself) depresses the roller on the snap switch.

Figure 24 shows 18 Bendix connector cup solder joints (1. 1. 2) in the Temperature-Altitude Chamber ready for stress-rupture testing under conditions of heat sterilization time and temperature. Note the two panels of running time meters outside the chamber.

4. 6 ELECTRICAL TEST DURING VIBRATION TEST PROCEDURES

4. 6. 1 Equipment

4. 6. 1. 1 Ling Electronics Vertical Vibration System, Model C-P 3/4, Serial No. 45. Calibrated on 16 Aug. 1965.

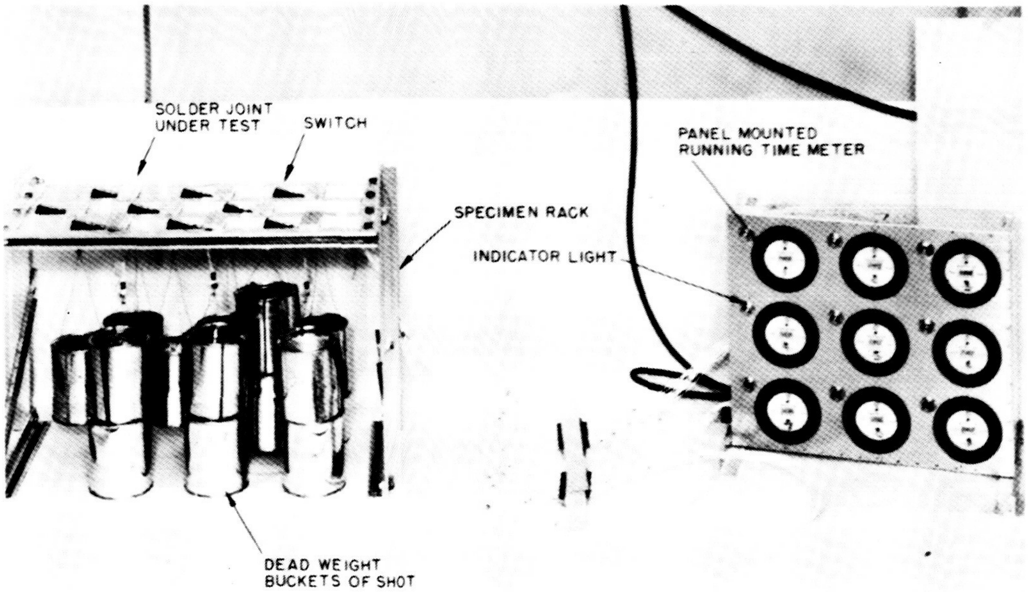


Figure 22. Stress-rupture test set-up under room temperature conditions (R105339).

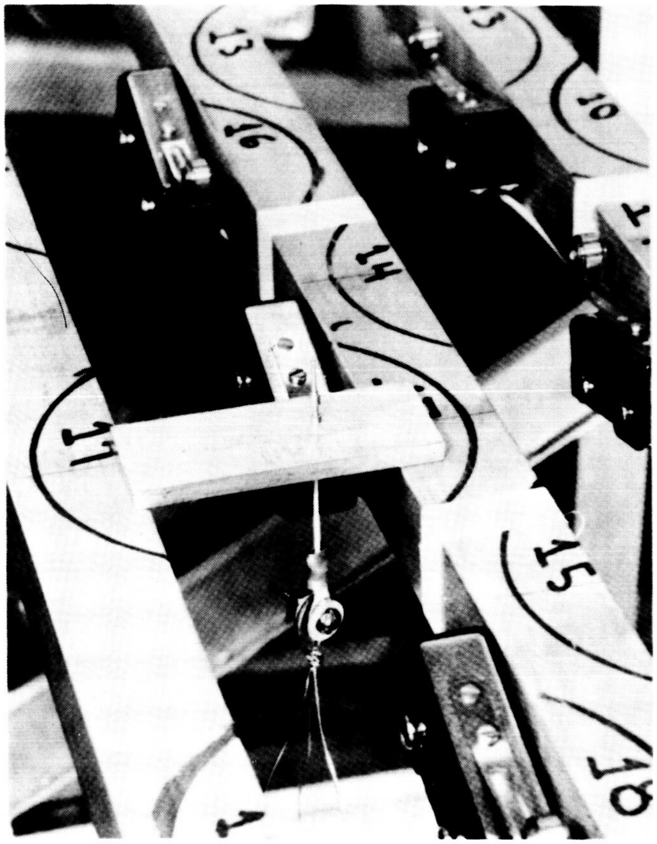


Figure 23. Close-up photograph showing a Bendix contractor cup solder joint suspended from the specimen rack for stress-rupture testing (R105340).

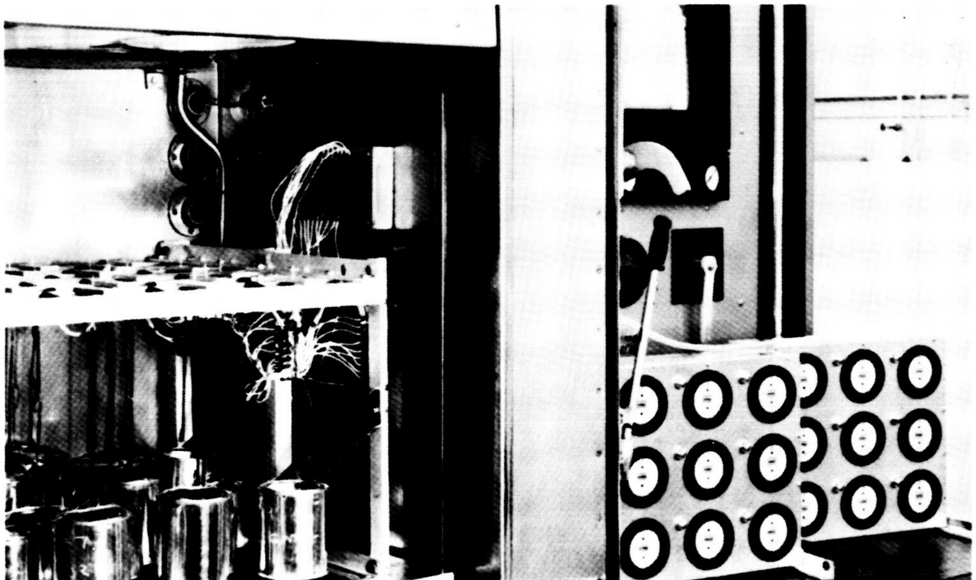


Figure 24. Stress-rupture test set-up for 18 solder joints under conditions of heat sterilization time and temperature (R105736).

4.6.1.2 Endevco Accelerometer, Model 2211, Serial No. R5641. Calibrated on 14 May 1965.

4.6.1.3 Hewlett Packard Wave Analyzer, Model 302A, Serial No. 149-00127. Calibrated on 28 May 1965.

4.6.1.4 Hewlett Packard Electronic Counter, Model 522B, Serial No. 1897. Calibrated on 21 June 1965.

4.6.1.5 Hewlett Packard Audio Signal Generator, Model 205AB, Serial No. 6965. Calibrated on 16 June 1965.

4.6.1.6 Hewlett Packard Vacuum Tube Voltmeter, Model 400 H, Serial No. 1197. Calibrated on 2 June 1965.

4.6.1.7 Hewlett Packard A. C. Current Probe, Model 456A, Serial No. 103-0939. Calibrated on 22 May 1965.

4.6.1.8 Chadwick-Helmuth Sweep Synchronizer, Model 201, Serial No. 103AR.

4.6.1.9 Chadwick-Helmuth Strobex, Model 121R.

4.6.1.10 Dynac Sweep Oscillator, Model DY-2200, Serial No. 167. Calibrated on 6 August 1965.

4.6.2 Procedures

The purpose of this test is to detect electrical variations in joint resistance during vibration and to compare these variations with other specimens. These electrical variations in joint resistance are assumed to be directly related to joint deterioration.

Electrical tests during vibration were done on all solder and weld joint types per the schedules outlined in Tables VI and VIII. A total of 220 solder joints and 188 weld joints were electrically tested during vibration before and after thermal sterilization. Weld joint specimens for this particular test were Type B as shown in Figure 6.

The electrical test setup as originally proposed (see Figure 25) was found unsatisfactory for joints involving magnetic materials. The lines of flux in the magnetic field created by the shake table would be cut by the vibrating joint generating a false display on the oscilloscope. This variation in scope output, although only in the microvolt region, was of a magnitude approximately equal to that of any expected joint variation and therefore it was impossible to tell with any certainty whether the joint or the noise was responsible for the change in waveform. Adequate magnetic shielding of the joint was not practical due to the heavy flux density. A new electrical test setup was developed which proved satisfactory. This setup is shown in Figure 26.

In the new set-up the d-c current source is replaced by an a-c signal and a tuned microvoltmeter is used as a detector. The a-c signal was set at 5 kilocycles and the microvoltmeter was tuned to maximum sensitivity at that frequency. This technique shows considerable improvement over the previous technique and will detect a change in joint resistance (i. e., voltage drop or rise) of less than 5%. A 5 KC

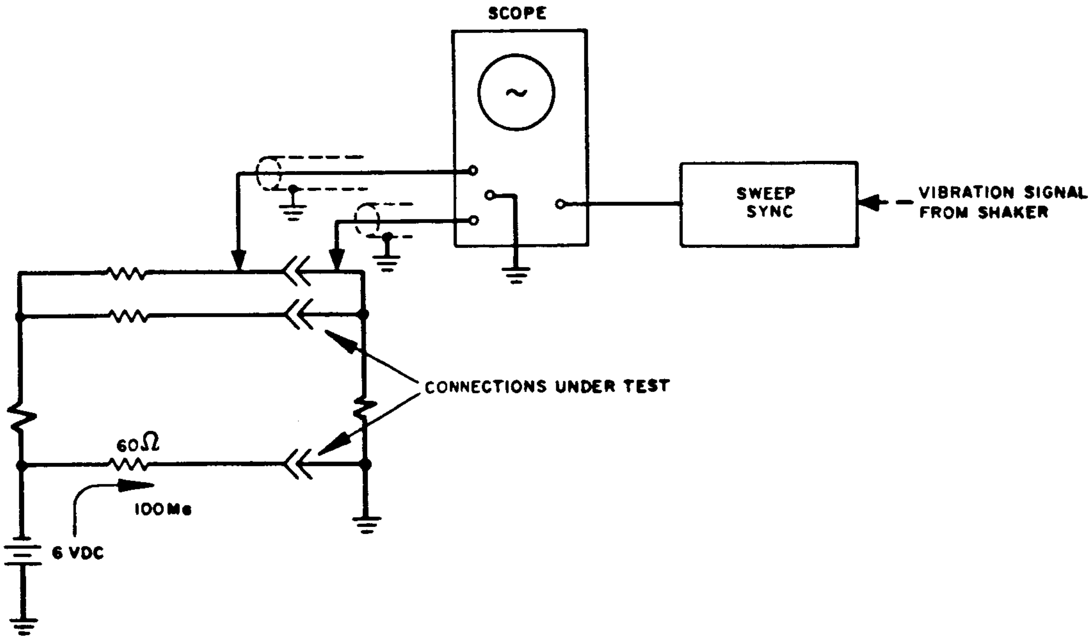


Figure 25. Old electrical test setup for electrical measurements of soldered and welded joints during vibration.

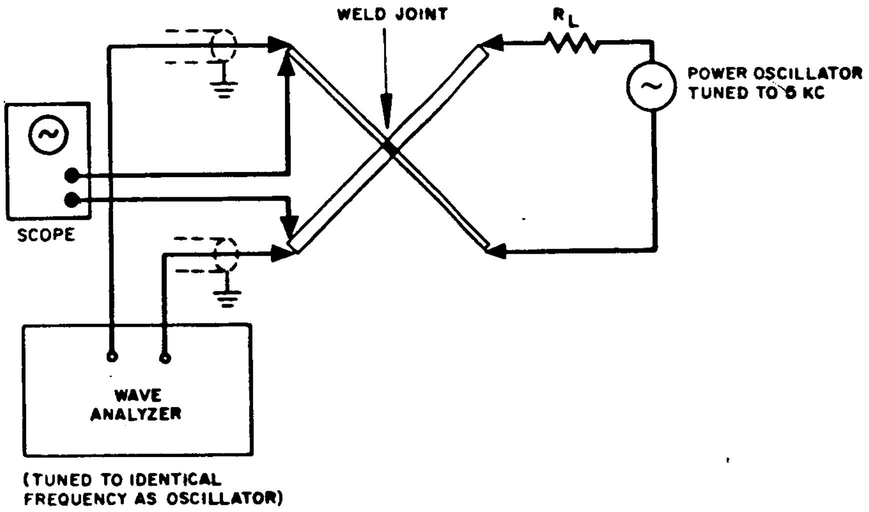


Figure 26. New electrical test setup for electrical measurements of soldered and welded joints during vibration.

signal (ac current as opposed to dc current) is used since this is above the shaker frequency and will eliminate any harmonics. This technique will reject any signal except that through the joint under test. Both good joints and bad joints (loose connections) were tested with this technique to insure that the measured signal was due only to the change in joint resistance. At a current input of only 15 milliamperes, it was possible to get a voltage change of 250 microvolts for bad joints. Good joints showed no change in resistance.

Vibration testing was done by running the joint under test from 60 to 2000 cycles per second at a 15-G acceleration level and noting the resonant frequency. The joint was then allowed to dwell at that resonant frequency for 5 to 10 minutes and any change in joint resistance (i.e., microvolt signal output to the wave analyzer) was noted at resonance. The current probe was used to monitor the current through the joint and the electronic counter was used to measure the resonant frequency. An a-c current input of 100 milliamperes was used for all weld joints and solder joints. All joints of one type were identically mounted on the shake table and were measured at the identical resonant frequency. All joints were mounted taut without slack to prevent different resonant frequencies for joints of the same type. Using a constant table displacement, weld joints at resonance exhibited a maximum amplitude of about 0.1155 inch. During vibration testing physical resonance was observed by watching the joint displacement and electrical resonance was observed by monitoring the scope display.

Figure 27 is a photograph showing one weld joint and three solder joints of different types mounted on the vibration platform. This photograph was taken to illustrate the different methods of mounting used for each type of weld joint and solder joint. During actual vibration testing, either four or two joints of one type in series were vibrated together. Weld joints and solder joints or joints of different types were not mixed together.

Figure 28 is a close-up photograph of these same four joints. The vibration plane was perpendicular to the plane of the photograph. Before vibration the series circuit of either four or two joints was measured for electrical resistance. The current input, resonant frequency, series joint resistance, and any change in resistance during vibration were all recorded on the applicable Raw Data Sheets.

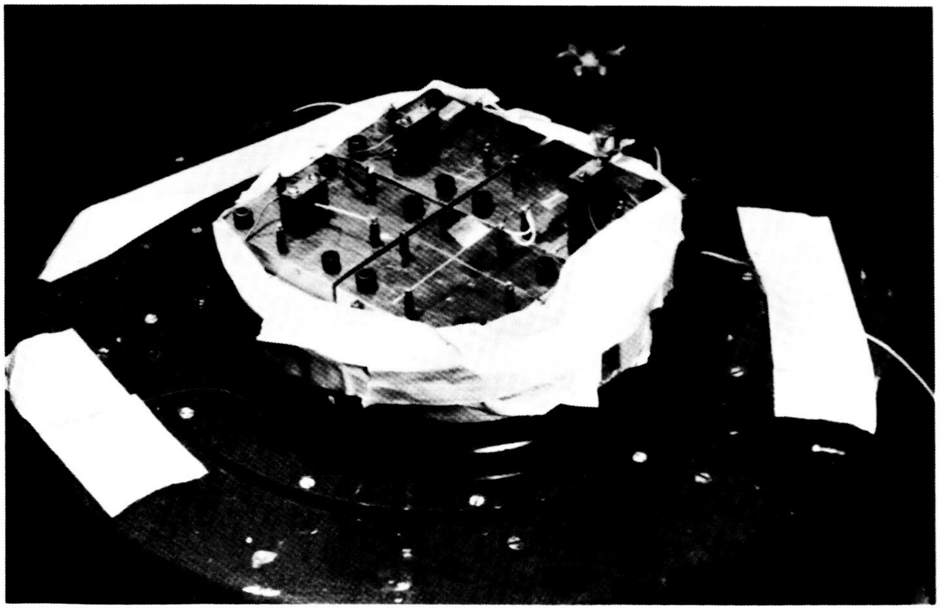


Figure 27. Weld joint and solder joint specimens mounted on vibration table in preparation for the electrical tests during vibration (R105473).

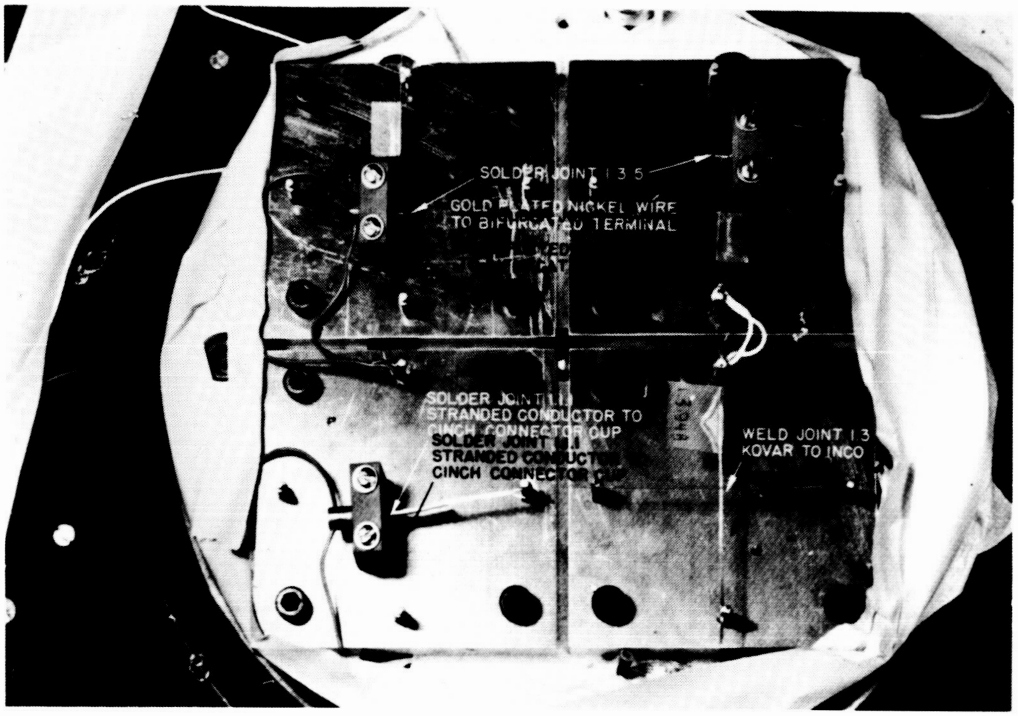


Figure 28. One weld joint and three solder joints mounted on vibration table (R105474).

4.7 METALLURGICAL EXAMINATION

4.7.1 Equipment

4.7.1.1 Zeiss Inverted Metallurgical Microscope, Model No. B-5000. Used for examining unetched mounts of all metallographic specimens at 500X magnification.

4.7.1.2 Reichert Metallograph, Model MeF. Used for examining etched mounts of all metallographic specimens at magnifications up to 1000 X. The Reichert Metallograph is equipped with a built-in camera and was also used for taking photomicrographs. The film used was Kodak Super Panchro Press.

4.7.1.3 Buehler Model 67-1509 Vibromet Polisher.

4.7.1.4 Buehler No. 1330AB Mounting Press.

4.7.1.5 Precision Scientific "Precisionite" mounting powder for all hot mounts.

4.7.1.6 Fulton Metallurgical "Quickmount" mounting powder for all cold mounts.

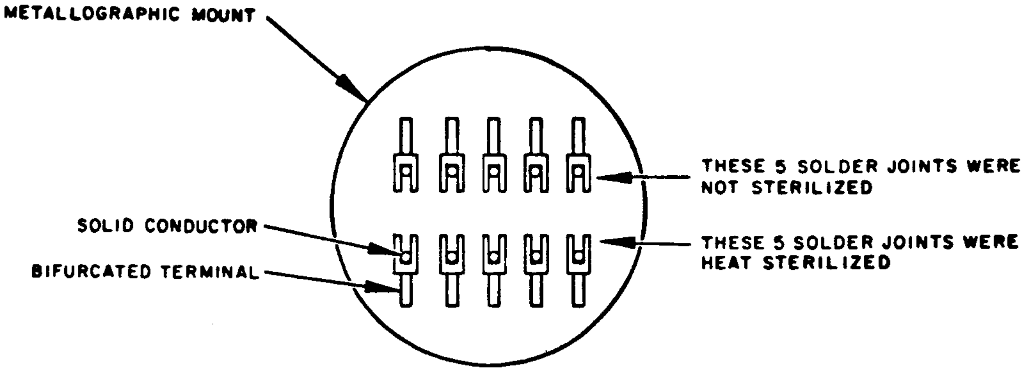
4.7.2 Procedures

Metallographic examination was done on all joint types as outlined in Tables VI and VIII. A total of 110 solder joints and 82 weld joints were metallographically mounted, sectioned and examined. This total does not include the additional metallographic mounts which were made for material incoming inspection and for specimen standardization. Photomicrographs were made of 26 weld joints at a magnification of 150X. The total of 26 weld joints included:

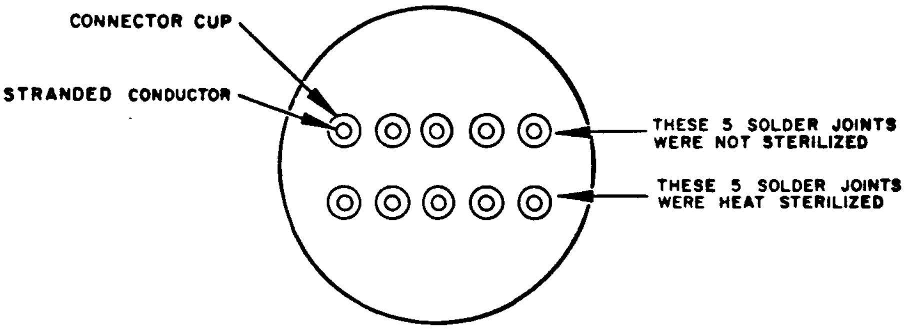
a) One each of 7 weld joint types before heat sterilization.
b) One each of 7 weld joint types, after heat sterilization.
c) One each of 6 JPL weld joint types before heat sterilization.
d) One each of 6 JPL weld joint types after heat sterilization.

Photomicrographs were made of 22 solder joints (2 each of 11 solder joint types - one before and one after heat sterilization). Photomicrographs of stranded conductors soldered to connector cups (joint types 1.1.1 and 1.1.2) were taken at 60X. Photomicrographs of solid wire conductors soldered to bifurcated terminals were taken at 100X. All solder joints were cold mounted in Quickmount and all weld joints (except joint type 1.6 - solder coated copper to Inco) were hot mounted in Precisionite. Weld joint 1.6 was cold mounted in Quickmount.

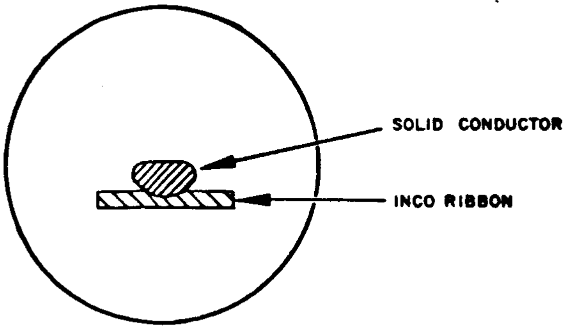
Metallographic mounts of solder joints (bifurcated terminal and connector cup types) were prepared by multiple mounting, as shown in Figure 29. Five joints which were not submitted to thermal sterilization were mounted directly above and adjacent to five joints which had been thermally sterilized. This enabled a quick visual comparison between specimens without switching mounts. Weld joints were individually mounted in separate mounts as shown in Figure 29. This was necessary since it is very difficult to polish into the exact center of two weld joints on the same mount.



SOLID CONDUCTORS TO BIFURCATED TERMINALS



STRANDED CONDUCTORS TO CONNECTOR CUPS



WELD JOINT

Figure 29. Metallographic mounting of solder joints and weld joints.

All weld joints and solder joint metallographic specimens were examined for any degradation which could be attributed to the thermal sterilization cycle.

The various etchants used to define the metallurgical structure of the solder and weld joints are listed at the bottom of each photomicrograph.

4.8 ELECTRON PROBE MICROANALYSIS

4.8.1 Equipment

4.8.1.1 Applied Research Laboratories Model 21000 Electron Microprobe X-Ray Analyzer, Serial No. EMX-39.

4.8.2 Procedures

Electron probe microanalysis was subcontracted to the Materials Testing Laboratories, Division of Magnaflux Corp., Los Angeles, California. A total of 8 solder joints and 4 weld joints were analyzed as shown in Table X.

The specimens were primarily examined for any signs of gold diffusion into the copper wire, brass terminal, or Inco (nickel) ribbon. Figure 30 is a photograph of the ARL Electron Microprobe X-Ray Analyzer.

All joints were mounted in standard 1" diameter metallographic mounts and final polishing was accomplished with diamond abrasive. All joints were sectioned in such manner as to expose the cross section of the copper wire.

The Applied Research Laboratories Microprobe was used for these analyses. Monochromatic crystal detectors were peaked out on suitable portions of the specimens, using the following radiation lines.

Copper K Alpha	1.542 Angstroms
Nickel K Alpha (2nd Order)	3.318 Angstroms
Gold L Alpha	1.277 Angstroms
Silver L Alpha	4.154 Angstroms

Table X. Solder and weld joint specimens submitted to electron probe microanalysis.

Specimen Number	Sterilized	Type of Joint	Joint Description
1.4.111 1.4.112 1.4.113 1.4.114	No No Yes Yes	Solder Solder Solder Solder	Gold Plated (approx. 88 microinches) Copper Wire (0.020" dia.) to Gold Plated Bifurcated Terminal. Terminal was 1/2 Hard Brass with Copper Strike, Silver Strike, Silver Plate (0.0002" - 0.0003") and gold Plate (70 microinches)
1.3.1.111 1.3.1.112 1.3.1.113 1.3.1.114	No No Yes Yes	Solder Solder Solder Solder	Gold Plated (88 microinches) Copper Wire (0.20" dia.) to Solder Coated Bifurcated Terminal. Terminal was 1/2 Hard Brass with Solder Coating (160-500 microinches).
1.5.111A 1.5.112A 1.5.113A 1.5.114A	No No Yes Yes	Weld Weld Weld Weld	Gold Plated (88 microinches) Copper Wire (0.029" dia.) to Nickel (Inco 200) Ribbon (0.010" x 0.031")

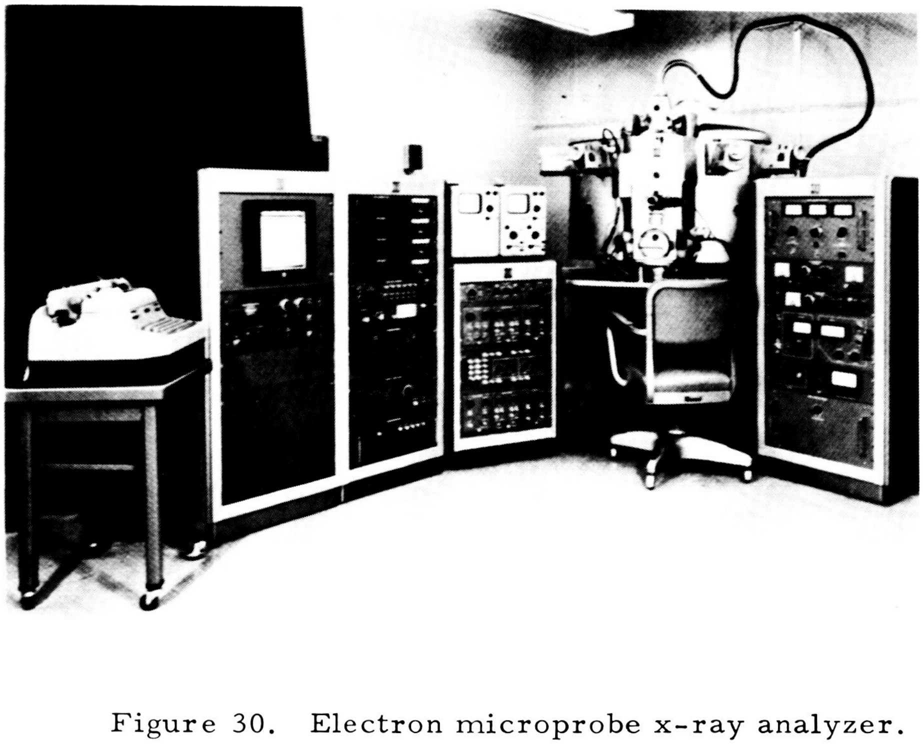


Figure 30. Electron microprobe x-ray analyzer.

The specimen in each case was set so that the beam travel would be in a direction perpendicular to the joint interface and as close as possible to its centerline. Traversing was in all cases by one micron increments. At each step the elements in question were read out after a fixed time integration (i. e. simultaneous counting into each recording channel). The attached charts are identified as to the elements run. A record of sample current was also made, this figure being inversely related to average atomic number. The units in all cases are arbitrary.

The following conditions were used for the analyses:

Exciting voltage	20 Kilovolts
Sample Current	0. 05 Microamperes on copper
Integration Time	30 seconds
Beam Diameter	0. 5 Micron (Approximately)
Diameter of Excited Area	2. 0 Microns (Approximately)

5. TEST RESULTS

5.1 ULTIMATE STRENGTH TEST RESULTS

5.1.1 Solder Joints

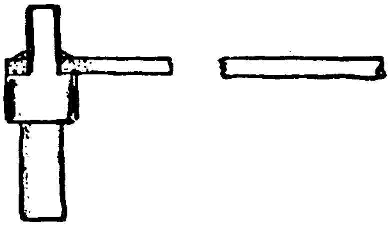
Pages 1 through 6 in Part II, Attachment 2, of this final report contain the Raw Data Sheets for the ultimate strength tests on the eleven types of solder joints. For each type of joint, numbers 1-40 were tested before heating (control specimens) and numbers 41-80 were tested after thermal sterilization. All ultimate strength values are given in pounds. After each strength value the mode of failure was noted:

W = Wire failure
J = Joint failure

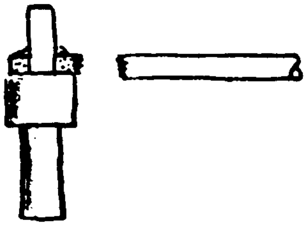
Wire and joint failures for bifurcated terminals and connector cups are illustrated in the sketches shown in Figure 31. Wire failures for bifurcated terminals usually occurred from 1/4" to 1/2" away from the solder joint. Connector cup solder joints (1. 1. 1 and 1. 1.2) all failed at the wire. Certain bifurcated terminal solder joints (i.e., 1.3.4, 1.3.5, and 1.5) were predominantly joint failures and other bifurcated terminal solder joints (i.e., 1.3.6) were all joint failures. Joint failures (see Figure 31) were of two types: 1) the wire broke right at the joint; and 2) the wire was pulled out of the bifurcated terminal without breaking.

Table XI presents a statistical analysis of variance for the ultimate strength test data on solder joints. A single factor analysis of variance was required since this was a destructive test. In view of the nature of the test data the significance level was determined using both the F test and Chi-Square test for significance. For example, a significance level of 0.01 means that there is only 1 chance in 100 that the analysis was wrong and a significance level of 0.001 means that there is only 1 chance in 1000 that the analysis was wrong. The 95% confidence intervals of means was calculated for both the control specimens and the sterilized. Taking the first solder joint in Table XI (1. 1. 1

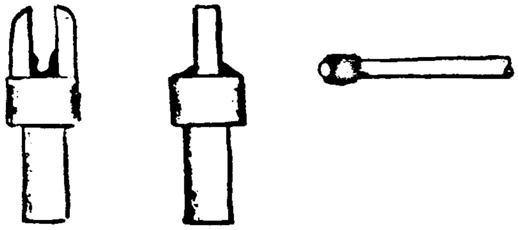
CONNECTOR CUP WIRE FAILURE



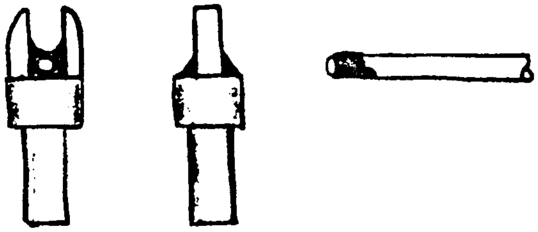
BIFURCATED TERMINAL WIRE FAILURE



BIFURCATED TERMINAL JOINT FAILURE



BIFURCATED TERMINAL JOINT FAILURE



BIFURCATED TERMINAL JOINT FAILURE

Figure 31. Failure modes for solder joints.

Table XI. Analysis of variance - ultimate strengths of soldered joints.

Type of Joint	Effect of Thermal Sterilization	Significance Level	95% Confidence Intervals of Means	
			Control	Sterilized
1.1.1 Stranded conductor to Cinch cup	None	---	14.6 - 14.7 lbs	14.5 - 14.6 lbs
1.1.2 Stranded conductor to Bendix cup	Decrease	0.01 (Chi-square)	14.6 - 14.7	14.5 - 14.5 (round-off limits)
1.2 Stranded conductor to Solder coated Bifurcated Terminal	Decrease	0.001 (Chi-square)	14.8 - 15.1	14.4 - 14.9
1.3.1 Gold plated Copper to Solder coated Bifurcated Terminal	Increase	0.001 (F-test)	10.4 - 10.6	10.7 - 10.9
1.3.2 Solder coated Copper to Solder coated Bifurcated Terminal	Decrease	0.01 (Chi-square)	11.2 - 11.7	10.8 - 11.2
1.3.3 Gold plated Dumet to Solder coated Bifurcated Terminal	None	---	23.2 - 25.0	21.9 - 23.7
1.3.4 Gold plated Kovar to Solder coated Bifurcated Terminal	None	---	20.9 - 22.2	20.5 - 21.8
1.3.5 Gold plated Nickel to Solder coated Bifurcated Terminal	None	---	25.8 - 28.7	27.2 - 30.1
1.3.6 Bare Nickel to Solder coated Bifurcated Terminal	None	---	27.3 - 30.4	26.8 - 29.8
1.4 Gold plated Copper to Gold plated Bifurcated Terminal	Decrease	0.001 (Chi-square)	11.5 - 12.0	11.0 - 11.2
1.5 1/4 Watt Resistor to Solder coated Bifurcated Terminal	None	---	19.4 - 21.8	18.4 - 20.1

Stranded conductor to Cinch cup), the control specimens have a lower limit of 14.6 pounds and an upper limit of 14.7 pounds. We are 95% confident that the arithmetic mean lies within this interval. The same reasoning applies to all specimens. Four of the solder joint types (i.e., 1.1.2, 1.2, 1.3.2, and 1.4) showed a decrease in ultimate strength due to sterilization and one type (1.3.1) showed an increase in ultimate strength. Thermal sterilization had no significant effect on any of the other joints or, putting it another way, any change in strength values before or after sterilization was due to chance or random error.

Figure 32 is a series of bar diagrams of the ultimate strength values for soldered joints. This is simply a different way of presenting the statistical values of Table XI. The control and sterilized specimen strength values are plotted side-by-side with the shaded area at the top of each bar graph being the 95% confidence intervals of means. When the shaded areas overlap each other, the conclusion is that there is no effect on strength due to thermal sterilization. It is also easy to see which of the solder joint types are strongest. Joint types 1.3.5 and 1.3.6 have higher ultimate strengths than any of the others, both being nickel wire.

Taking as an example joint type 1.1.2 which shows a decrease in ultimate strength after sterilization, this decrease (although significant statistically) is actually only a decrease of 1%. A 1% change in the strength of a solder joint is, for all practical purposes, relatively unimportant in view of the many other variables involved.

5.1.2 Welded Joints

Pages 7 through 10 in Part II, Attachment 2, of this final report contain the Raw Data Sheets for the ultimate strength tests on the seven types of weld joints. For each type of joint, numbers 1-40 were tested before heating and numbers 41-80 were tested after thermal sterilization. All ultimate strength values are given in pounds. At the right of each strength value is noted the mode of failure:

W2 = Wire broke adjacent to weld
R2 = Ribbon broke adjacent to weld
WS = Weld separation

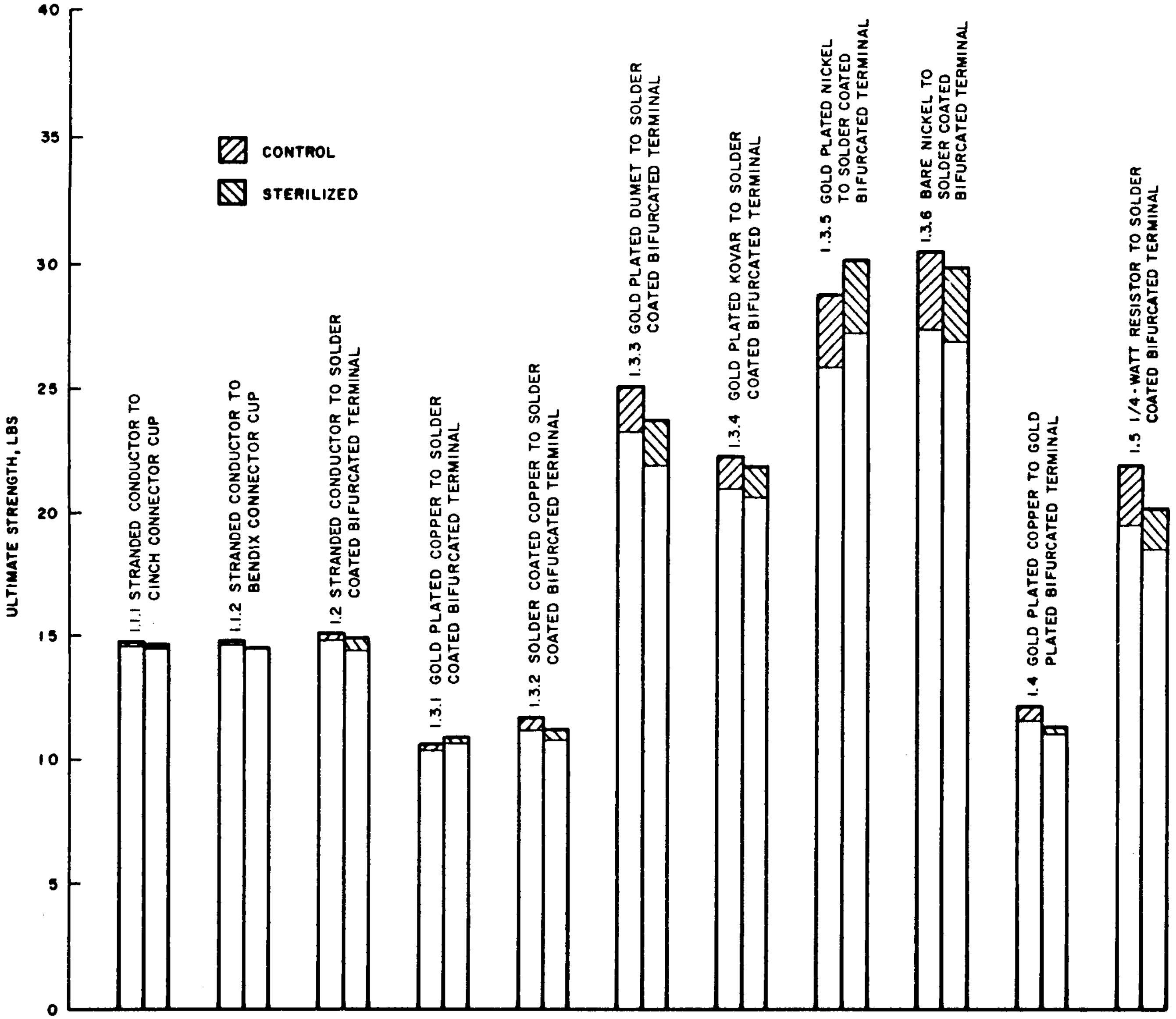


Figure 32. Bar diagrams of ultimate strengths of soldered joints. 95 percent confidence intervals of means are shown shaded.

Figure 33 contains sketches illustrating these three failure modes for the weld joints. Certain of the weld joints (i.e., 1.1, 1.2, 1.5) failed predominantly in the W2 mode, while other types of weld joints failed predominantly in the R2 mode (i.e., 1.3, 1.4, 2.0) or the WS mode (i.e., 1.6).

Table XII presents a statistical analysis of variance for the ultimate strengths of welded joints. One weld joint type (1.5 gold plated copper to Inco) showed a significant decrease in strength after sterilization. The "gold plated Kovar foil to itself" weld joint showed a slight effect due to sterilization primarily due to the comparative increase in standard deviation. Although joint type 1.5 exhibited an effect with a significance level of 0.001 by the F test, the actual change in ultimate strength was only 5%. This change is attributed to a shift in the distribution of the test result data, as illustrated by the histogram shown in Figure 34.

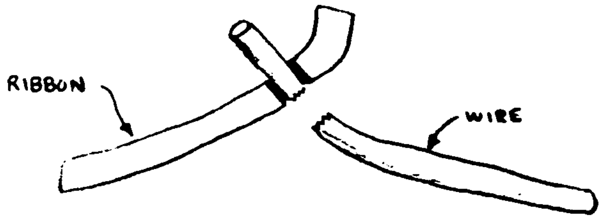
Figure 35 is a series of bar diagrams for the ultimate strengths of weld joint presenting, in a more graphical manner, the statistical data given in Table XII.

5.2 ELECTRICAL RESISTANCE TEST RESULTS

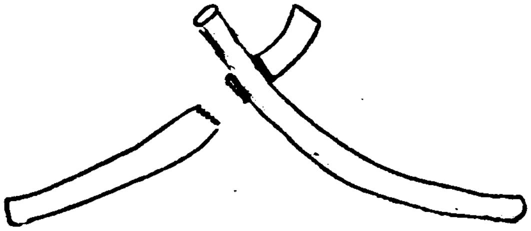
5.2.1 Solder Joints

Pages 11 through 15 in Part II, Attachment 2, of this final report contain the Raw Data Sheets for the electrical resistance tests on ten types of soldered joints. For each joint type, specimens 41-80 were tested before thermal sterilization and the identical specimens were again tested after thermal sterilization. All resistance values are given in milliohms (ohms x 10^{-3}).

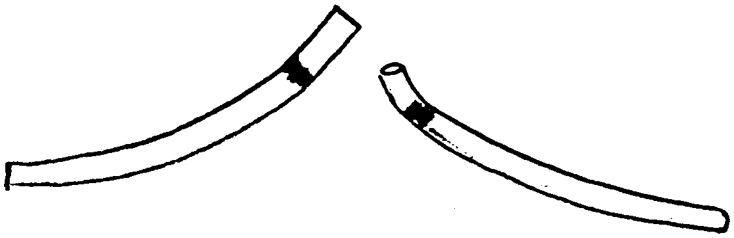
Table XIII presents a two factor statistical analysis of variance for the electrical resistance test data on solder joints. Four of the solder joint types (i.e., 1.1.1, 1.1.2, 1.3.5, and 1.3.6) exhibited a slight decrease in electrical resistance as a result of thermal sterilization and two of the solder joint types (i.e., 1.2 and 1.3.2) showed a slight increase in electrical resistance due to thermal sterilization.



W2 : WIRE BROKE ADJACENT TO WELD



R 2 = RIBBON BROKE ADJACENT TO WELD



WS = WELD SEPARATION

Figure 33. Failure modes for welded joints.

Table XII. Analysis of variance - ultimate strengths of welded joints.

Type of Joint	Effect of Thermal Sterilization	Significance Level - F-test	95% Confidence Intervals of Means	
			Control	Sterilized
1.1 Bare nickel to Inco	None	---	9.0 - 9.7 lbs	9.3 - 9.9 lbs
1.2 Gold plated nickel to Inco	None	---	12.4 - 12.8	12.1 - 12.6
1.3 Gold plated Kovar to Inco	None	---	16.5 - 16.9	16.5 - 16.9
1.4 Gold plated Dumet to Inco	None	---	12.1 - 12.6	11.8 - 12.2
1.5 Gold plated copper to Inco	Decrease	0.001	9.8 - 10.0	9.3 - 9.5
1.6 Solder coated copper to Inco	None	---	7.4 - 7.6	7.4 - 7.6
2.0 Gold plated Kovar foil to itself	Small drop, increased dispersion	0.05 (?)	3.5 - 3.6	3.1 - 3.5

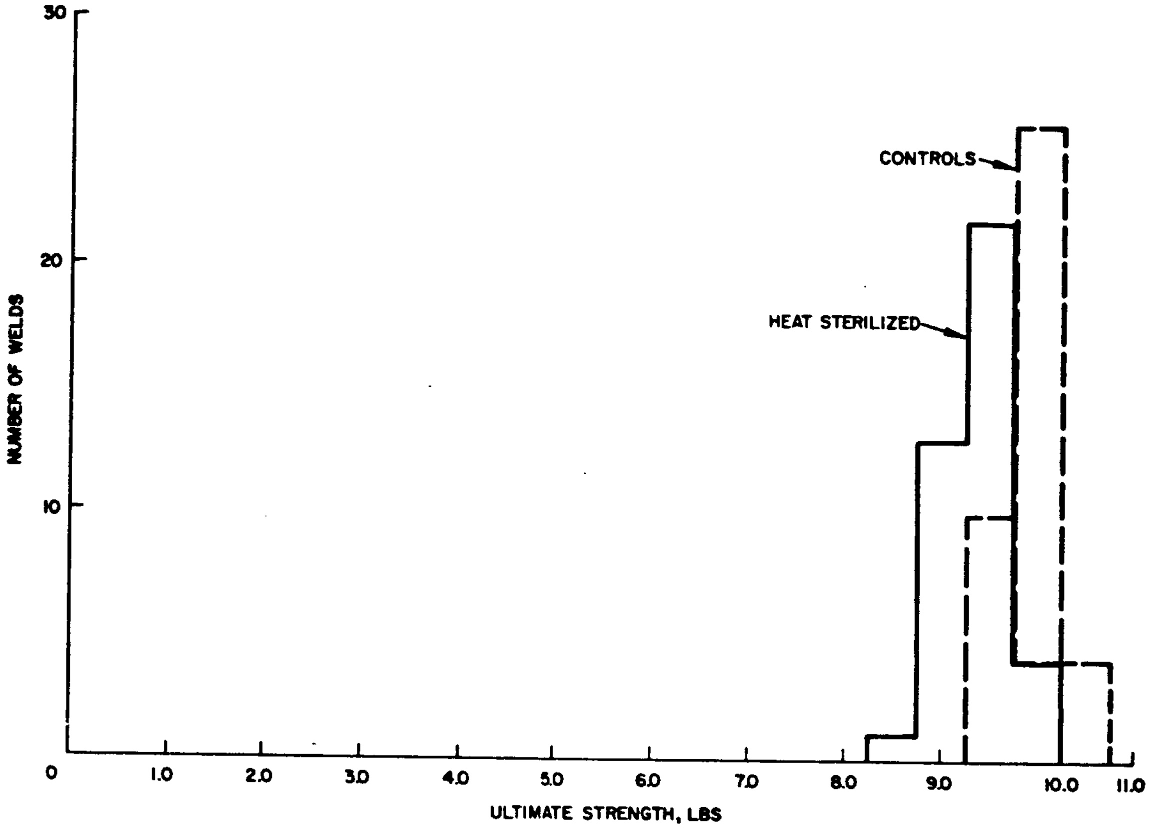


Figure 34. Histograms of strengths of gold-plated copper to Inco weld joints showing shift due to heat sterilization.

The F test was used throughout for significance level calculations and all shifts in the 95% confidence intervals of means had a significance level of 0.001.

Figure 36 is a series of bar diagrams for the electrical resistances of soldered joints presenting, in a more graphical manner, the statistical data given in Table XIII. Note the extremely high resistance of the gold plated Kovar solder joint (1.3.4) compared to the others. The average resistance of this joint is 18 times greater than the average resistance of a stranded conductor (1.2) soldered to the same bifurcated terminal. It is also interesting to note that the Bendix connector cup joint (1.1.2) had more than twice the resistance of the Cinch connector cup joint (1.1.1).

Although joints 1.2 and 1.3.2 showed an increase in resistance after thermal sterilization, this increase was only 4.7% in the case of joint 1.2 and 5.4% in the case of joint 1.3.2.

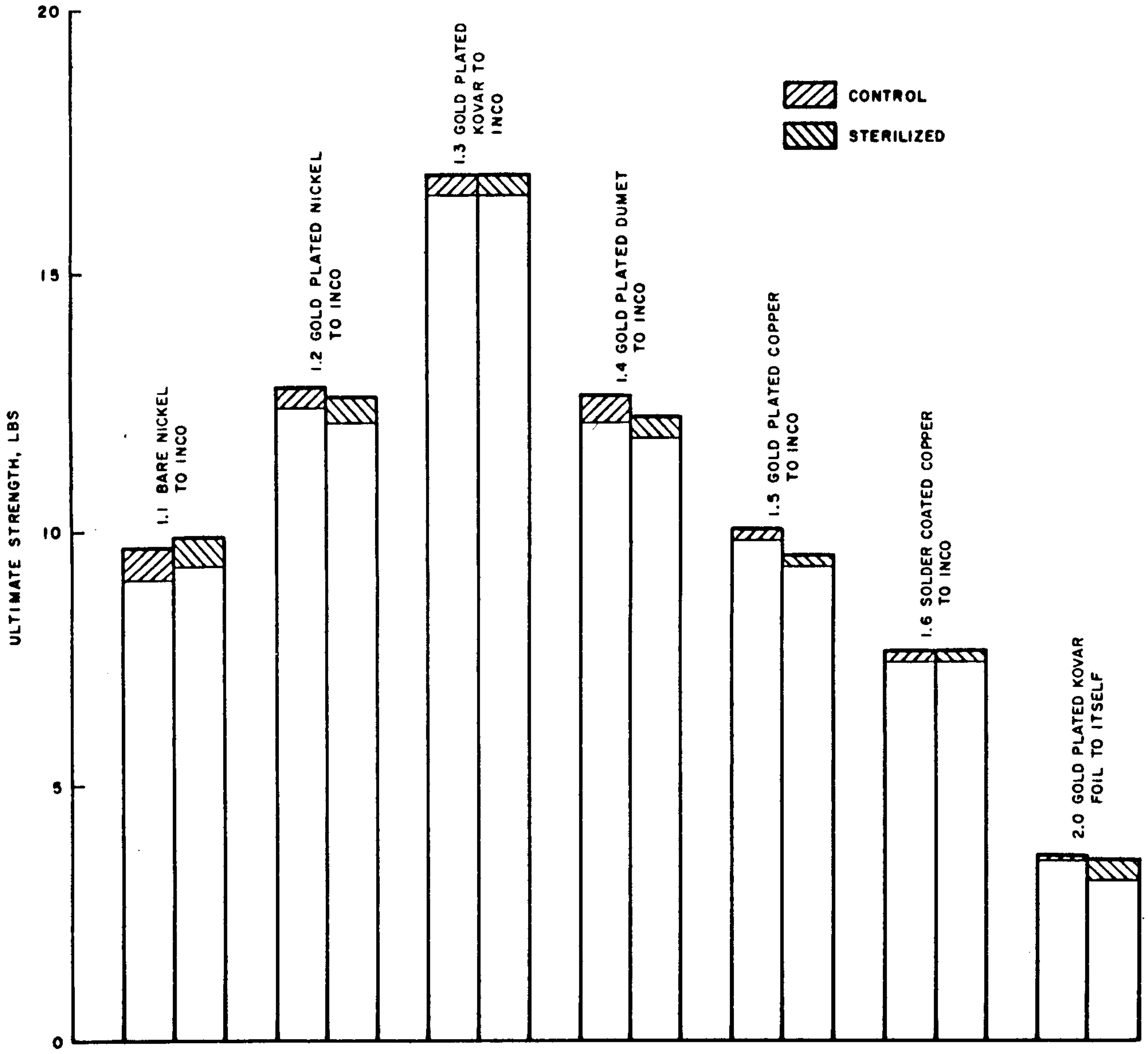


Figure 35. Bar diagrams of ultimate strengths of weld joints. 95 percent confidence intervals of means are shown shaded.

Table XIII. Analysis of variance - electrical resistance of soldered joints.

Type of Joint	Effect of Thermal Sterilization	Significance Level - F-test	95% Confidence Intervals of Means	
			Before Sterilization	After Sterilization
1. 1. 1 Stranded conductor to Cinch cup	Decrease	0. 001	0. 250 - 0. 254 x 10^{-3} ohms	0. 234 - 0. 238 x 10^{-3} ohms
1. 1. 2 Stranded conductor to Bendix cup	Decrease	0. 001	0. 555 - 0. 570 x 10^{-3}	0. 514 - 0. 529 x 10^{-3}
1. 2 Stranded conductor to Solder coated Bifurcated Terminal	Increase	0. 001	0. 167 - 0. 173 x 10^{-3}	0. 175 - 0. 181 x 10^{-3}
1. 3. 1 Gold plated Copper to Solder coated Bifurcated Terminal	None	---	0. 219 - 0. 226 x 10^{-3}	0. 218 - 0. 225 x 10^{-3}
1. 3. 2 Solder coated Copper to Solder coated Bifurcated Terminal	Increase	0. 001	0. 216 - 0. 223 x 10^{-3}	0. 228 - 0. 235 x 10^{-3}
1. 3. 3 Gold plated Dumet to Solder coated Bifurcated Terminal	None	---	0. 735 - 0. 756 x 10^{-3}	0. 726 - 0. 747 x 10^{-3}
1. 3. 4 Gold plated Kovar to Solder coated Bifurcated Terminal	None	---	2. 92 - 3. 15 x 10^{-3}	2. 98 - 3. 22 x 10^{-3}
1. 3. 5 Gold plated Nickel to Solder coated Bifurcated Terminal	Decrease	0. 001	0. 432 - 0. 446 x 10^{-3}	0. 384 - 0. 397 x 10^{-3}
1. 3. 6 Bare Nickel to Solder coated Bifurcated Terminal	Decrease	0. 001	0. 470 - 0. 483 x 10^{-3}	0. 436 - 0. 449 x 10^{-3}
1. 4 Gold plated Copper to Gold plated Bifurcated Terminal	None	---	0. 211 - 0. 219 x 10^{-3}	0. 209 - 0. 217 x 10^{-3}

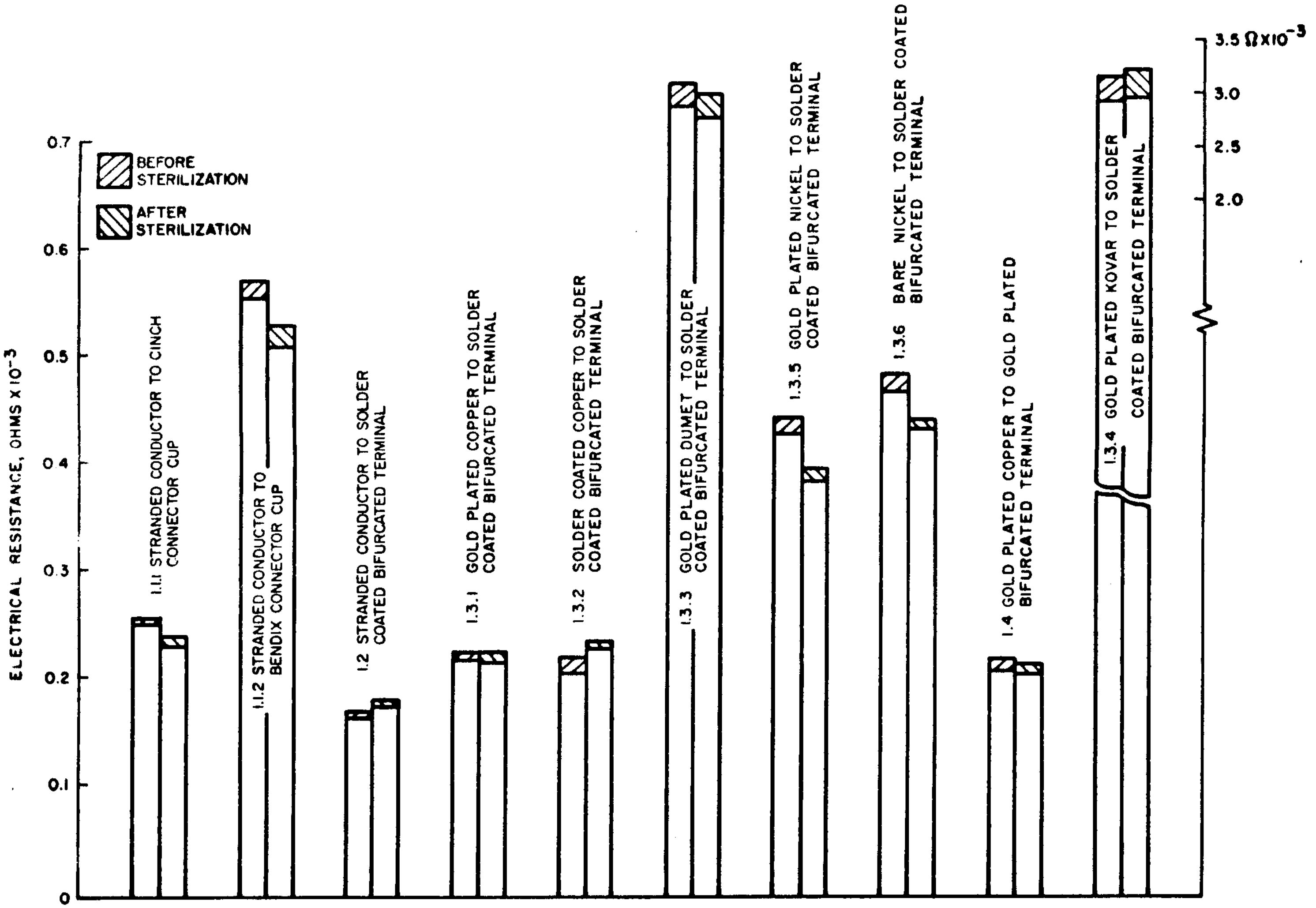


Figure 36. Bar diagrams of electrical resistances of soldered joints before and after sterilization. 95 percent confidence intervals of means are shown shaded.

5.2.2 Weld Joints

Pages 16 through 19 in Part II, Attachment 2, of this final report contain the Raw Data Sheets for the electrical resistance tests on the seven types of weld joints. For each joint type specimens 41-80 were tested before thermal sterilization and the identical specimen was again tested after thermal sterilization. All resistance values are in micro-ohms (ohms x 10^{-6}). A negative sign in front of the resistance reading indicates that the needle of the microvoltmeter indicated a negative polarity for that point. The lack of a sign in front of the resistance reading indicates a positive polarity reading on the microvoltmeter. Note that weld joints 1.1, 1.2, 1.5 and 2.0 have negative polarities, while weld joint 1.3 had a positive polarity. Joints 1.4 and 1.6 had both "+" and "-" polarities. This is a phenomenon observed by others for which no satisfactory explanation is known. Of course a resistance reading has no polarity and therefore the values on the Raw Data Sheets should be interpreted as absolute readings.

Table XIV presents a statistical analysis of variance for the electrical resistances of welded joints. Three weld joint types (i.e., 1.3, 1.5, and 1.6) showed an increase in resistance after sterilization and one weld joint type (i.e., 1.2) showed a very slight decrease in electrical resistance after thermal sterilization. It is interesting to note that the variance of the resistance readings for the weld joints was much greater than the variance for the solder joints and also that the joint resistances for weld joints were a magnitude lower than the solder joint resistances. The gold plated Kovar foil weld joint had a resistance almost 73 times greater than the solder coated copper wire weld joint.

Figure 37 is a series of bar diagrams for the electrical resistances of weld joints presenting, in a more graphical manner, the statistical data of Table XIV. In the case of both solder and weld joints the Kovar materials exhibited high resistances. From Figure 37 one also notes that the nickel weld joints (1.1 and 1.2) had less shaded areas on the bar diagrams indicating the electrical resistances of these materials had less spread (i.e., the joints were more consistent and predictable).

Table XIV. Analysis of variance - electrical resistance of welded joints.

Type of Joint	Effect of Thermal Sterilization	Significance Level - F-test	95% Confidence Intervals of Means	
			Before Sterilization	After Sterilization
1.1 Bare nickel to Inco	None	---	46 - 47 x 10^{-6} ohms	46 - 47 x 10^{-6} ohms
1.2 Gold plated nickel to Inco	Decrease	0.05	32 - 33 x 10^{-6}	31 - 32 x 10^{-6}
1.3 Gold plated Kovar to Inco	Increase	0.01	64 - 76 x 10^{-6}	79 - 92 x 10^{-6}
1.4 Gold plated Dumet to Inco	None	---	9.1 - 17.4 x 10^{-6}	9.5 - 17.8 x 10^{-6}
1.5 Gold plated copper to Inco	Increase	0.001	10 - 16 x 10^{-6}	19 - 25 x 10^{-6}
1.6 Solder coated copper to Inco	Increase	0.001	1.9 - 9.4 x 10^{-6}	14.9 - 22.3 x 10^{-6}
2.0 Gold plated Kovar foil to itself	None	---	404 - 412 x 10^{-6}	406 - 413 x 10^{-6}

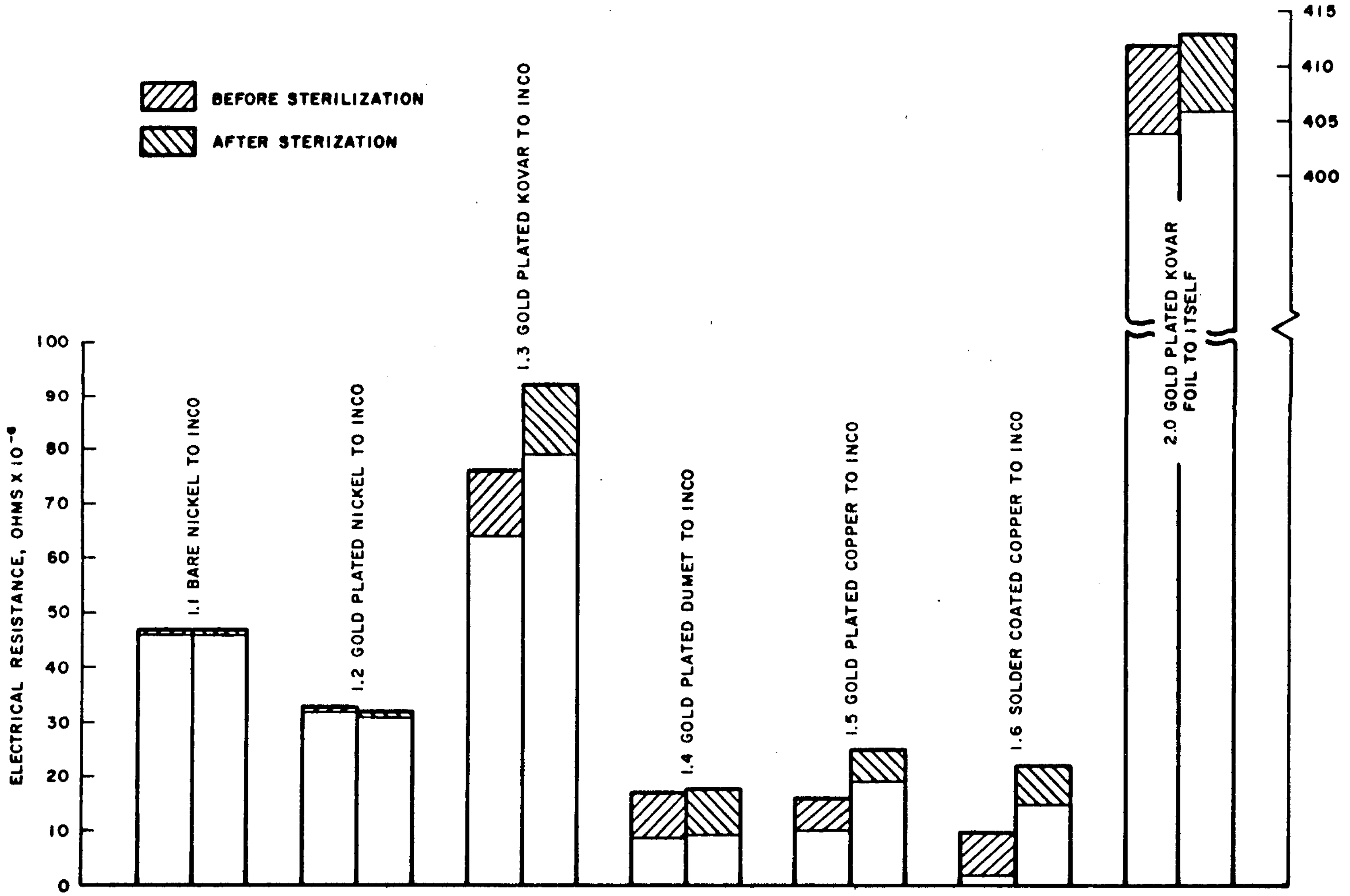


Figure 37. Bar diagrams of electrical resistances of welded joints before and after sterilization. 95 percent confidence intervals of means are shown shaded.

5.3 STRESS-RUPTURE STRENGTH TEST RESULTS

Pages 20 through 23 in Part II, Attachment 2, of this final report contain the Raw Data Sheets for the Stress-Rupture Strength tests on two types of solder joints (i.e., stranded conductor to Cinch connector cup and stranded conductor to Bendix connector cup). Both types of solder joints were tested for the full sterilization time (108 hours) at room temperature (74°F) and also for the full sterilization time at sterilization temperature (145°C) in a nitrogen atmosphere. Each test was repeated 4 times with 9 specimens loaded during each test. For each joint type specimens 111-146 were tested at room temperature and specimens 147-182 were tested at sterilization temperature. Failures were of two types: 1) wire failures; and 2) joint failures. These failure modes are illustrated in Figure 38. Wire failures were predominant at the 80% and 90% of ultimate strength loadings (i.e., 12 lb.-1 oz. and 13 lb.-9 oz.) due to untwisting of the wire strands under load. Joint failures occurred at the lower loadings with the wire pulling right out of the connector cup.

Creep was <u>not</u> observed on any specimen. A small amount of creep could have occurred and would not have been detected, since the test was basically for stress-rupture strength. Creep is usually observed over a period of 1000 hours with axial deformation being read periodically.

WIRE FAILURE

JOINT FAILURE

Figure 38. Failure modes during stress-rupture strength tests.

In view of the nature of the data and since the loads were not left on the wires until all joints failed, a meaningful statistical analysis was not possible. However a graph of the results is presented in Figure 39. Considering first the room temperature results, one notes that the Bendix cup joints up to and including 70% of ultimate strength lasted the full 108 hours. The Cinch cup joints up to and including 50% of ultimate strength lasted the full 108 hours. Again from Figure 39 consider the results of sterilization temperature. None of the Cinch joints--even at only 10% of ultimate strength--lasted through 108 hours. Failures occurred within the first 5 hours.

The Bendix cup joints for 1%, 2%, 3%, 4%, and 5% of ultimate strength lasted the full 108 hours. Unfortunately none of the Cinch cup joints were tested at such low loads. Even at 10% of ultimate strength the Bendix cup joints lasted an average of 27 hours. Figure 39 certainly points out that the Bendix cup joints are stronger than the Cinch cup joints in stress-rupture strength. Figure 39 also shows that the stress-rupture strength of a connector cup solder joint decreases considerably at elevated temperatures.

Taking the Bendix cup joint as an example, the strength dropped from 70% of ultimate strength to only 5% of ultimate strength at 145°C. In other words, the strength at sterilization temperature was only 14% of the strength at room temperature.

By way of explaining the higher stress-rupture strength of the Bendix cup, the Bendix cup had a copper + silver + gold outer electroplate while the Cinch cup had only a copper + gold outer electroplate. The Bendix cup was also deeper (0. 134" as compared to 0. 100") and had a larger inside diameter (0.048" as compared to 0.0445").

5.4 ELECTRICAL TEST DURING VIBRATION TEST RESULTS

5.4.1 Solder Joints

Pages 24 through 27 in Part II, Attachment 2, of this final report contain the Raw Data Sheets for the electrical tests during vibration of the eleven types of solder joints. For each joint type, specimens 91-100

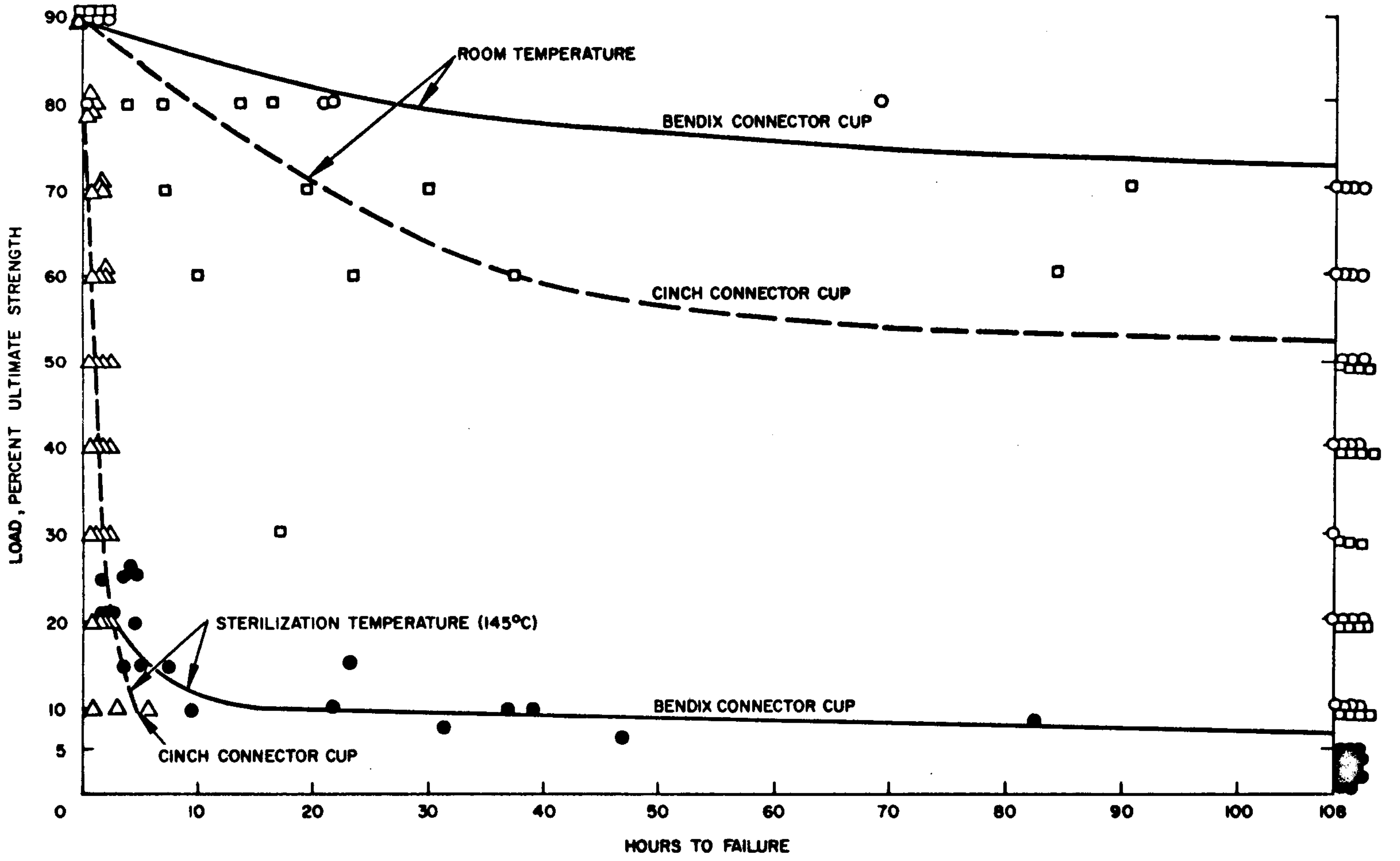


Figure 39. Stress-rupture test results at room temperature and at sterilization time and temperature.

were the control specimens and numbers 101-110 were vibrated after having been submitted to thermal sterilization. For each set of either 4 or 2 joints, the a-c joint resistance is given (at 100 milliamperes current input) together with the percentage change in joint resistance at resonance.

In no instance, with either the control specimens or the heated specimens, was any detectable change in joint resistance observed during vibration. Figure 40 summarizes the results showing the various resonant frequencies of each joint type and the series electrical resistances. The Cinch connector cup joints had an unusually high joint resistance--approximately 225 micro-ohms per joint--as compared to the other joint types. However if we compare this resistance value with Figure 36, which contains the electrical resistance test results, we note that the dc electrical resistance of the Cinch connector cup joint was about 250 micro-ohms. Since this was an extremely sensitive test which was capable of picking up resistance changes as small as 5%, it must be assumed that the solder joints were made so well that they, in fact, did not change electrically under vibration conditions.

5.4.2 Weld Joints

Pages 28 through 31 in Part II, Attachment 2, of this final report contain the Raw Data Sheets for the electrical tests during vibration of the seven types of weld joints. For each joint type, specimens 91-100 and JPL specimens 3-6 were tested without prior treatment, while specimens 101-110 and JPL specimens 7-10 were tested after thermal sterilization.

In no instance, with either the control or the sterilized specimens, was any detectable change in joint resistance observed at resonance during vibration testing. Figure 41 summarizes the test results for weld joints in a similar manner as was done for solder joints in Figure 40. One interesting thing to note is that the resonant frequencies of the weld joints are almost twice that of the solder joints. The joint resistances of the Hughes and JPL weld joints are of a similar magnitude. In two joint types (i.e., 1.3 and 1.5) the Hughes joints had lower

Type of Joint	Joint Resistance 4 Joints in Series ($\Omega \times 10^{-6}$)	Resonant Frequency (cps)	Percent Change in Joint Resistance During Vibration	
			Control	Sterilized
1.1.1 Stranded conductor to CINCH connector cup	900	244	0	0
1.1.2 Stranded conductor to BENDIX connector cup	520	170	0	0
1.2 Stranded conductor to solder coated bifurcated terminal	400	140	0	0
1.3.1 Gold plated copper to solder coated bifurcated terminal	230	220	0	0
1.3.2 Solder coated copper to solder coated bifurcated terminal	250	252	0	0
1.3.3 Gold plated Dumet to solder coated bifurcated terminal	700	190	0	0
1.3.4 Gold plated Kovar to solder coated bifurcated terminal	600	180	0	0
1.3.5 Gold plated nickel to solder coated bifurcated terminal	270	205	0	0
1.3.6 Bare nickel to solder coated bifurcated terminal	500	175	0	0
1.4 Gold plated copper to gold plated bifurcated terminal	140	172	0	0
1.5 Resistor lead to solder coated bifurcated terminal	190	212	0	0

Figure 40. Summation of results for electrical tests during vibration of soldered joints.

Type of Joint	Joint Resistance 4 Joints in Series (Ω x 10^{-6})		Resonant Frequency (cps)	Percent Change in Joint Resistance During Vibration	
	Hughes	JPL		Control	Sterilized
1.1 Bare nickel to Inco	550	550	420	0	0
1.2 Gold plated nickel to Inco	500	500	420	0	0
1.3 Gold plated Kovar to Inco	1000	1370	411	0	0
1.4 Gold plated Dumet to Inco	480	*155 ?	418	0	0
1.5 Gold plated copper to Inco	240	270	390	0	0
1.6 Solder coated coper to Inco	280	240	478	0	0
2.0 Gold plated Kovar foil to itself	4600	-	280	0	0

*Questionable

Figure 41. Summation of results for electrical tests during vibration of welded joints.

resistances and in two joint types (i.e., 1.4 and 1.6) the JPL joints had lower resistances.

5.5 ULTIMATE STRENGTH AFTER VIBRATION TEST RESULTS

5.5.1 Solder Joints

Pages 32 and 33 in Part II, Attachment 2, of this final report contain the Raw Data Sheets for the ultimate strength after vibration test results for the eleven types of solder joints. All strength values are given in pounds. After each strength value, a "W" or "J" has been recorded denoting the failure mode for that particular joint.

Table XV is a statistical analysis of variance of the ultimate strengths of solder joints after vibration. None of the joints showed any significant effect due to thermal sterilization. Figure 42 contains a series of bar diagrams which present the statistical data of Table XV in a more graphical manner. Comparing Figure 42 with Figure 32 (ultimate strengths of solder joints without vibration) one notes that the strengths of the joints are approximately the same regardless of whether they have been vibrated or not. Comparing the 95% confidence intervals of means (shaded areas), it is noted that vibration has obviously caused a marked change in the variance about the mean of the strength data. Remembering the difference in sample sizes, it is possible that this difference in variance could be attributed to the fact that only 25% as many specimens were tested for ultimate strength after vibration as were tested for ultimate strength without being vibrated first.

5.5.2 Weld Joints

Pages 34 and 35 in Part II, Attachment 2, of this final report contain the Raw Data Sheets for the ultimate strength after vibration test results for the seven types of weld joints. After each strength value (in pounds) is noted the mode of failure as described earlier in Figure 33.

Table XV. Analysis of variance - ultimate strengths of soldered joints after vibration.

Type of Joint	Effect of Thermal Sterilization	Significance Level	95% Confidence Intervals of Means	
			Control	Sterilized
1. 1. 1 Stranded conductor to Cinch cup	None	---	14. 5 - 14. 5 lbs*	14. 5 - 14. 5 lbs*
1. 1. 2 Stranded conductor to Bendix cup	None	---	14. 5 - 14. 5*	14. 5 - 14. 5*
1. 2 Stranded conductor to Solder coated Bifurcated Terminal	None	---	13. 7 - 14. 7	13. 9 - 14. 9
1. 3. 1 Gold plated Copper to Solder coated Bifurcated Terminal	None	---	10. 6 - 11. 0	11. 0 - 11. 4
1. 3. 2 Solder coated Copper to Solder coated Bifurcated Terminal	None	---	11. 0 - 11. 9	11. 5 - 11. 9
1. 3. 3 Gold plated Dumet to Solder coated Bifurcated Terminal	None	---	19. 2 - 26. 2	18. 0 - 25. 0
1. 3. 4 Gold plated Kovar to Solder coated Bifurcated Terminal	None	---	18. 8 - 23. 4	17. 7 - 22. 3
1. 3. 5 Gold plated Nickel to Solder coated Bifurcated Terminal	None	---	22. 0 - 29. 7	24. 0 - 31. 7
1. 3. 6 Bare Nickel to Solder coated Bifurcated Terminal	None	---	26. 4 - 33. 4	25. 7 - 32. 7
1. 4 Gold plated Copper to Gold plated Bifurcated Terminal	None	---	10. 8 - 11. 0	10. 3 - 11. 7
1. 5 1/4 Watt resistor to Solder coated Bifurcated Terminal	None	---	20. 1 - 23. 4	19. 4 - 22. 7

*Within round-off limits

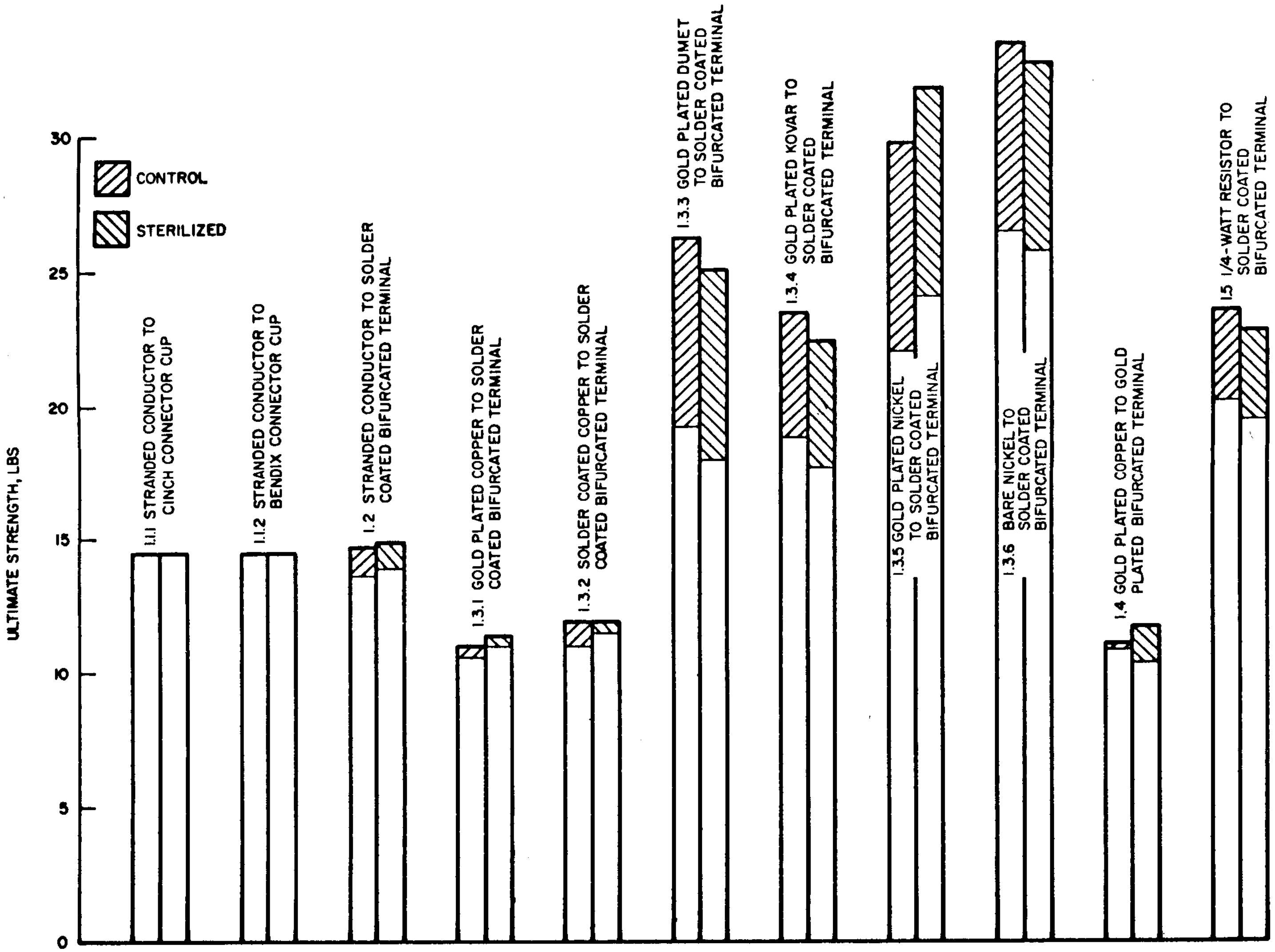


Figure 42. Bar diagrams of ultimate strengths of soldered joints after vibration. 95 percent confidence intervals of means are shown shaded.

Table XVI is a statistical analysis of variance of the ultimate strengths of the weld joints after vibration. None of the joints showed any significant effect due to thermal sterilization. Figure 43 contains a series of bar diagrams which present the statistical data of Table XVI in a more graphical manner. Comparing Figure 43 with Figure 35 (ultimate strengths of weld joints not vibrated) one notes that the strength values are quite similar in value. As with the solder joints, the variance about the mean was greater with the weld joints which had been pulled apart after being vibrated. Certain of the weld joint types (i.e., 1.1, 1.2, 1.4, 1.6, and 2.0) even exhibited slightly higher average ultimate strengths after being vibrated.

Figure 44 demonstrates the consistencies of the ultimate strengths of the weld joints made by Hughes and JPL using different equipment, different weld schedules, and different operators. The values plotted as bar diagrams are the arithmetic means taken from the Raw Data Sheets (Pages 34 and 35) and using the "before heat" readings in all cases. Even the weld joint with the greatest difference of means (number 1.4) shows only a difference of 16%.

5.6 METALLURGICAL EXAMINATION TEST RESULTS

5.6.1 Solder Joints

Figure 1 through 22 in Part II, Attachment 3, of this final report contain the photomicrographs of the metallographic mounts of the 11 types of solder joints. The solder joint in the photomicrograph at the top of each page was not sterilized, while the solder joint in the photomicrograph at the bottom of each page had been thermally sterilized. A potassium dichromate etchant was used for all solder joints to bring out the metallurgical structure. By visually comparing the top and bottom photomicrographs, the observer can examine the solder joints for any metallurgical effect due to thermal sterilization.

Although the photomicrographs are only at magnifications of 60x and 100x, all mounted solder joint specimens (110 in total) were examined at 500x in both the polished and etched condition. None of the

Table XVI. Analysis of variance - ultimate strengths of welded joints after vibration.

Type of Joint		Effect of Thermal Sterilization	Significance Level - F-test	95% Confidence Intervals of Means	
				Control	Sterilized
1.1	Bare nickel to Inco	None	---	9.8 - 11.0 lbs	10.7 - 11.9 lbs
1.2	Gold plated nickel to Inco	None	---	11.8 - 13.0	12.3 - 13.4
1.3	Gold plated Kovar to Inco	None	---	14.8 - 16.8	15.0 - 17.0
1.4	Gold plated Dumet to Inco	None	---	14.2 - 17.5	15.3 - 18.3
1.5	Gold plated copper to Inco	None	---	9.2 - 9.7	8.8 - 9.3
1.6	Solder coated copper to Inco	None	---	7.9 - 8.4	8.0 - 8.4
2.0	Gold plated Kovar foil to itself	None	---	3.4 - 4.1	3.2 - 3.8

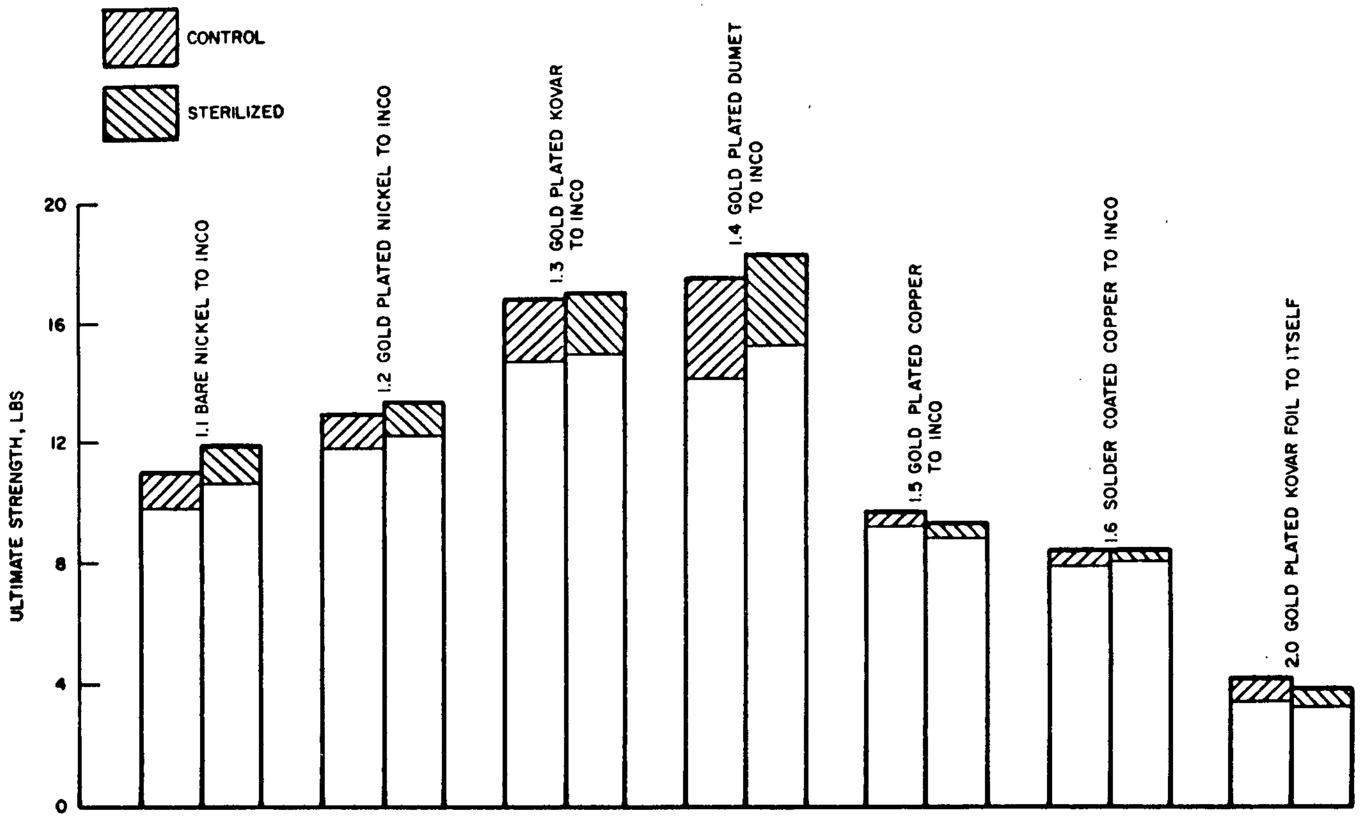


Figure 43. Bar diagrams of ultimate strengths of weld joints after vibration. 95 percent confidence intervals of means are shown shaded.

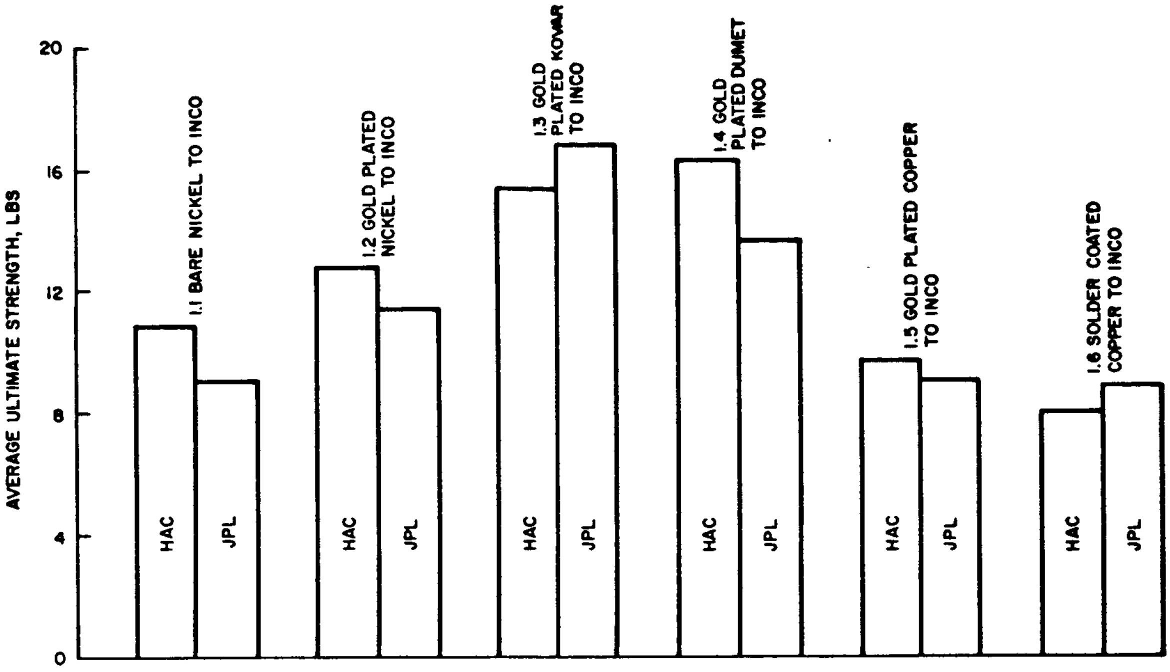


Figure 44. Comparison of the average ultimate strengths of the Hughes and JPL weld joints.

eleven types of solder joints showed any degradation in the metallurgical structure of the solder joint which could be attributed to thermal sterilization.

5.6.2 Weld Joints

Figures 23 through 48 in Part II, Attachment 3, of this final report contain the photomicrographs of the metallographic mounts of the 7 types of weld joints. The weldjoint in the photomicrograph at the top of each page was not sterilized, while the weld joint in the photomicrograph at the bottom of each page had been thermally sterilized. For each of the weld joint types (except joint 2.0 - Kovar foil to itself) a set of photomicrographs showing the before and after sterilization structure has been prepared for the weld joints made by JPL. These joints are identified by the letters JPL 1 or JPL 2 following the weld joint number.

All JPL 1 joints were not sterilized, while the JPL 2 joints were thermally sterilized. The etchants used for the weld joints were either: a) nitric-acetic; b) Carapella; or c) Carapella + nitric-acetic. All weld joint photomicrographs are at 150x magnification.

All of the mounted weld joint specimens (82 in total) were examined at 500x in both the polished and etched condition. None of the seven types of weld joints showed any degradation in the metallurgical structure of the weld joint which could be attributed to thermal sterilization. The only weld joint showing any unusual characteristic was the gold plated copper to Inco joint (joint no. 1.5). Figures 39-42 in Part II, Attachment 3, show this particular weld joint. An internal structural change was present within the middle of the Inco ribbon in both the Hughes and JPL joints. Looking back at the original weld schedules (Table V), it is noted that this particular joint required the highest weld energy (33 watt-seconds for the Hughes weld joint) of any of the weld joints. This energy has apparently penetrated deeply within the Inco ribbon. However this defect has not seemed to detract from the ultimate strength of this joint, since the ultimate strength bar diagrams (Figure 35 and Figure 43) appear normal.

5.7 ELECTRON PROBE MICROANALYSIS TEST RESULTS

Pages 1 through 8 in Attachment 4, Part II, of this final report contain the electron probe microanalysis charts for both the wire end and terminal end of solder joint 1.3.1 (gold plated copper wire to solder coated bifurcated terminal). Two charts are included for each of the four specimens examined.

Pages 9 through 16 in Attachment 4, Part II, of this final report contain the electron probe microanalysis charts for both the wire end and terminal end of solder joint 1.4 (gold plated copper wire to gold plated bifurcated terminal). Two charts are included for each of the four specimens examined.

Pages 17 through 24 in Attachment 4, Part II, of this final report contain the electron probe microanalysis charts for both the wire side and ribbon side of weld joint 1.5 (gold plated copper wire to Inco (nickel) ribbon). Two charts are included for each of the four specimens examined.

The major consideration in these analyses was the comparative extent of gold penetration into the copper for the sterilized and the unsterilized specimens. To this end the charts were read in terms of the width of the apparent diffusion zone.

For specimens 1.4.111 through 1.4.114 there were two interfaces of interest. The charts show no diffusion of gold into the copper wire or the terminal. The gold coating on the brass appeared to be absent. It should be noted that the 0% Gold point (i.e. background) is higher for the heavier metals than for copper.

Specimens 1.3.1.111 through 1.3.1.114 showed no gold diffusion into the copper. It should be noted that the gold layer did not appear on these specimens.

Specimen 1.5.111 and 1.5.112 showed no evidence of gold in the copper at the point examined. Specimen 1.5.113 showed no penetration at the center and 6 microns of gold diffusion into the copper near one edge of the weld. Specimen 1.5.114 showed 6 microns of gold diffusion into the copper. In these cases there were very large local variations in composition in the weld metal. It appeared that the gold had been caused to migrate to the edges, away from the point of maximum pressure.

Although the results on the weld specimens were somewhat inconclusive, it is concluded that no gold diffusion into the copper or copper alloy was caused by the sterilization treatment. This is particularly borne out by the lack of any indication of diffusion of gold into copper in the gold to copper interface in the soldered joints, where the interface was very sharp. There is no logical reason to expect more gold diffusion in one specimen than another. It is believed, therefore, that all the observed variations resulted from the joining conditions.

The Materials Testing Laboratories has recommended that if further work on this problem is contemplated, it is suggested that the same specimen be examined before and after sterilization, so that other variables would be blanked out. The use of such tiny weld specimens would involve treating it in the mount. If it is necessary to avoid this, it would seem that more massive specimens would serve the purpose.

6. CONCLUSIONS

Table XVII presents a summary of the test results on soldered and welded joints. A more detailed discussion of the results of each particular test is included in Sections 5.1 through 5.7 of this final report. Analyses of variance, bar diagrams, and histograms of the test results are included in Tables XI-XVI and Figures 31-44.

In general both the welded and soldered joints show little or no change in ultimate strength or electrical resistance as a result of thermal sterilization. This conclusion applies to ultimate strength before and after vibration and to both static electrical resistance tests and the percentage change in dynamic electrical resistance during vibration. From Table XVII it is noted that two solder joints (1.3.3 gold plated Dumet to solder coated bifurcated terminal and 1.3.4 gold plated Kovar to solder coated bifurcated terminal) showed no significant changes for all tests. In the case of the welded joints, two joints (1.1 bare nickel to Inco and 1.4 gold plated Dumet to Inco) showed no significant changes for all tests.

Where significant shifts occurred (increase or decrease), these shifts, although significant statistically, were actually minor in magnitude. For example, in the case of ultimate strengths, the random errors were such that the use of 80 specimens (40 sterilized and 40 unsterilized) permitted detection of strength shifts of considerably less than 5% with ease. Comparing changes in strength or electrical resistance before and after sterilization, these changes were, on the whole, usually less than 5%. Since such small shifts are not likely to be of importance in actual applications, it is concluded that, for all practical purposes, there was no significant change due to the effects of thermal sterilization.

Neither the metallurgical examination nor the electron probe microanalysis showed any degradation in metallurgical structure or in the extent of gold diffusion which could be attributed to the thermal sterilization process.

Table XVII. Summary of test results on soldered and welded joints.

Types of Joints / Various Tests	Effect of Thermal Sterilization						
	Ultimate Strength	Electrical Resistance	Stress-Rupture Strength	Electrical Test During Vibration	Ultimate Strength After Vibration	Metallurgical Examination	Electron Probe Microanalysis
Solder Joints							
1.1.1 Stranded conductor to Cinch connector cup	None	Decrease	Decrease	None	None	None	–
1.1.2 Stranded conductor to Bendix connector cup	Decrease	Decrease	Decrease	None	None	None	–
1.2 Stranded conductor to solder coated bifurcated terminal	Decrease	Increase	–	None	None	None	–
1.3.1 Gold plated copper to solder coated bifuricated terminal	Increase	None	–	None	None	None	None
1.3.2 Solder coated copper to solder coated bifurcated terminal	Decrease	Increase	–	None	None	None	–
1.3.3 Gold plated Dumet to solder coated bifurcated terminal	None	None	–	None	None	None	–
1.3.4 Gold plated Kovar to solder coated bifurcated terminal	None	None	–	None	None	None	–
1.3.5 Gold plated nickel to solder coated bifurcated terminal	None	Decrease	–	None	None	None	–
1.3.6 Bare nickel to solder coated bifurcated terminal	None	Decrease	–	None	None	None	–
1.4 Gold plated copper to gold plated bifurcated terminal	Decrease	None	–	None	None	None	None
1.5 Resistor lead to solder coated bifurcated terminal	None	–	–	None	None	None	–
Weld Joints							
1.1 Bare nickel to Inco	None	None	–	None	None	None	–
1.2 Gold plated nickel to Inco	None	Decrease	–	None	None	None	–
1.3 Gold plated Kovar to Inco	None	Increase	–	None	None	None	–
1.4 Gold plated Dumet to Inco	None	None	–	None	None	None	–
1.5 Gold plated copper to Inco	Decrease	Increase	–	None	None	None	None
1.6 Solder coated copper to Inco	None	Increase	–	None	None	None	–
2.0 Gold plated Kovar foil to itself	Decrease	None	–	None	None	None	–

Only the stress-rupture tests demonstrated that thermal sterilization times and temperatures can seriously affect the strength of soldered joints under load. These tests (refer to Section 5.3) pointed out that steady-state loads of only 10% of the ultimate strength of a connector cup solder joint were enough to cause short-term joint failures under sterilization conditions. However these same joints would withstand loads of 50%-70% of the ultimate strength for the full 108 hours at room temperature conditions. It is therefore recommended that solder joints be under little or no stress during the thermal sterilization treatment.

ACKNOWLEDGMENT

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Mr. D. Teter for soldering all of the solder joints.

Miss E. Manning for welding all of the weld joints and for ultimate strength testing of all weld joints.

Mr. J. Holberton for ultimate strength testing of all solder joints and for assistance in stress-rupture testing.

Mr. D. Cranmer for electrical resistance testing of all solder joints and weld joints.

Mr. R. Kassebaum for vibration testing of all solder joints and all weld joints.

Mr. N. Ferguson for all metallographic mount preparation and photomicrographs.

Mr. R. Rydelek for conducting all thermal sterilization and lead bake-out tests.

Mr. D. Hirsch for the design and construction of the various special test fixtures required for ultimate strength testing and stress-rupture strength testing.

Mr. C. Bahun for statistical analysis of variance calculations.

Mr. G. Dreyer for assistance in weld schedule determination.

Mr. J. Fraser and Mr. R. Bays for the design of the electrical resistance test fixtures and for assistance in conducting the vibration and stress-rupture tests.

FINAL REPORT - PART II

Contract No. 951069

DETERMINATION OF THE EFFECTS OF A THERMAL STERILIZATION PROCESS ON THE MECHANICAL AND ELECTRICAL PROPERTIES OF SOLDERED AND WELDED JOINTS

by

F. Z. Keister, Hughes Project Engineer

9 October 1965

For

Jet Propulsion Laboratory
California Institute of Technology
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Materials Technology Department

Materials Technology Department
AEROSPACE GROUP
Hughes Aircraft Company · Culver City, California

CONTENTS

INTRODUCTION TO PART II

Part II of the final report on the determination of the effects of a thermal sterilization process on the mechanical and electrical properties of soldered and welded joints is intended to supplement Part I. Part II contains four basic sections identified as follows:

Attachment 1 - Weld Joint Schedule Isoforce Diagrams
Attachment 2 - Raw Data Sheets (Pages 1 - 35)
Attachment 3 - Photomicrographs of Solder Joint and Weld Joint Metallographic Specimens (Figures 1 - 48)
Attachment 4 - Electron Probe Microanalysis Charts (Pages 1 - 24)

Attachment 1 is intended for use with Section 3. 5 "Fabrication of Weld Joints" in Part I.

Attachment 2 is intended for use with Section 5 "Test Results" in Part I.

Attachment 3 is intended for use with Section 5. 6 "Metallurgical Examination Test Results" in Part I.

Attachment 4 is intended for use with Section 5. 7 "Electron Probe Microanalysis Test Results" in Part I.

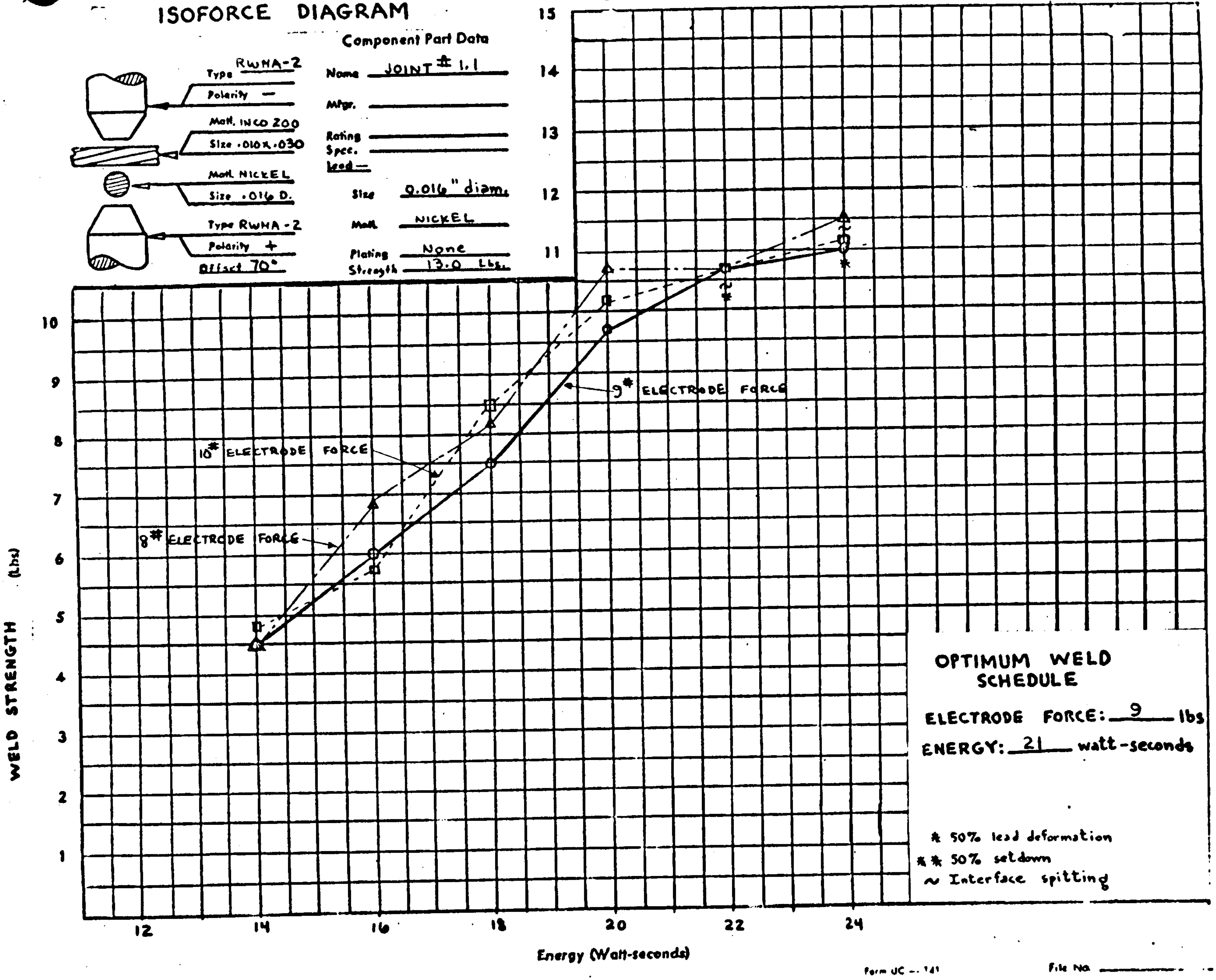
6

ATTACHMENT 1

ATTACHMENT 1

WELD JOINT SCHEDULE ISOFORCE DIAGRAMS

ISOFORCE DIAGRAM



Type RWHA-2
Polarity —
Mat'l. INCO 200
Size .010 x .030
Mat'l. NICKEL
Size .016 D.
Type RWHA-2
Polarity +
Offset 70°

Component Part Data

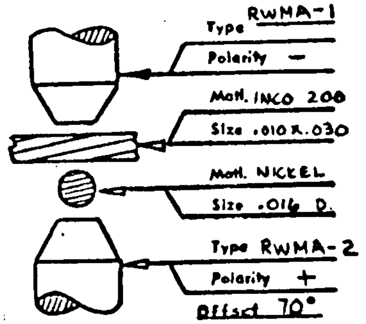
Name JOINT # 1.1
Mfgr.
Rating
Spec.
lead —
Size 0.016" diam.
Mat'l. NICKEL
Plating None
Strength 13.0 Lbs.

OPTIMUM WELD SCHEDULE

ELECTRODE FORCE: 9 lbs
ENERGY: 21 watt-seconds

* 50% lead deformation
** 50% setdown
~ Interface spitting

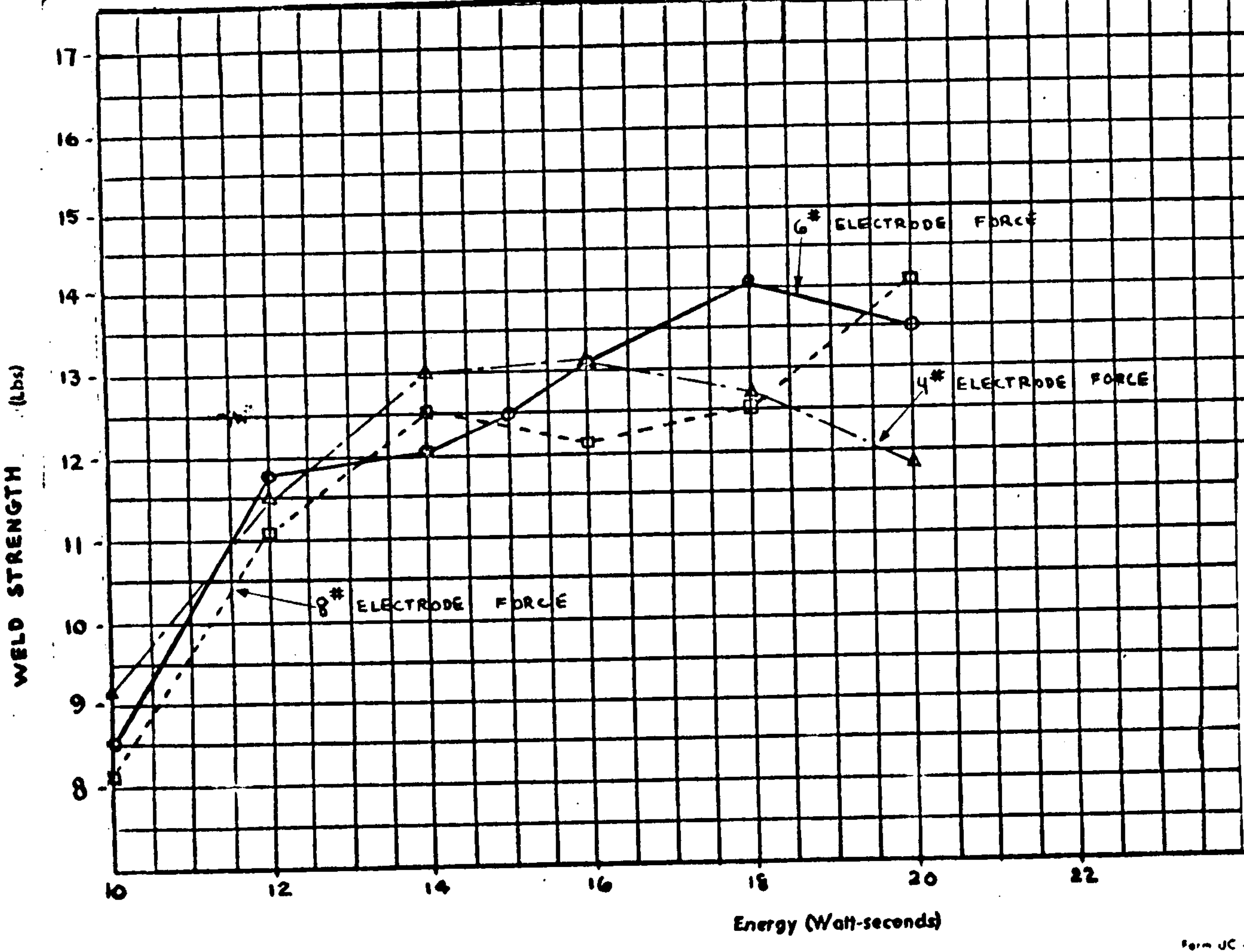
ISOFORCE DIAGRAM



Type RWMA-1
Polarity —
Matl. INCO 208
Size .010 X .030
Matl. NICKEL
Size .016 D.
Type RWMA-2
Polarity +
Offset 70°

Component Part Data

Name JOINT # 1.2
Mfgr.
Rating
Spec.
Lead —
Size 0.016" diam.
Matl. NICKEL
Plating Gold
Strength 14.0 Lbs.



OPTIMUM WELD
SCHEDULE

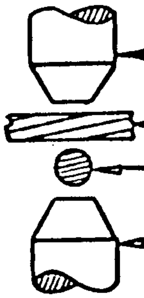
ELECTRODE FORCE: 6 lbs
ENERGY: 15 watt-seconds

* 50% lead deformation
** 50% setdown
~ Interface spitting

Form UC -- 141

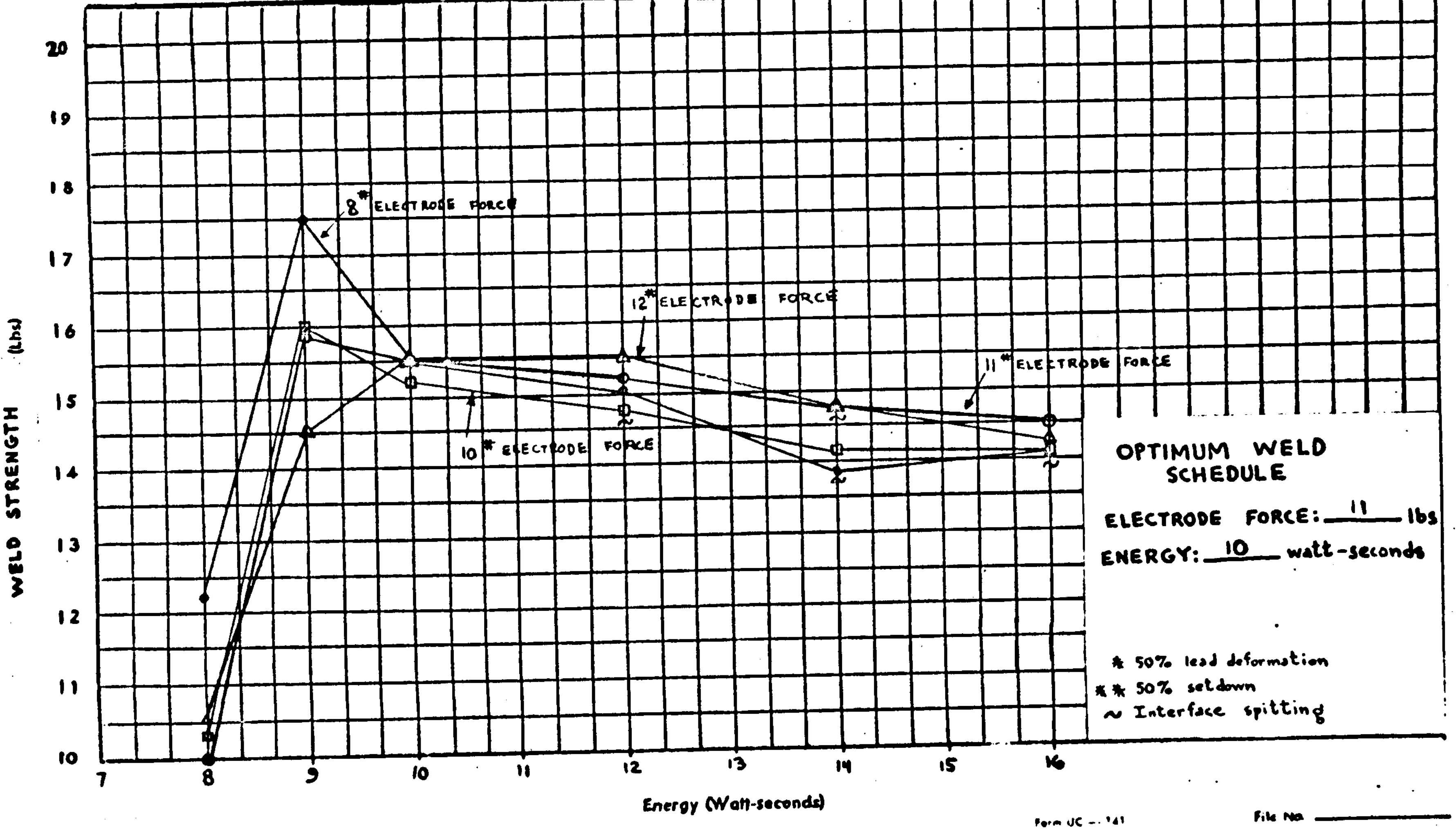
File No.

ISOFORCE DIAGRAM



Type RWHA-2
Polarity —
Mat'l. INCO 200
Size .010X.030
Mat'l. KOVAR
Size .018 D.
Type RWHA-2
Polarity +
Offset 70°

Component Part Data
Name JOINT # 1.3
Mfgr.
Rating
Spec.
Lead —
Size 0.018" diam.
Mat'l. KOVAR
Plating Gold
Strength 22.5 Lbs.



OPTIMUM WELD SCHEDULE

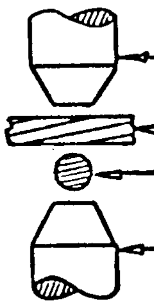
ELECTRODE FORCE: 11 lbs
ENERGY: 10 watt-seconds

* 50% lead deformation
** 50% setdown
~ Interface spitting

Form UC -- 141

File No. ____

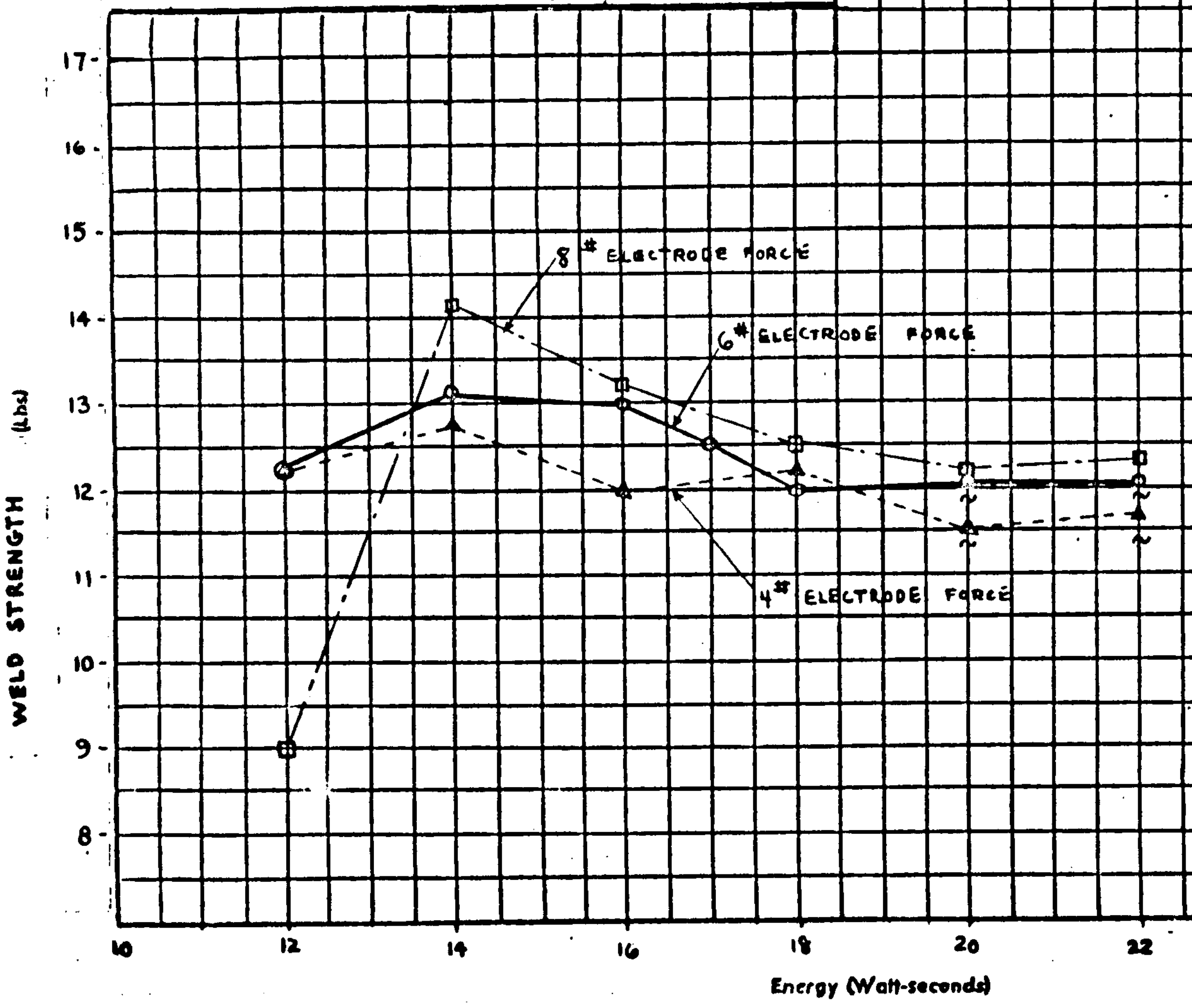
ISOFORCE DIAGRAM



Type RWMA-1
Polarity −
Mat'l. INCO 200
Size .010x.030
Mat'l DUMET
Size .020 Ø
Type RWMA-2
Polarity +
Offset 70°

Component Part Data

Name JOINT # 1,4
Mfgr.
Rating
Spec.
Lead—
Size 0.020" diam.
Mat'l DUMET
Plating Gold
Strength 25.0 Lbs.



OPTIMUM WELD SCHEDULE

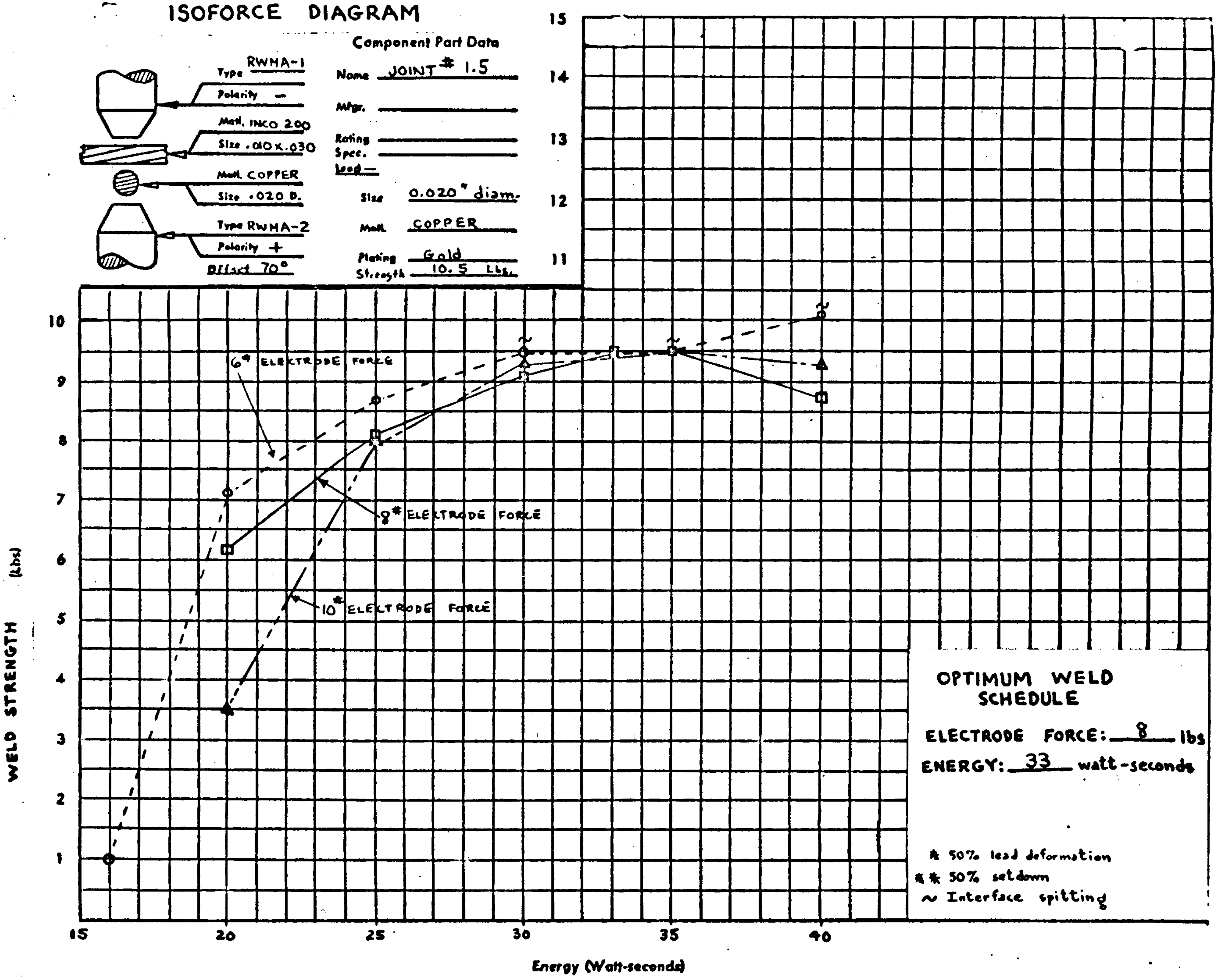
ELECTRODE FORCE: 6 lbs
ENERGY: 17 watt-seconds

* 50% lead deformation
** 50% setdown
~ Interface spitting

Form UC -- 141

File No. ______

ISOFORCE DIAGRAM



Type RWMA-1
Polarity —
Mat'l. INCO 200
Size .010 x .030
Mat'l. COPPER
Size .020 D.
Type RWMA-2
Polarity +
Offset 70°

Component Part Data

Name JOINT # 1.5
Mfgr.
Rating
Spec.
Lead —
Size 0.020" diam.
Mat'l. COPPER
Plating Gold
Strength 10.5 Lbs.

OPTIMUM WELD
SCHEDULE

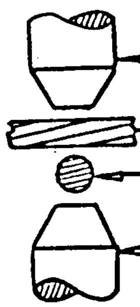
ELECTRODE FORCE: 8 lbs
ENERGY: 33 watt-seconds

* 50% lead deformation
** 50% setdown
~ Interface spitting

File No.

5

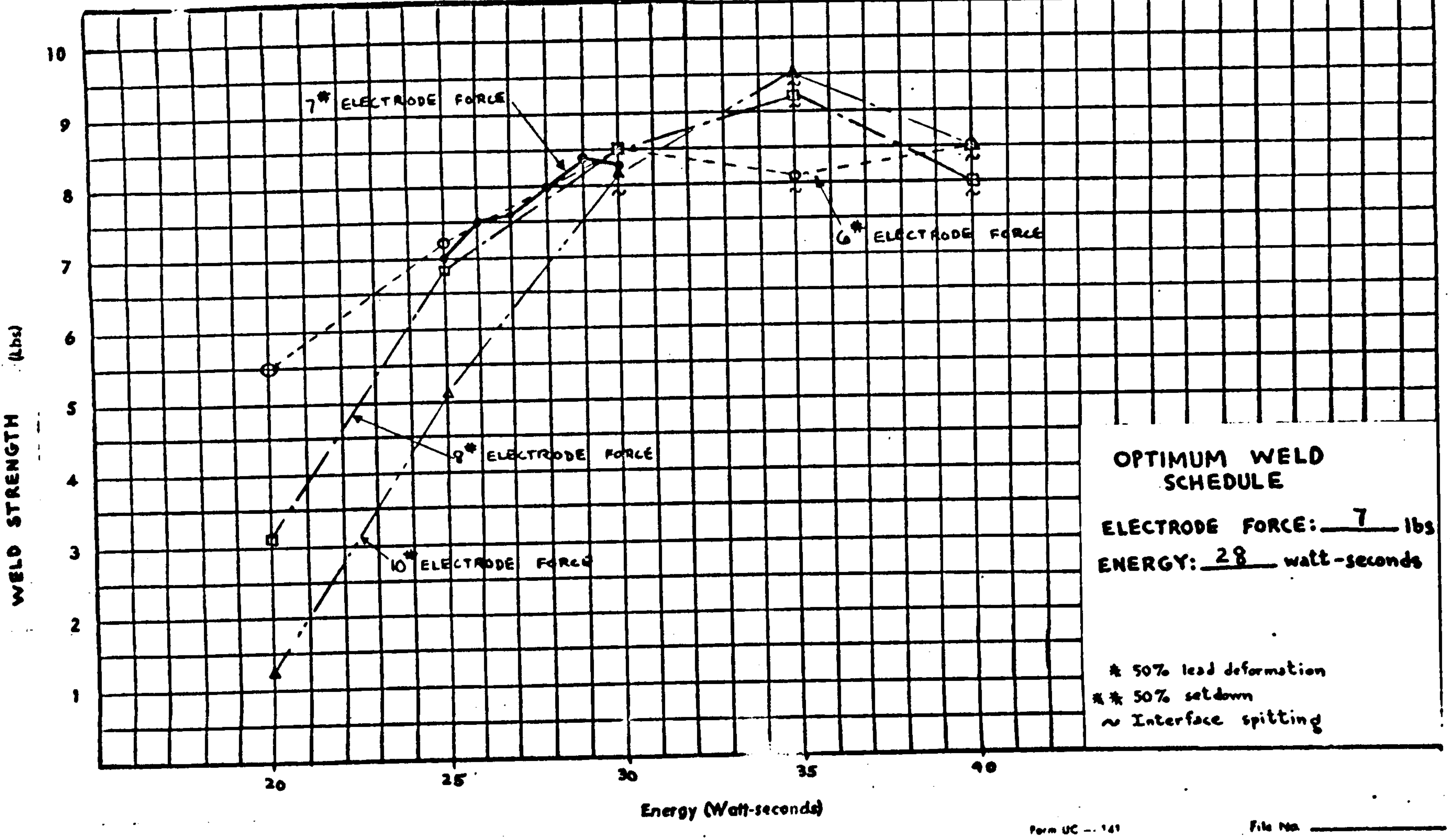
ISOFORCE DIAGRAM



Type RWNA-1
Polarity –
Mat'l. INCO 200
Size .010 x .030
Mat'l. COPPER
Size .020 D
Type RWNA-2
Polarity +
Offset 70°

Component Part Data

Name JOINT # 1.6
Mfgr.
Rating
Spec.
Lead –
Size 0.020 " diam.
Mat'l. COPPER
Plating Solder
Strength 11.0 Lbs.



OPTIMUM WELD SCHEDULE

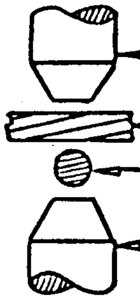
ELECTRODE FORCE: 7 lbs
ENERGY: 28 watt-seconds

* 50% lead deformation
** 50% setdown
~ Interface spitting

Form UC – 141

File No.

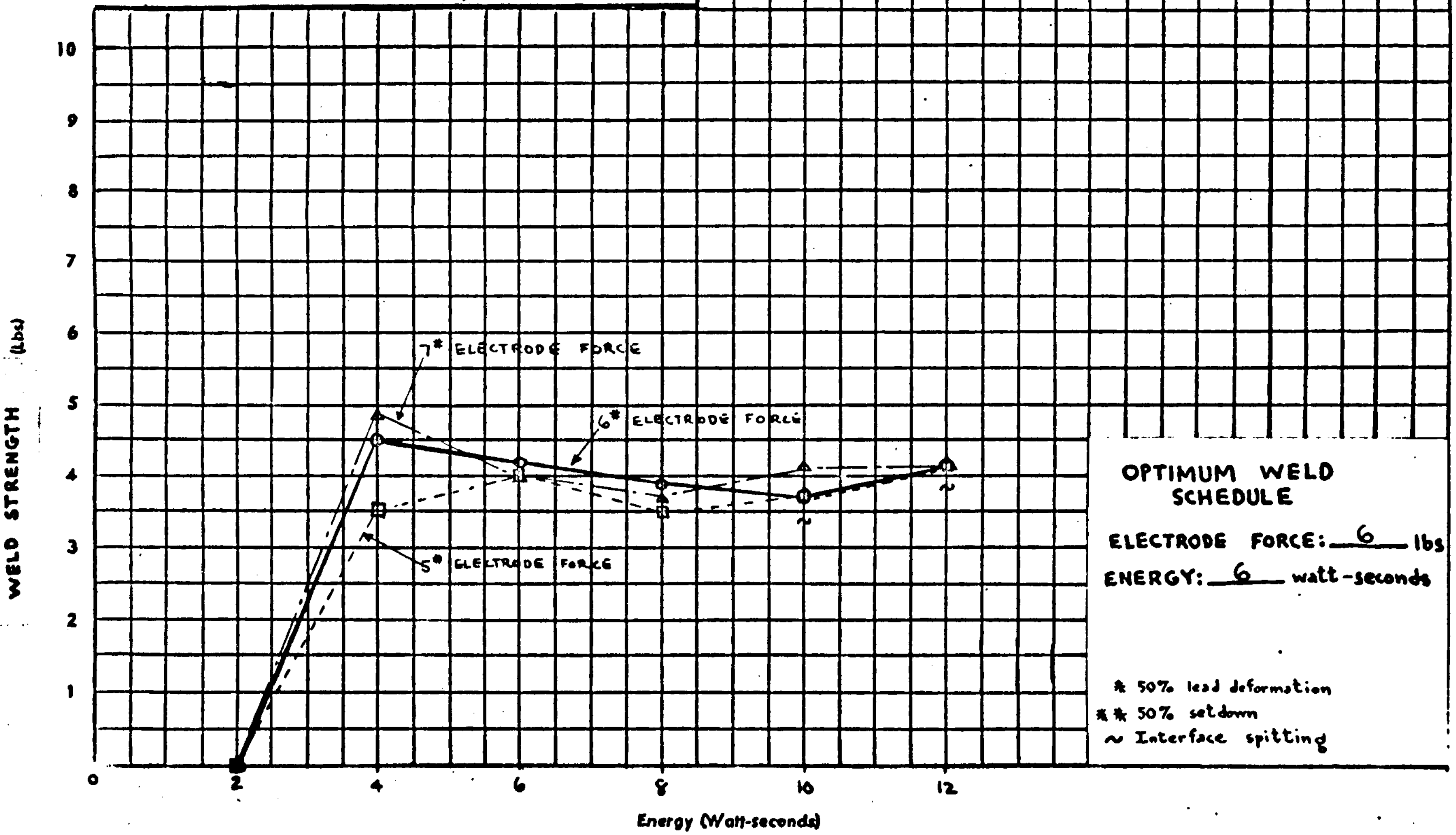
ISOFORCE DIAGRAM



Type RWMA-2
Polarity —
Mat'l KOVAR
Size .005 x .016
Mat'l KOVAR
Size .005 x .016
Type RWMA-2
Polarity +
Offset 70°

Component Part Data

Name JOINT # 2.
Mfgr.
Rating
Spec.
lead —
Size 0.005" x 0.016"
Mat'l KOVAR
Plating Gold
Strength 6.0 Lbs.



OPTIMUM WELD SCHEDULE

ELECTRODE FORCE: 6 lbs
ENERGY: 6 watt-seconds

Form UC -- 141

File No.

ATTACHMENT 2

RAW DATA SHEETS

JPL CONTRACT - 951069

Page 1

TEST ULTIMATE STRENGTH – Solder Joints

TYPE OF JOINT Stranded conductor to CINCH connector cup (1.1.1)
Stranded conductor to BENDIX connector cup (1.1.2)

TESTED BY JOHN HOLBERTON

DATE 7-2-65

Equipment: Hunter Spring Tensile Tester, Model TJN
Serial No. 175
Mechanical Force Gage, Model D-50-T
Serial No. 261, Calibrated on 4/26/65

W = wire failure
J = Joint failure

All values in pounds

JOINT NO. 1.1.1	STRENGTH (before heat)	JOINT NUMBER 1.1.1	STRENGTH (after heat sterilization)	JOINT No. 1.1.2	STRENGTH (BEFORE HEAT)	JOINT No. 1.1.2	STRENGTH (AFTER HEAT STERILIZATION)
1	15.0 w	41	14.5 w	1	14.5 w	41	14.5 w
2	14.5 w	42	14.5 w	2	14.5 w	42	14.5 w
3	14.5 w	43	14.0 w	3	14.5 w	43	14.5 w
4	15.0 w	44	14.5 w	4	14.5 w	44	14.5 w
5	14.5 w	45	14.5 w	5	14.5 w	45	14.5 w
6	14.5 w	46	14.5 w	6	15.0 w	46	14.5 w
7	14.5 w	47	14.5 w	7	15.0 w	47	14.5 w
8	14.5 w	48	14.5 w	8	15.0 w	48	14.5 w
9	15.0 w	49	14.5 w	9	15.0 w	49	14.5 w
10	14.5 w	50	14.5 w	10	14.5 w	50	14.5 w
11	15.0 w	51	14.5 w	11	15.0 w	51	14.5 w
12	14.5 w	52	14.5 w	12	14.5 w	52	14.5 w
13	14.5 w	53	14.5 w	13	15.0 w	53	14.5 w
14	14.5 w	54	14.5 w	14	14.5 w	54	14.5 w
15	14.5 w	55	14.5 w	15	15.0 w	55	14.5 w
16	14.5 w	56	14.5 w	16	14.5 w	56	14.5 w
17	14.5 w	57	15.0 w	17	14.5 w	57	14.5 w
18	14.5 w	58	14.5 w	18	14.5 w	58	14.5 w
19	15.0 w	59	14.5 w	19	14.5 w	59	14.5 w
20	14.5 w	60	14.5 w	20	14.5 w	60	14.5 w
21	14.5 w	61	15.0 w	21	14.5 w	61	14.5 w
22	14.5 w	62	14.5 w	22	15.0 w	62	14.5 w
23	14.5 w	63	15.0 w	23	14.5 w	63	14.5 w
24	14.5 w	64	14.5 w	24	14.5 w	64	14.5 w
25	14.5 w	65	14.5 w	25	14.5 w	65	14.5 w
26	14.5 w	66	15.0 w	26	14.5 w	66	14.5 w
27	14.5 w	67	14.5 w	27	14.5 w	67	14.5 w
28	14.5 w	68	14.5 w	28	14.5 w	68	14.5 w
29	14.5 w	69	14.5 w	29	14.5 w	69	14.5 w
30	14.5 w	70	14.5 w	30	14.5 w	70	14.5 w
31	15.0 w	71	14.5 w	31	14.5 w	71	14.5 w
32	15.0 w	72	14.5 w	32	14.5 w	72	14.5 w
33	15.0 w	73	14.5 w	33	14.5 w	73	14.5 w
34	14.5 w	74	14.5 w	34	14.5 w	74	15.0 w
35	15.0 w	75	14.5 w	35	15.0 w	75	14.5 w
36	14.5 w	76	14.5 w	36	14.5 w	76	14.5 w
37	14.5 w	77	14.5 w	37	14.5 w	77	14.5 w
38	14.5 w	78	14.5 w	38	14.5 w	78	14.5 w
39	15.0 w	79	14.5 w	39	15.0 w	79	14.5 w
40	14.5 w	80	14.5 w	40	14.5 w	80	14.5 w

7-2-65

7-6-65

PROJECT ENGR. F. KEISTER

JPL CONTRACT · 951069

Page 2

TEST ULTIMATE STRENGTH – Solder Joints

TYPE OF JOINT STRANDED CONDUCTOR TO SOLDER COATED BIFURCATED TERMINAL (1.2)
Gold plated copper to solder coated bifurcated terminal (1.3.1)

TESTED BY JOHN HOLBERTON **DATE** 7-6-65

W = WIRE FAILURE
J = JOINT FAILURE

ALL VALUES IN POUNDS

JOINT No 1.2	STRENGTH (BEFORE HEAT)	JOINT NO 1.2	STRENGTH (AFTER HEAT)	JOINT No. 1.3.1	STRENGTH (before heat)	JOINT NO 1.3.1	STRENGTH (AFTER HEAT)
1	14.5 W	41	15.0 W	1	11.0 W	41	11.5 W
2	14.5 J	42	13.5 J	2	10.5 W	42	10.5 W
3	15.0 J	43	15.5 W	3	10.5 W	43	11.5 W
4	15.0 W	44	14.5 W	4	10.5 W	44	10.5 W
5	15.0 W	45	14.5 W	5	11.0 W	45	11.0 W
6	15.0 J	46	15.0 W	6	10.5 W	46	11.0 W
7	15.0 W	47	15.0 W	7	10.5 W	47	11.0 W
8	15.0 W	48	12.5 J	8	10.5 W	48	11.0 W
9	14.5 W	49	15.5 W	9	10.5 W	49	10.5 W
10	15.0 W	50	15.0 W	10	10.5 W	50	11.0 W
11	15.0 W	51	14.5 J	11	10.5 W	51	11.0 W
12	13.5 J	52	16.0 W	12	10.5 W	52	10.5 W
13	15.0 W	53	15.5 W	13	11.0 W	53	11.0 W
14	15.0 W	54	15.0 J	14	10.5 W	54	11.5 W
15	15.0 W	55	12.5 J	15	10.5 W	55	10.5 W
16	15.5 W	56	14.5 W	16	11.0 W	56	11.0 W
17	13.0 J	57	15.0 W	17	10.5 W	57	10.5 W
18	15.0 W	58	14.5 J	18	10.5 J	58	11.0 W
19	15.0 W	59	15.0 W	19	10.5 W	59	10.5 W
20	15.0 W	60	14.5 W	20	10.5 W	60	10.5 W
21	15.0 J	61	15.5 W	21	10.5 W	61	10.5 W
22	15.5 W	62	14.5 W	22	10.5 W	62	10.5 W
23	15.5 W	63	14.5 W	23	10.5 W	63	11.0 W
24	15.0 W	64	15.0 W	24	9.5 W	64	11.0 W
25	15.0 W	65	14.5 W	25	10.5 W	65	11.0 W
26	15.5 W	66	13.0 J	26	10.5 W	66	10.5 J
27	15.0 W	67	15.5 J	27	10.0 W	67	10.5 W
28	15.5 W	68	14.5 J	28	10.5 W	68	11.0 W
29	15.5 W	69	15.0 W	29	10.5 W	69	10.5 W
30	15.0 W	70	15.0 W	30	10.5 W	70	10.5 W
31	15.5 W	71	14.5 W	31	10.0 W	71	11.0 W
32	15.0 W	72	14.5 W	32	10.5 W	72	11.0 W
33	15.0 W	73	14.5 W	33	10.5 W	73	10.5 W
34	15.0 W	74	14.5 W	34	10.5 W	74	11.0 W
35	15.0 J	75	14.5 W	35	11.0 W	75	11.0 W
36	15.5 W	76	14.5 W	36	10.5 W	76	10.5 W
37	15.0 W	77	15.5 J	37	10.5 W	77	11.0 W
38	15.0 W	78	14.5 J	38	10.5 W	78	11.0 W
39	15.0 W	79	13.0 J	39	11.0 W	79	10.5 W
40	15.0 W	80	15.0 W	40	11.0 W	80	11.0 W

7-2-65

PROJECT ENGR. F.KEISTER

JPL CONTRACT 951069

TEST ULTIMATE STRENGTH - Solder Joints

TYPE OF JOINT Solder coated copper to solder coated bifurcated terminal (1.3.2)
Gold plated Dumet to solder coated bifurcated terminal (1.3.3)

TESTED BY John Holberton DATE 7-6-65

W = WIRE FAILURE
J = JOINT FAILURE ALL VALUES IN POUNDS

JOINT NO 1.3.2	STRENGTH (BEFORE HEAT)	JOINT NO 1.3.2	STRENGTH (AFTER HEAT)	JOINT NO. 1.3.3	STRENGTH (BEFORE HEAT)	JOINT NO. 1.3.3	STRENGTH (AFTER HEAT)
1	11.5 W	41	10.0 J	1	25.5 J	41	23.5 J
2	11.0 W	42	11.5 W	2	26.0 W	42	16.5 J
3	11.5 W	43	11.5 W	3	26.0 W	43	20.5 J
4	11.0 W	44	11.5 W	4	26.0 W	44	25.0 W
5	11.0 W	45	11.0 W	5	26.5 W	45	25.0 W
6	11.5 W	46	11.0 W	6	22.0 J	46	25.0 W
7	10.0 J	47	11.5 W	7	18.5 J	47	21.5 J
8	11.5 W	48	[illegible]	8	25.5 J	48	24.5 J
9	11.0 W	49	11.0 W	9	27.0 W	49	25.0 W
10	11.0 W	50	10.5 J	10	18.5 J	50	25.0 W
11	11.5 W	51	11.0 W	11	24.0 J	51	[illegible]
12	11.0 W	52	9.0 J	12	26.0 W	52	17.5 J
13	11.5 W	53	11.5 J	13	26.0 W	53	22.5 J
14	11.5 W	54	11.5 W	14	26.0 W	54	25.0
15	11.0 W	55	11.0 W	15	22.0 J	55	24.0 J
16	11.0 W	56	10.5 J	16	26.0 J	56	25.5 W
17	11.0 W	57	11.0 W	17	22.0 J	57	25.0 W
18	11.0 W	58	11.0 W	18	22.5 J	58	23.5 J
19	11.5 W	59	11.0 W	19	26.0 W	59	17.5 J
20	11.5 W	60	11.5 W	20	26.0 J	60	24.5 W
21	12.0 W	61	11.0 W	21	24.0 J	61	25.0 J
22	12.0 W	62	11.0 W	22	26.0 W	62	25.0 J
23	12.0 W	63	11.5 W	23	25.5 W	63	24.5 W
24	12.5 W	64	11.0 W	24	23.5 J	64	23.5 J
25	9.5 J	65	11.0 J	25	23.5 J	65	24.0 J
26	11.5 W	66	11.5 W	26	26.5 W	66	75.0
27	11.0 J	67	11.0 W	27	22.5 J	67	25.0 J
28	13.0 W	68	11.0 W	28	19.0 J	68	20.5 J
29	12.0 J	69	11.0 W	29	26.0 W	69	17.5 J
30	10.5 J	70	11.0 W	30	26.0 W	70	25.0 J
31	12.0 W	71	11.0 W	31	25.0 J	71	25.5 W
32	12.5 W	72	11.0 W	32	23.0 J	72	24.5 J
33	11.5 W	73	[illegible]	33	26.5 W	73	25.[illegible] W
34	12.0 W	74	11.5 W	34	26.0 W	74	18.5 J
35	12.0 W	75	11.5 W	35	20.5 J	75	25.5 W
36	11.0 J	76	11.5 W	36	21.5 J	76	18.5 J
37	10.5 J	77	11.0 W	37	24.5 J	77	24.[illegible]
38	13.0 W	78	[illegible]	38	22.0 J	78	25.[illegible]
39	12.0 W	79	10.0 J	39	19.0 J	79	17.5 J
40	12.0 W	80	[illegible]	40	25.5 W	80	25.5 J

PROJECT ENGR. F. KEISTER

JPL CONTRACT 951069

TEST ULTIMATE STRENGTH - Solder Joints

TYPE OF JOINT Gold plated Kovar (0.018") to solder coated bifurcated terminal (1.3.4)
Gold plated nickel (.025") to solder coated bifurcated terminal (1.3.5)

TESTED BY JOHN HOLBERTON DATE 7-7-65

W = WIRE FAILURE
J = JOINT FAILURE

ALL VALUES IN POUNDS

JOINT No. 1.3.4	STRENGTH (BEFORE HEAT)	JOINT NO 1.3.4	STRENGTH (AFTER HEAT)	JOINT No 1.3.5	STRENGTH (BEFORE HEAT)	JOINT No 1.3.5	STRENGTH (AFTER HEAT)
1	19.5 J	41	17.0 J	1	29.0 J	41	31.5 J
2	23.0 W	42	23.0 W	2	34.5 J	42	24.5 J
3	23.0 W	43	22.5 W	3	20.5 J	43	25.5 J
4	22.0 J	44	22.0 J	4	35.0 J	44	32.5 J
5	23.0 W	45	23.5 J	5	21.0 J	45	32.0 J
6	19.5 J	46	17.5 J	6	32.0 J	46	34.5 J
7	22.0 J	47	23.0 W	7	23.5 J	47	30.0 J
8	23.0 W	48	22.5 W	8	35.0 J	48	27.5 J
9	18.0 J	49	23.0 W	9	30.5 J	49	24.0 J
10	21.0 J	50	22.5 J	10	28.5 J	50	25.0 J
11	23.5 W	51	18.5 J	11	22.0 J	51	31.5 J
12	21.0 J	52	23.0 J	12	26.0 J	52	26.0 J
13	22.5 J	53	23.0 W	13	27.5 J	53	34.5 J
14	20.0 J	54	17.5 J	14	31.5 J	54	29.5 J
15	22.5 W	55	19.5 J	15	24.0 J	55	28.0 J
16	23.0 W	56	22.5 W	16	29.0 J	56	26.0 J
17	18.0 J	57	22.5 W	17	32.5 J	57	27.0 J
18	23.0 J	58	22.5 W	18	32.5 J	58	29.0 J
19	22.5 W	59	22.5 W	19	22.5 J	59	31.0 J
20	19.5 J	60	18.0 J	20	30.0 J	60	23.5 J
21	23.5 W	61	23.0 W	21	30.0 J	61	29.0 J
22	22.5 J	62	22.5 W	22	39.0 J	62	23.5 J
23	23.0 J	63	19.0 J	23	24.5 J	63	36.0 J
24	23.5 W	64	22.0 J	24	28.5 J	64	31.0 J
25	20.0 J	65	17.5 J	25	28.5 J	65	35.0 J
26	23.5 W	66	22.5 W	26	24.0 J	66	30.5 J
27	21.0 J	67	18.0 J	27	23.0 J	67	22.5 J
28	23.0 W	68	22.5 W	28	26.5 J	68	26.5 J
29	21.5 J	69	22.5 W	29	25.5 J	69	34.0 J
30	21.0 J	70	22.5 W	30	28.0 J	70	35.5 J
31	18.5 J	71	20.5 J	31	21.0 J	71	31.5 J
32	20.0 J	72	22.5 W	32	21.0 J	72	36.5 J
33	18.5 J	73	18.5 J	33	20.0 J	73	22.0 J
34	23.5 J	74	22.5 W	34	25.0 J	74	26.0 J
35	23.0 J	75	23.0 W	35	37.0 W	75	33.0 J
36	23.0 W	76	18.0 J	36	29.0 J	76	23.0 J
37	22.0 J	77	22.5 W	37	23.0 J	77	27.5 J
38	23.0 W	78	18.5 J	38	21.5 J	78	29.5 J
39	20.5 J	79	22.5 W	39	21.0 J	79	25.0 J
40	17.0 J	80	22.5 W	40	36.5 J	80	20.0 J

PROJECT ENGR. F. KEISTER

JPL CONTRACT 951069

TEST ULTIMATE STRENGTH - Solder Joints

TYPE OF JOINT Bare nickel to solder coated bifurcated terminal (1.3.6)
Gold plated copper to gold plated bifurcated terminal (1.4)

TESTED BY JOHN HOLLERTON DATE 1-7-65

W = WIRE FAILURE
J = JOINT FAILURE

ALL VALUES IN POUNDS

JOINT No 1.3.6.	STRENGTH (BEFORE HEAT)	JOINT No 1.3.6	STRENGTH (AFTER HEAT STERILIZATION)	JOINT No 1.4	STRENGTH BEFORE HEAT	JOINT No 1.4	STRENGTH (AFTER HEAT)
1	35.5 J	41	30.0 J	1	12.0 W	41	11.[illegible]
2	28.0 J	42	40.0 J	2	12.0 W	42	11.5 W
3	26.0 J	43	27.5 J	3	13.0 W	43	11.0 W
4	29.5 J	44	34.[illegible]	4	13.0 W	44	11.5 W
5	34.0 J	45	31.5 J	5	12.5 W	45	11.5 W
6	23.5 J	46	28.0 J	6	11.5 W	46	11.5 W
7	23.0 J	47	25.5 J	7	12.5 W	47	11.5 W
8	29.0 J	48	27.0 J	8	12.5 W	48	11.5 J
9	23.5 J	49	28.0 J	9	12.5 W	49	11.5 W
10	39.0 J	50	31.0 J	10	12.5 W	50	11.[illegible]
11	30.5 J	51	15.[illegible]	11	13.5 W	51	11.5 W
12	30.0 J	52	30.[illegible]	12	12.0 W	52	11.[illegible]
13	25.0 J	53	24.5 J	13	11.5 W	53	11.0 W
14	22.0 J	54	22.0 J	14	11.5 W	54	11.[illegible]
15	30.5 J	55	[illegible].5 J	15	13.0 W	55	11.[illegible]
16	22.0 J	56	22.[illegible]	16	12.0 W	56	[illegible]
17	22.5 J	57	29.5 J	17	12.0 W	57	11.[illegible]
18	24.5 J	58	24.0 J	18	11.5 W	58	11.5 [illegible]
19	29.0 J	59	36.5 J	19	11.5 W	59	11.0 W
20	36.5 J	60	24.0 J	20	11.0 W	60	11.0 J
21	29.0 J	61	27.[illegible]	21	12.0 W	61	11.0 W
22	20.0 J	62	37.0 J	22	10.5 W	62	11.[illegible]
23	38.5 J	63	27.5 J	23	11.0 W	63	11.0 W
24	23.5 J	64	25.5 J	24	11.5 W	64	11.0 W
25	25.0 J	65	27.0 J	25	11.5 W	65	11.0 W
26	39.0 J	66	31.5 J	26	11.5 W	66	11.0 W
27	36.5 J	67	23.0 J	27	11.0 W	67	11.0 W
28	26.0 J	68	24.5 J	28	11.5 W	68	10.5 W
29	30.5 J	69	24.5 J	29	11.0 W	69	11.0 W
30	28.5 J	70	3[illegible]	30	11.5 W	70	11.0 W
31	26.0 J	71	28.5 J	31	11.5 W	71	11.[illegible]
32	33.0 J	72	24.0 J	32	11.0 W	72	11.0 W
33	30.0 J	73	27.5 J	33	11.0 W	73	[illegible]
34	22.5 J	74	33.0 J	34	11.0 W	74	11.0 W
35	27.0 J	75	32.0 J	35	11.5 W	75	11.0 W
36	32.5 J	76	22.5 J	36	11.0 W	76	10.5 W
37	37.0 J	77	24.0 J	37	11.0 W	77	[illegible]
38	29.5 J	78	34.5 J	38	11.0 W	78	11.0 W
39	27.0 J	79	23.5 J	39	11.5 W	79	11.0 W
40	31.0 J	80	24.[illegible]	40	12.5 W	80	11.0 W

PROJECT ENGR. F. KEISTER

JPL CONTRACT 951069

TEST ULTIMATE STRENGTH - Solder Joint

TYPE OF JOINT ¼ WATT RESISTOR TO SOLDER COATED BIFURCATED TERMINAL

TESTED BY JOHN HOLBERTON **DATE** 7-7-65

W = WIRE FAILURE
J = JOINT FAILURE

ALL VALUES IN POUNDS

JOINT NO. 1.5.	STRENGTH (BEFORE HEAT)	JOINT NO. 1.5	STRENGTH (after heat sterilization)				
1	20.0 W	41	16.0 J				
2	14.0 J	42	19.0 J				
3	22.5 J	43	19.5 W				
4	20.0 W	44	18.5 J				
5	21.5 J	45	26.0 W				
6	19.5 W	46	20.5 J				
7	20.5 J	47	19.0 W				
8	22.0 J	48	22.0 W				
9	23.0 J	49	20.5 W				
10	20.5 W	50	19.5 W				
11	22.0 J	51	22.0 W				
12	21.0 J	52	19.0 W				
13	24.0 J	53	11.0 J				
14	22.0 W	54	19.[illegible] J				
15	22.5 W	55	20.0 J				
16	22.0 J	56	19.0 W				
17	20.5 J	57	17.0 J				
18	24.0 J	58	19.5 J				
19	19.5 W	59	18.5 J				
20	21.0 J	60	16.0 [illegible]				
21	21.5 J	61	20.5 W				
22	19.5 W	62	18.0 J				
23	22.5 J	63	19.5 J				
24	22.0 J	64	22.0 J				
25	21.5 J	65	21.0 J				
26	19.0 W	66	19.0 W				
27	22.0 J	67	20.0 W				
28	22.0 J	68	21.5 J				
29	18.0 J	69	24.0 J				
30	21.0 J	70	13.[illegible] J				
31	22.0 J	71	18.0 J				
32	21.0 J	72	19.0 W				
33	22.0 J	73	19.5 J				
34	22.5 J	74	16.5 J				
35	19.5 J	75	16.5 J				
36	20.5 J	76	21.5 W				
37	20.5 W	77	21.0 W				
38	21.5 J	78	22.0 W				
39	22.5 W	79	17.5 J				
40	22.0 J	80	21.5 W				

PROJECT ENGR. F. KEISTER

JPL CONTRACT 951069

Page 7

TEST ULTIMATE STRENGTH - WELD JOINTS

TYPE OF JOINT Bare nickel to Inco (1.1A) and Gold plated nickel to Inco (1.2A)

TESTED BY E. Manning **DATE** 8-2-65

W2 = wire broke adjacent to weld.
WS = Weld separation.

JOINT NO. 1.1 A	STRENGTH (before heat) in pounds	JOINT NO. 1.1 A	STRENGTH (after heat) in pounds 8-24-65	JOINT NO. 1.2 A	STRENGTH (before heat) in pounds	JOINT NO. 1.2 A	STRENGTH (after heat) in pounds 8-24-65
1	10.0 W2	41 L	10.5 W2	1	13.0 W2	41 L	12.0 W2
2	11.0 W2	42 R	10.5 W2	2	12.0 W2	42 R	13.0 W2
3	8.5 W2	43 L	9.0 W2	3	13.0 W2	43 L	12.5 W2
4	10.5 W2	44 R	8.0 W2	4	12.5 W2	44 R	12.5 W2
5	8.5 W2	45 L	9.0 W2	5	14.0 W2	45 L	12.5 W2
6	10.0 W2	46 R	9.5 W2	6	12.0 W2	46 R	13.0 W2
7	8.5 W2	47 L	9.0 W2	7	12.0 W2	47 L	11.5 W2
8	8.5 W2	48 R	8.0 W2	8	12.5 W2	48 R	13.0 W2
9	9.5 W2	49 L	10.5 W2	9	12.5 W2	49 L	12.0 WS
10	9.0 W2	50 R	8.5 W2	10	12.5 W2	50 R	13.5 W2
11	11.0 W2	51 L	10.5 W2	11	13.5 W2	51 L	13.0 W2
12	9.5 W2	52 R	11.0 W2	12	11.5 WS	52 R	12.5 W2
13	11.0 W2	53 L	8.0 W2	13	14.0 W2	53 L	12.5 W2
14	9.0 W2	54 R	9.5 W2	14	12.5 W2	54 R	13.5 W2
15	8.5 W2	55 L	10.5 W2	15	12.5 W2	55 L	13.0 W2
16	9.0 W2	56 R	9.0 W2	16	13.0 WS	56 R	12.5 W2
17	10.0 W2	57 L	8.5 W2	17	14.0 W2	57 L	12.5 W2
18	10.0 W2	58 R	9.0 W2	18	12.5 W2	58 R	12.5 W2
19	10.5 W2	59 L	9.0 W2	19	12.0 W2	59 L	14.0 W2
20	10.5 W2	60 R	9.0 W2	20	12.0 W2	60 R	12.5 W2
21	9.5 W2	61 L	10.5 W2	21	11.5 W2	61 L	12.5 W2
22	10.5 W2	62 R	9.5 W2	22	13.0 W2	62 R	12.5 W2
23	9.0 W2	63 L	7.5 WS	23	12.5 W2	63 L	12.0 W2
24	9.5 W2	64 R	7.5 W2	24	12.5 W2	64 R	12.0 W2
25	8.0 W2	65 L	10.5 W2	25	12.0 W2	65 L	12.5 W2
26	9.0 W2	66 R	9.0 W2	26	11.5 W2	66 R	12.0 W2
27	8.5 W2	67 L	9.5 W2	27	13.0 W2	67 L	12.0 W2
28	8.5 W2	68 R	9.0 W2	28	13.0 W2	68 R	11.5 W2
29	8.0 W2	69 L	11.0 W2	29	13.0 W2	69 L	11.5 W2
30	9.0 W2	70 R	11.0 W2	30	13.5 W2	70 R	12.0 W2
31	8.5 W2	71 L	10.0 W2	31	13.0 W2	71 L	12.0 W2
32	11.0 W2	72 R	10.5 W2	32	12.5 W2	72 R	12.0 W2
33	8.0 W2	73 L	11.0 W2	33	12.5 W2	73 L	12.5 W2
34	10.0 W2	74 R	11.0 W2	34	12.5 W2	74 R	12.5 W2
35	9.0 W2	75 L	9.5 W2	35	13.0 W2	75 L	11.0 W2
36	9.5 W2	76 R	11.0 W2	36	13.0 W2	76 R	10.5 W2
37	9.0 W2	77 L	10.5 W2	37	12.0 WS	77 L	11.0 WS
38	8.5 W2	78 R	10.5 W2	38	11.5 WS	78 R	13.0 W2
39	8.0 W2	79 L	10.0 W2	39	12.0 W2	79 L	12.0 W2
40	10.5 W2	80 R	8.5 W2	40	13.0 W2	80 R	13.0 W2

PROJECT ENGR. **F. KEISTER**

JPL CONTRACT 951069

TEST ULTIMATE STRENGTH - WELD JOINTS

TYPE OF JOINT Gold plated Kovar to Inco (1.3 A) and Gold plated Dumet to Inco (1.4 A)

TESTED BY E. Manning **DATE** 8-2-65

R2 = Ribbon broke adjacent to weld.
WS = weld separation

8-24-65 8-24-65

JOINT NO. 1.3 A	STRENGTH (before heat) in pounds	JOINT NO. 1.3A		STRENGTH (AFTER HEAT) LBS	JOINT NO. 1.4 A	STRENGTH (before heat) in pounds	JOINT NO. 1.4A		STRENGTH (AFTER HEAT) LBS
1	16.5 R2	41.	L	16.0 R2	1	12.0 R2	41.	L	12.0 R2
2	16.5 R2	42	R	17.0 R2	2	12.0 R2	42	R	12.5 R2
3	17.0 R2	43	L	16.5 R2	3	11.5 R2	43	L	12.5 R2
4	16.5 R2	44	R	17.5 R2	4	13.0 R2	44	R	12.0 R2
5	17.0 R2	45	L	17.5 R2	5	11.5 R2	45	L	12.0 R2
6	17.5 R2	46	R	17.0 R2	6	11.5 R2	46	R	12.0 R2
7	17.5 R2	47	L	16.5 R2	7	12.0 R2	47	L	11.5 R2
8	16.5 R2	48	R	16.0 R2	8	11.0 R2	48	R	11.5 R2
9	16.0 R2	49	L	16.5 R2	9	13.0 R2	49	L	11.5 R2
10	16.0 R2	50	R	17.0 R2	10	11.5 R2	50	R	11.5 R2
11	16.5 R2	51	L	17.0 R2	11	12.0 R2	51	L	11.5 R2
12	17.0 R2	52	R	17.5 R2	12	11.5 R2	52	R	11.5 R2
13	16.0 R2	53	L	17.0 R2	13	12.5 R2	53	L	13.0 R2
14	17.0 R2	54	R	17.0 R2	14	12.0 R2	54	R	12.5 R2
15	17.0 R2	55	L	18.5 R2	15	12.0 R2	55	L	11.5 R2
16	17.5 R2	56	R	16.5 R2	16	12.5 R2	56	R	12.0 R2
17	16.5 R2	57	L	17.5 R2	17	11.5 R2	57	L	12.0 R2
18	16.5 R2	58	R	17.0 R2	18	12.5 R2	58	R	12.0 R2
19	17.0 R2	59	L	16.5 R2	19	12.5 R2	59	L	11.5 R2
20	15.5 R2	60	R	16.5 R2	20	14.0 R2	60	R	11.5 R2
21	16.0 R2	61	L	16.0 R2	21	12.5 R2	61	L	12.5 R2
22	16.5 R2	62	R	14.5 WS	22	12.0 R2	62	R	12.0 R2
23	17.0 R2	63	L	16.0 R2	23	13.0 R2	63	L	12.0 R2
24	17.0 R2	64.	R	16.5 R2	24	12.5 R2	64.	R	11.5 R2
25	17.0 R2	65	L	17.0 R2	25	12.0 R2	65	L	11.0 R2
26	16.5 R2	66	R	17.0 R2	26	12.5 R2	66	R	11.0 R2
27	16.5 R2	67	L	16.5 R2	27	12.0 R2	67	L	12.5 R2
28	16.0 R2	68	R	16.5 R2	28	13.5 R2	68	R	12.5 R2
29	17.0 R2	69	L	16.0 R2	29	13.0 R2	69	L	12.5 R2
30	17.5 R2	70	R	15.5 R2	30	12.0 R2	70	R	12.0 R2
31	17.5 R2	71.	L	17.5 R2	31	12.0 R2	71	L	12.0 R2
32	17.5 R2	72	R	17.5 R2	32	13.0 R2	72	R	13.5 R2
33	16.5 R2	73	L	16.5 R2	33	12.5 R2	73	L	12.0 R2
34	17.0 R2	74	R	16.5 R2	34	12.0 R2	74	R	12.5 R2
35	16.5 R2	75	L	17.0 R2	35	14.0 R2	75	L	10.5 R2
36	16.5 R2	76	R	17.5 R2	→ 36	12.5 R2	76	R	10.5 R2
37	16.5 R2	77	L	16.5 R2	37	12.0 R2	77	L	11.5 R2
38	16.5 R2	78	R	16.5 R2	38	11.5 R2	78	R	14.0 R2
39	16.5 R2	79	L	16.0 R2	39	13.5 R2	79	L	12.0 R2
40	16.0 R2	80.	R	18.0 WS	40	13.5 R2	80	R	14.5 R2

PROJECT ENGR. F.KEISTER

JPL CONTRACT 951069

TEST ULTIMATE STRENGTH - WELD JOINTS

TYPE OF JOINT Gold plated copper to Inco (1.5A) and Solder coated copper to Inco (1.6A)

TESTED BY E. Manning **DATE** 8-3-65

W2 = wire broke adjacent to weld.
WS = weld separation

8-24-65

JOINT NO. 1.5A	STRENGTH (before heat) in pounds	JOINT NO. 1.5A	STRENGTH (AFTER HEAT) LBS	JOINT NO. 1.6A	STRENGTH (before heat) in pounds	JOINT NO. 1.6A	STRENGTH (AFTER HEAT) LBS
1	10.0 W2	41 L	9.5 W2	1	7.0 WS	[illegible] L	8.0 W2
2	10.0 W2	42 R	10.0 W2	2	8.0 W2	[illegible] R	7.5 WS
3	10.0 W2	[illegible] L	9.5 W2	3	7.0 WS	[illegible] L	7.0 WS
4	10.0 W2	44 R	9.5 W2	4	7.5 WS	[illegible] R	8.0 WS
5	10.0 W2	45 L	9.0 W2	5	7.5 WS	45 L	7.5 WS
6	10.0 W2	46 R	9.0 W2	6	7.5 WS	46 R	7.5 WS
7	10.0 W2	47 L	9.5 W2	7	7.5 WS	47 L	7.0 WS
8	10.0 W2	48 R	9.5 W2	8	7.5 WS	48 R	7.5 WS
9	10.0 W2	[illegible] L	9.0 W2	9	8.0 WS	[illegible] L	8.0 WS
10	10.0 W2	[illegible] R	9.5 W2	10	7.5 WS	[illegible] R	8.0 WS
11	10.0 W2	51 L	9.5 W2	11	7.5 WS	51 L	7.0 WS
12	10.0 W2	52 R	10.0 W2	12	7.0 WS	52 R	7.0 WS
13	10.0 W2	53 L	9.0 W2	13	8.0 WS	53 L	7.5 WS
14	10.0 W2	54 R	9.5 W2	14	8.0 WS	[illegible] R	7.0 WS
15	10.0 W2	[illegible] L	9.0 W2	15	7.5 WS	[illegible] L	7.0 WS
16	10.0 W2	[illegible] R	9.5 W2	16	7.5 WS	[illegible] R	7.5 WS
17	9.5 W2	[illegible] L	9.5 W2	17	7.5 WS	[illegible] L	7.5 WS
18	10.5 W2	[illegible] R	9.0 W2	18	7.5 WS	[illegible] R	8.0 WS
19	10.0 W2	[illegible] L	9.5 W2	19	7.0 WS	[illegible] L	7.0 WS
20	10.0 W2	[illegible] R	9.5 W2	20	7.0 WS	[illegible] R	7.5 WS
21	10.0 W2	61 L	8.5 W2	21	7.5 WS	[illegible] L	8.0 WS
22	9.5 W2	62 R	9.5 W2	22	7.5 WS	[illegible] R	7.5 WS
23	9.5 W2	[illegible] L	9.0 W2	23	8.0 WS	[illegible] L	7.5 WS
24	9.5 W2	[illegible] R	9.5 W2	24	7.5 WS	[illegible] R	7.5 WS
25	9.5 W2	[illegible] L	9.0 W2	25	7.0 WS	65 L	7.5 WS
26	10.0 W2	[illegible] R	9.5 W2	26	7.5 WS	[illegible] R	7.0 WS
27	10.0 W2	[illegible] L	9.5 W2	27	7.5 WS	[illegible] L	7.0 WS
28	10.5 W2	[illegible] R	9.5 W2	28	8.0 WS	[illegible] R	8.0 WS
29	9.5 W2	[illegible] L	9.0 W2	29	7.5 WS	[illegible] L	7.5 WS
30	10.0 W2	[illegible] R	9.5 W2	30	7.5 WS	[illegible] R	7.5 WS
31	10.0 W2	[illegible] L	9.0 W2	31	8.0 WS	71 L	7.5 WS
32	10.5 W2	[illegible] R	9.5 W2	32	8.0 WS	72 R	8.0 WS
33	10.0 W2	[illegible] L	9.0 W2	33	7.5 WS	[illegible] L	7.5 WS
34	10.0 W2	[illegible] R	9.5 W2	34	7.5 WS	[illegible] R	7.0 WS
35	10.0 W2	[illegible] L	9.5 W2	35	7.5 WS	[illegible] L	7.5 WS
36	10.5 W2	[illegible] R	10.0 W2	36	7.5 WS	[illegible] R	8.5 WS
37	9.5 W2	[illegible] L	9.0 W2	37	7.5 WS	[illegible] L	7.0 WS
38	9.5 W2	[illegible] R	9.0 W2	38	7.5 WS	[illegible] R	7.0 WS
39	9.5 W2	[illegible] L	10.0 W2	39	7.5 WS	[illegible] L	7.5 WS
40	9.5 W2	[illegible] R	9.5 W2	40	7.5 WS	[illegible] R	7.0 WS

PROJECT ENGR. F. KEISTER

JPL CONTRACT 951069

TEST ULTIMATE STRENGTH - weld Joint

TYPE OF JOINT Gold plated Kovar foil to itself.

TESTED BY

DATE 2-3-65

R2 = Ribbon broke adjacent to weld
W2 = Wire broke adjacent to weld

8-25-65

JOINT NO. 2 A	STRENGTH (before heat) in pounds		[illegible]	STRENGTH AFTER HEAT LBS			
1	3.0 R2		41 L	2.1 R2			
2	3.5 R2		[illegible] R	3.8 R2			
3	3.7 R2		[illegible] L	2.5 R2			
4	3.7 R2		[illegible] R	4.0 R2			
5	2.7 R2		[illegible] L	2.5 R2			
6	3.9 R2		[illegible] R	3.5 R2			
7	2.5 R2		[illegible] L	2.5 W2			
8	3.9 R2		[illegible] R	3.5 R2			
9	2.7 R2		[illegible] L	2.8 R2			
10	4.2 R2		[illegible] R	4.0 R2			
11	3.0 R2		[illegible] L	2.5 R2			
12	4.5 R2		[illegible] R	3.7 R2			
13	3.5 R2		[illegible] L	2.3 R2			
14	4.0 R2		[illegible] R	4.1 R2			
15	3.5 R2		55 L	2.7 R2			
16	4.4 R2		[illegible] R	4.1 R2			
17	3.1 R2		[illegible] L	3.2 W2			
18	4.4 R2		[illegible] R	3.9 R2			
19	3.0 R2		59 L	2.8 W2			
20	4.3 R2		[illegible] R	4.0 R2			
21	3.0 R2		[illegible] L	3.2 R2			
22	4.0 R2		[illegible] R	4.0 R2			
23	3.4 R2		[illegible] L	2.7 R2			
24	4.0 R2		[illegible] R	3.5 R2			
25	3.0 R2		[illegible] L	2.8 R2			
26	4.4 R2		[illegible] R	3.9 R2			
27	3.0 R2		[illegible] L	2.7 R2			
28	4.5 R2		[illegible] R	4.2 R2			
29	3.0 R2		[illegible] L	2.9 R2			
30	4.0 R2		[illegible] R	4.0 R2			
31	3.0 R2		[illegible] L	2.4 R2			
32	4.2 R2		[illegible] R	3.6 R2			
33	3.0 R2		[illegible] L	3.0 W2			
34	4.0 R2		[illegible] R	3.9 R2			
35	3.3 R2		[illegible] L	3.4 R2			
36	3.9 R2		[illegible] R	4.1 R2			
37	3.0 R2		[illegible] L	3.0 W2			
38	4.0 R2		[illegible] R	3.9 R2			
39	3.3 R2		[illegible] L	2.4 R2			
40	2.5 R2		[illegible] R	3.7 R2			

PROJECT ENGR. F. KEISTER

JPL CONTRACT 951069

TEST Electrical Resistance - Solder Joints

TYPE OF JOINT Stranded Conductor to CINCH cup & stranded conductor to BENDIX cup.
(1.1.1) (1.1.2)

TESTED BY D Cranmer **DATE** 7-15-65

NOTE: 200 gram weight used for contact pressure, where applicable

Joint No 1.1.1	Before heating Resistance ohm x 10^{-3}	After heating Resistance ohm x 10^{-3}	Strength lbs		Joint No 1.1.2	Before heating Resistance ohm x 10^{-3}	After heating Resistance ohm x 10^{-3}
41	.245	.225			41	.56	.51
42	.245	.23			42	.56	.53
43	.255	.24			43	.50	.49
44	.25	.245			44	.57	.53
45	.26	.25			45	.59	.54
46	.255	.24			46	.58	.51
47	.25	.24			47	.58	.52
48	.25	.245			48	.57	.51
49	.25	.24			49	.56	.54
50	.255	.245			50	.54	.56
51	.25	.235			51	.56	.53
52	.22	.215			52	.56	.51
53	.25	.24			53	.59	.52
54	.25	.25			54	.61	.53
55	.23	.215			55	.61	.56
56	.225	.225			56	.61	.52
57	.25	.225			57	.59	.50
58	.255	.235			58	.60	.54
59	.245	.22			59	.53	.50
60	.25	.23			60	.52	.50
61	.255	.23			61	.53	.53
62	.255	.235			62	.59	.54
63	.26	.24			63	.59	.54
64	.25	.25			64	.57	.50
65	.26	.24			65	.61	.50
66	.26	.23			66	.58	.51
67	.24	.21			67	.57	.52
68	.275	.26			68	.60	.53
69	.25	.235			69	.60	.54
70	.25	.23			70	.58	.51
71	.27	.25			71	.57	.49
72	.27	.25			72	.58	.52
73	.25	.23			73	.50	.50
74	.265	.24			74	.55	.55
75	.265	.24			75	.52	.52
76	.245	.23			76	.50	.52
77	.255	.24			77	.53	.52
78	.24	.22			78	.52	.52
79	.26	.24			79	.51	.51
80	.255	.25			80	.52	.53

7-15-65

PROJECT ENGR. F. KEISTER

JPL CONTRACT 951069

TEST Electrical Resistance - Solder Joints

TYPE OF JOINT Standed conductor to solder coated terminal (1.2) & Gold plated copper wire to solder coated terminal (1.3.1)

TESTED BY D. Cranmer **DATE**

Joint No 1.2	Before heating Resistance ohm x 10^{-3}	After heating Resistance ohm x 10^{-3}	Strength lbs		Joint No 1.3.1	Before heating Resistance ohm x 10^{-3}	After heating Resistance ohm x 10^{-3}
41	.16	.17			41	.23	.20
42	.16	.175			42	.24	.21
43	.17	.175			43	.215	.22
44	.185	.195			44	.24	.235
45	.165	.18			45	.245	.235
46	.185	.21			46	.215	.23
47	.175	.19			47	.21	.22
48	.165	.18			48	.225	.225
49	.18	.185			49	.20	.19
50	.175	.17			50	.22	.20
51	.165	.165			51	.225	.205
52	.165	.185			52	.22	.20
53	.16	.175			53	.22	.19
54	.18	.18			54	.225	.23
55	.17	.17			55	.225	.23
56	.16	.19			56	.23	.24
57	.165	.195			57	.22	.20
58	.16	.175			58	.21	.23
59	.165	.165			59	.225	.245
60	.16	.175			60	.24	.24
61	.195	.195			61	.225	.20
62	.150	.145			62	.22	.22
63	.18	.175			63	.23	.235
64	.185	.16			64	.215	.25
65	.165	.18			65	.22	.22
66	.18	.185			66	.23	.21
67	.16	.18			67	.22	.21
68	.18	.18			68	.215	.22
69	.16	.16			69	.22	.225
70	.165	.175			70	.215	.235
71	.195	.195			71	.235	.235
72	.18	.18			72	.215	.225
73	.185	.175			73	.22	.23
74	.17	.195			74	.23	.24
75	.175	.175			75	.21	.215
76	.16	.16			76	.22	.22
77	.18	.17			77	.23	.22
78	.16	.16			78	.215	.22
79	.15	.19			79	.215	.23
80	.16	.18			80	.22	.22

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JPL CONTRACT 951069

Hewlett Packard Model 425A
DC Micro Volt-Ammeter
Serial 399-01060
Calib. 6-18-65

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Daystrom Model 931 D.C. Milliammeter
No. 28020 Calib. 5-18-65

Ohmite No. 0528 rheostat, Series A

Kepco Model SM-36-5M
Voltage Regulated DC Power Supply
Serial C-28791

TEST Electrical Resistance - Solder Joints

TYPE OF JOINT Solder coated Cu to solder coated terminal (1.3.2) and gold plated Dumet to solder coated terminal (1.3.3)

TESTED BY D. Cranmer **DATE**

Joint No 1.3.2	Before heating Resistance ohm x 10^{-3}	After heating Resistance ohm x 10^{-3}	Joint No 1.3.3	Before heating Resistance ohm x 10^{-3}	After heating Resistance ohm x 10^{-3}		
41	.235	.235	41	.78	.74		
42	.21	.22	42	.70	.70		
43	.23	.235	43	.70	.68		
44	.23	.24	44	.68	.66		
45	.225	.205	45	.70	.70		
46	.20	.215	46	.76	.76		
47	.215	.215	47	.74	.71		
48	.225	.225	48	.69	.66		
49	.21	.23	49	.74	.72		
50	.21	.22	50	.73	.66		
51	.23	.24	51	.84	.91		
52	.23	.25	52	.72	.80		
53	.23	.235	53	.84	.89		
54	.22	.23	54	.71	.71		
55	.245	.25	55	.71	.71		
56	.235	.235	56	.81	.72		
57	.26	.25	57	.68	.66		
58	.235	.245	58	.74	.73		
59	.24	.26	59	.71	.73		
60	.215	.24	60	.77	.70		
61	.205	.215	61	.76	.70		
62	.205	.25	62	.78	.69		
63	.22	.265	63	.74	.74		
64	.22	.20	64	.76	.72		
65	.21	.235	65	.78	.72		
66	.20	.215	66	.75	.82		
67	.215	.215	67	.74	.84		
68	.22	.22	68	.70	.70		
69	.22	.24	69	.73	.73		
70	.21	.25	70	.76	.71		
71	.235	.22	71	.70	.74		
72	.215	.23	72	.77	.77		
73	.20	.21	73	.74	.80		
74	.22	.24	74	.77	.77		
75	.19	.22	75	.77	.74		
76	.205	.23	76	.76	.76		
77	.22	.24	77	.74	.71		
78	.24	.24	78	.76	.72		
79	.195	.225	79	.80	.82		
80	.22	.22	80	.77	.71		

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T ENGR. F.KEISTER

JPL CONTRACT 951069

TEST Electrical Resistance - Solder Joints

TYPE OF JOINT Au plated Kovar to solder coated terminal (1.3.4)
Au plated nickel to solder coated terminal (1.3.5)

TESTED BY D. Cronmer **DATE**

Joint No 1.3.4	Before heating Resistance ohm x 10^{-3}	After heating Resistance ohm x 10^{-3}	Strength lbs		Joint No 1.35	Before heating Resistance ohm x 10^{-3}	After heating Resistance ohm x 10^{-3}
41	1.3	2.2			41	.43	.40
42	3.2	3.2			42	.41	.37
43	2.55	3.0			43	.43	.38
44	4.1	3.9			44	.42	.36
45	2.55	3.5			45	.44	.44
46	2.9	3.0			46	.48	.43
47	3.2	3.8			47	.42	.39
48	3.2	3.2			48	.45	.40
49	3.0	3.2			49	.43	.40
50	3.0	2.8			50	.43	.38
51	2.8	2.8			51	.39	.34
52	3.6	3.9			52	.41	.36
53	3.0	2.9			53	.46	.46
54	2.8	2.8			54	.42	.34
55	3.2	2.8			55	.44	.39
56	2.3	3.2			56	.44	.39
57	2.85	2.9			57	.40	.38
58	4.0	2.9			58	.47	.42
59	2.6	2.5			59	.46	.44
60	4.0	3.4			60	.43	.40
61	3.0	2.8			61	.44	.38
62	2.5	1.9			62	.48	.38
63	3.6	4.0			63	.48	.37
64	4.1	3.2			64	.51	.37
65	3.3	3.8			65	.45	.36
66	3.4	3.3			66	.45	.39
67	2.4	2.2			67	.44	.38
68	3.3	3.3			68	.42	.37
69	3.3	2.75			69	.42	.39
70	3.1	3.7			70	.42	.38
71	3.1	2.7			71	.43	.39
72	2.75	2.5			72	.41	.41
73	2.50	3.6			73	.41	.40
74	3.0	2.9			74	.42	.37
75	2.4	2.9			75	.42	.40
76	3.7	3.2			76	.47	.37
77	2.5	2.5			77	.50	.46
78	3.6	3.8			78	.48	.42
79	3.2	4.3			79	.40	.39
80	2.6	2.7			80	.44	.37

PROJECT ENGR. F. KEISTER

JPL CONTRACT 951069

TEST Electrical Resistance - Solder Joints

TYPE OF JOINT Bare Ni to solder coated terminal (1.3.6)
Gold plated copper to gold plated terminal (1.4)

TESTED BY D. Cranmer **DATE**

Joint No 1, 3, 6	Before heating Resistance ohm x 10^{-3}	After heating Resistance ohm x 10^{-3}	Strength lbs		Joint No 1. 4	Before heating Resistance ohm x 10^{-3}	After heating Resistance ohm x 10^{-3}
41	.50	.46			41	.225	.23
42	.46	.43			42	.195	.215
43	.55	.42			43	.215	.22
44	.46	.42			44	.195	.225
45	.45	.43			45	.21	.20
46	.44	.43			46	.22	.26
47	.46	.45			47	.20	.235
48	.46	.47			48	.20	.22
49	.46	.44			49	.22	.20
50	.48	.44			50	.20	.185
51	.62	.58			51	.25	.25
52	.48	.42			52	.22	.22
53	.58	.55			53	.22	.22
54	.48	.47			54	.22	.22
55	.43	.43			55	.215	.225
56	.44	.45			56	.235	.21
57	.44	.41			57	.210	.21
58	.49	.51			58	.215	.22
59	.46	.41			59	.23	.215
60	.45	.41			60	.23	.185
61	.48	.47			61	.205	.21
62	.42	.44			62	.195	.20
63	.50	.48			63	.21	.21
64	.46	.43			64	.21	.21
65	.49	.45			65	.23	.20
66	.43	.40			66	.21	.20
67	.48	.44			67	.235	.22
68	.47	.41			68	.21	.21
69	.50	.45			69	.21	.21
70	.44	.43			70	.21	.205
71	.45	.41			71	.21	.20
72	.49	.46			72	.22	.215
73	.51	.40			73	.21	.20
74	.51	.43			74	.21	.195
75	.44	.40			75	.21	.21
76	.48	.40			76	.21	.21
77	.50	.49			77	.215	.215
78	.50	.44			78	.23	.20
79	.46	.42			79	.225	.23
80	.46	.42			80	.215	.21

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JPL CONTRACT. 951069

TEST Electrical Resistance

TYPE OF JOINT WELD JOINT - Bare nickel to Inco (1.1A) & Gold plated nickel to Inco (1.2A)

TESTED BY D Cranmer DATE

Joint No 1.1 A	Before heating Resistance ohm x 10^{-6}	After heating Resistance ohm x 10^{-6}	Strength lbs		Joint No 1.2 A	Before heating Resistance ohm x 10^{-6}	After heating Resistance ohm x 10^{-6}
41	-47.	-42			41	-36.	-35
42	-48.	-45			42	-32.	-32
43	-45.	-42			43	-30.	-31
44	-44.	-43			44	-32.	-33
45	-44.	-42			45	-30.	-30
46	-50.	-50			46	-27.	-33
47	-44.	-43			47	-33.	-33
48	-45.	-47			48	-32.	-32
49	-44.	-48			49	-30.	-30
50	-43.	-47			50	-27.	-28
51	-46.	-44			51	-38.	-33
52	-50.	-50			52	-32.	-32
53	-47.	-46			53	-33.	-32
54	-46.	-47			54	-32.	-32
55	-48.	-46			55	-34.	-31
56	-49.	-52			56	-33.	-33
57	-44.	-42			57	-34.	-33
58	-47.	-50			58	-33.	-33
59	-43.	-43			59	-34.	-26
60	-50.	-53.			60	-36.	-32
61	-48.	-47			61	-30.	-30
62	-50.	-51			62	-32.	-29
63	-50.	-50			63	-34.	-34
64	-44.	-47			64	-32.	-34
65	-43.	-44			65	-32.	-32
66	-51.	-49			66	-33.	-36
67	-44.	-44			67	-33.	-33
68	-48.	-47			68	-36.	-35
69	-47.	-46			69	-35.	-30
70	-48.	-49			70	-36.	-36
71	-46.	-45			71	-34.	-32
72	-48.	-50			72	-25.	-30
73	-48.	-45			73	-31.	-31
74	-44.	-48			74	-32.	-29
75	-48.	-49			75	-30.	-22
76	-48.	-49			76	-34.	-28
77	-45.	-48			77	-28.	-25
78	-47.	-48			78	-30.	-30
79	-48.	-48			79	-33.	-33
80	-44.	-44			80	-33.	-31

PROJECT ENGR. F.KEISTER

JPL CONTRACT 951069

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TEST Electrical Resistance - Weld Joints

TYPE OF JOINT Gold Plated Kovar to Inco (1.3A)
Gold plated Dumet. to Inco (1.4A)

TESTED BY D. Cranmer DATE

Joint No 1.3 A	Before heating Resistance ohm x 10^{-6}	After heating Resistance ohm x 10^{-6}	Strength lbs	
41	53.	73		
42	58.	68		
43	62.	110		
44	97.	90		
45	97.	99		
46	82.	70		
47	61.	63		
48	73.	88		
49	70.	84		
50	82.	110		
51	77.	77		
52	62.	74		
53	100.	80		
54	82.	70		
55	76.	84		
56	72.	75		
57	68.	78		
58	68.	210		
59	63.	63		
60	71.	78		
61	75.	77		
62	65.	78		
63	70.	68		
64	60.	110		
65	59.	72		
66	60.	64		
67	43.	72		
68	88.	72		
69	65.	130		
70	74.	82		
71	81	81		
72	70.	85		
73	62.	85		
74	64.	62		
75	70.	110		
76	75.	130		
77	75.	76		
78	68.	80		
79	58.	80		
80	52.	70		

Joint No 1.4 A	Before heating Resistance ohm x 10^{-6}	After heating Resistance ohm x 10^{-6}
41	8.0	- 50
42	14.	+ 10
43	* -0.2	- 7
44	19.	- 2
45	6.0	+ 6
46	12.	+ 7
47	11.	+ 8
48	24.	+ 20
49	7.0	- 10
50	- 3.5	- 23
51	7.	- 7
52	14.	* +.2
53	- 9.	- 17
54	16.	+ 10
55	11.	8
56	* 0.2	- 7
57	5.	+ 7.
58	13.	+ 8.0
59	9.0	- 32
60	- 10.0	+ 4
61	18.	- 16
62	- 2.	+ 17
63	- 5.	- 14
64	2.	8
65	- 16.	- 25
66	* +0.2	- 30.
67	2.0	- 3.0
68	36.	- 50.
69	- 5.5	- 5.5
70	- 45.	* - 0.2
71	4.0	- 12
72	20.	- 6
73	12.	- 36
74	- 12.	- 12
75	- 18.	- 21
76	7.	7
77	- 10.	- 9
78	72.	* + 0.2
79	15.	- 4.0
80	- 28.	- 28

7-22-65

* Almost too low a resistance to read accurately.

JPL CONTRACT 951069

TEST Electrical Resistance - Weld Joints

TYPE OF JOINT Gold plated Copper to Inco (1.5A)
Solder coated copper to Inco (1.6A)

TESTED BY D. Cranmer DATE

Joint No 1.5 A	Before heating Resistance ohm x 10^{-6}	After heating Resistance ohm x 10^{-6}	Strength lbs		Joint No 1.6 A	Before heating Resistance ohm x 10^{-6}	After heating Resistance ohm x 10^{-6}
41	- 10	- 42			41-	- 2.8	- 9
42	- 11	- 7			42	- 7.0	- 24
43	- 8	- 30			43	- 8.2	- 3
44	- 8	- 18			44	- 1.8	- 8.0
45	- 10	- 14			45	- 0.5	- 12
46	- 7.5	- 33			46	- 7.5	- 4.0
47	- 9.	- 12			47	- 7.4	- 10
48	- 18.	- 32			48	- 2.8	- 30
49	- 8.5	- 60.			49	- 4.8	- 10
50	- 16.	- 5			50	- 4.5	- 60
51	- 12.	- 2			51	- 0.2	- 19
52	- 16.	- 19			52	+ 2.2	- 32
53	- 10.	- 12			53	- 1.0	- 23
54	- 18.	- 24			54	+ 1.2	- 18
55	- 12.	- 28			55	+ 2.5	- 11
56	- 14.	- 24			56	- 42.0	- 16
57	- 18.	- 12			57	+ 3.0	- 16
58	- 10.	- 23			58	+ 0.5	- 6
59	- 11.	- 11			59	- 20.0	- 38
60	- 8.	- 13			60	+ 0.5	- 17
61	- 19.	- 7			61	- 18.0	- 35
62	- 10.	- 17			62	+ 2.5	- 16
63	- 15.	- 62			63	- 3.5	- 10
64	- 18.	- 24			64	- 19.0	- 40
65	- 17.	- 25			65	- 3.0	- 42
66	- 9.5	- 17			66	- 6.0	- 9
67	- 9.	- 13			67	- 10.0	- 30
68	- 11.	- 18			68	- 3.0	- 18
69	- 11.	- 21			69	+ 1.5	- 13
70	- 14.	- 23			70	- 23.	- 38
71	- 14.	- 20			71	- 0.2	- 22
72	- 10.	- 14			72	+ 2.0	- 5
73	- 20.	- 35			73	+ 0.2	- 17
74	- 14.	- 9			74	+ 2.8	- 5
75	- 15.	- 35			75	+ 3.5	- 7
76	- 5.	- 3			76	+ 2.5	- 20.
77	- 20.	- 40			77	- 2.0	- 14
78	- 10.	- 45			78	- 0.2	- 12
79	- 18.	- 13			79	+ 3.0	- 10
80	- 12.	- 20.			80	+ 1.6	- 15
	7-22-65	8-18-65				7-21-65	

JPL CONTRACT 951069

TEST Electrical Resistance-Weld Joint

TYPE OF JOINT Kovar foil to Kovar foil

TESTED BY D. Cranmer **DATE** ________________

Joint No 2 A	Before heating Resistance ohm x 10^{-6}	After heating Resistance ohm x 10^{-6}	Strength lbs				
41	- 480	- 480					
42	- 440	- 430					
43	- 410	- 410					
44	- 350	- 360					
45	- 460	- 460					
46	- 450	- 440					
47	- 500	- 500					
48	- 440	- 480					
49	- 410	- 410					
50	- 460	- 380					
51	- 500	- 500					
52	- 420	- 410					
53	- 410	- 410					
54	- 330	- 360					
55	- 410	- 410					
56	- 360	- 380					
57	- 360	- 380					
58	- 360	- 380					
59	- 410	- 410					
60	- 440	- 450					
61	- 380	- 380					
62	- 340	- 340					
63	- 400	- 410					
64	- 400	- 380					
65	- 420	- 410					
66	- 410	- 420					
67	- 430	- 420					
68	- 360	- 360					
69	- 440	- 440					
70	- 390	- 390					
71	- 400	- 410					
72	- 430	- 430					
73	- 390	- 390					
74	- 330	- 340					
75	- 390	- 400					
76	- 370	- 370					
77	- 440	- 440					
78	- 400	- 460					
79	- 400	- 410					
80	- 390	- 400					

PROJECT ENGR. F. KEISTER

JPL CONTRACT 951069

TEST STRESS - RUPTURE

TYPE OF JOINT STRANDED CONDUCTOR TO CINCH CONNECTOR CUP

TESTED BY JOHN HOLBERTON DATE 7-8-65 → 7-14-65

TEST CONDITION: 108 HOURS AT 21° C IN NORMAL ATMOSPHERE.

SAMPLE NUMBER	WEIGHT (lbs)	TIMER READINGS (HOURS) INITIAL	FINAL	ΔT HRS $T_F - T_I$	CREEP (YES OR NO) ⊗	REMARKS
111	1 lb. 10 oz	0.1	116.4	116.3	NO	NO FAILURE
112	3 lbs. 2 oz	0.1	116.4	116.3	No	NO FAILURE
113	4 lbs. 10 oz	0.1	116.4	116.3	No	NO FAILURE
114	6 lbs. 2 oz	0.1	116.4	116.3	No	NO FAILURE
115	7 lbs. 10 oz	0.1	116.4	116.3	No	NO FAILURE
116	9 lbs. 2 oz	0.1	37.5	37.4	—	JOINT FAILURE
117	10 lbs. 8 oz	0.1	90.8	90.7	—	JOINT FAILURE
118	12 lbs. 1 oz	0.1	16.6	16.5	No	BROKE WIRE EN FINCH CONNECTING WT. TO WIRE.
119	13 lbs 9 oz	0.1	0.1	2 MIN	No	CANTWIRLES AND BROKE WIRE
120	1 lb. 10 oz	116.4	231.7	115.3	No	No failure
121	3 lbs. 2 oz	116.4	231.7	115.3	NO	" "
122	4 lbs. 10 oz	116.4	231.7	115.3	NO	" "
123	6 lbs. 2 oz	116.4	231.3	114.9	—	Joint failure
124	7 lbs. 10 oz	116.4	231.6	115.2	NO	No failure
125	9 lbs. 2 oz	37.5	60.9	23.4	No	WIRE BROKE WHERE ATTACHED TO WEIGHT.
126	10 lbs. 8 oz	90.8	97.8	7.0	No	Crimp failure
127	12 lbs. 1 oz	16.8	21.1	4.3	NO	Wire failure
128	13 lbs 9 oz	0.1	0.2	4 MIN	No	WIRE FAILURE
129	1# 10 oz.	231.7	393.6	161.9	No	No failure
130	3# 2 oz.	231.7	393.6	161.9	No	No failure
131	4# 10 oz.	231.7	248.7	17.0	—	Joint failure
132	6# 2 oz.	231.3	393.1	161.8	No	No failure
133	7# 10 oz.	231.6	393.4	161.8	No	No failure
134	9# 2 oz.	60.9	71.1	10.2	—	Joint failure
135	10# 8 oz.	97.8	128.6	30.8	—	Joint failure
136	12# 1 oz.	21.1	28.2	7.1	—	Joint failure
137	13# 9 oz.	0.2	0.3	10 min.	No	wire failure (Fails when strands untwist)
138	1# 10 oz.	393.6	518.9	125.3	No	No failure
139	3# 2 oz.	393.6	518.9	125.3	NO	No failure
140	4# 10 oz.	248.7	373.9	135.2	No	No failure
141	6# 2 oz.	393.1	518.4	125.3	NO	No failure
142	7# 10 oz.	393.4	518.7	125.3	No	No failure
143	9# 2 oz.	71.1	155.5	84.4	—	Joint failure
144	10# 8 oz.	128.6	148.0	19.4	—	Joint failure
145	12# 1 oz.	28.2	42.0	13.8	No	Wire failure
146	13# 9 oz.	0.3	.4	.1	No	Wire failure

STARTED ON JULY 19 →

PROJECT ENGR. F. KEISTER

JPL CONTRACT 951069

TEST STRESS-RUPTURE @ room temperature (74°F)

TYPE OF JOINT Stranded conductor to BENDIX connector cup

TESTED BY J. Holberton DATE

TEST STARTED AT 5:30pm on July 31, 1965

SPECIMEN NUMBER 1.1.2	WEIGHT (pounds)	INITIAL TIME (T$_i$)	FINAL TIME (T$_f$)	TOTAL TIME (T$_f$ - T$_i$) hours	CREEP OBSERVED ?	Remarks
111	1 lb. 10 oz.	518.9	630.6	111.7	No	NO FAILURE
112	3 lb. 2 oz.	518.9	630.6	111.7	No	NO FAILURE
113	4 lb. 10 oz.	373.9	485.6	111.7	No	NO FAILURE
114	6 lb. 2 oz.	518.4	630.1	111.7	No	NO FAILURE
115	7 lb. 10 oz.	518.7	630.4	111.7	No	NO FAILURE
116	9 lb. 2 oz.	155.5	267.2	111.7	No	NO FAILURE
117	10 lb. 8 oz.	148.0	259.7	111.7	No	NO FAILURE
118	12 lb. 1 oz.	42.0	63.0	21.0	—	JOINT FAILURE
119	13 lb. 9 oz.	0.4	0.5	0.1	NO	Wire Failure
120	1 lb. 10 oz.	630.6	755.3	124.7	No	NO FAILURE
121	3 lb. 2 oz.	630.6	755.3	124.7	No	NO FAILURE
122	4 lb. 10 oz.	485.6	610.3	124.7	No	NO FAILURE
123	6 lb. 2 oz.	630.1	754.8	124.7	No	NO FAILURE
124	7 lb. 10 oz.	630.4	755.1	124.7	No	NO FAILURE
125	9 lb 2 oz.	267.2	391.9	124.7	No	NO FAILURE
126	10 lb. 8 oz.	259.7	384.4	124.7	No	NO FAILURE
127	12 lb. 1 oz	63.0	63.1	0.1	No	WIRE FAILURE
128	13 lb. 9 oz.	.5	.6	0.1	No	WIRE FAILURE
129	1 lb 10 oz	755.3	891.3	136.0	No	NO FAILURE
130	3 lb 2 oz	755.3	891.2	135.9	No	NO FAILURE
131	4 lb 10 oz	610.3	746.3	136.0	No	NO FAILURE
132	6 lb 2 oz	754.8	890.7	135.9	No	NO FAILURE
133	7 lb 10 oz	755.1	891.0	135.9	No	NO FAILURE
134	9 lb 2 oz	391.9	527.8	135.9	No	NO FAILURE
135	10 lb 2 oz	384.4	520.2	135.8	No	NO FAILURE
136	12 lb 1 oz	63.1	132.2	69.1	—	JOINT FAILURE
137	13 lb 9 oz	.6	0.7	0.1	No	WIRE FAILURE
138	1 lb 10 oz	0.0	135.7	135.7	No	NO FAILURE
139	3 lb 2 oz	0.0	135.7	135.7	No	NO FAILURE
140	4 lb 10 oz	0.0	135.7	135.7	No	NO FAILURE
141	6 lb 2 oz	0.0	135.7	135.7	No	NO FAILURE
142	7 lb 10 oz	0.0	135.7	135.7	No	NO FAILURE
143	9 lb 2 oz	0.0	135.7	135.7	No	NO FAILURE
144	10 lb 10	0.0	135.7	135.7	No	[illegible]
145	12 lb 3 oz	0.0	21.5	21.5	No	W[illegible]
146	13 lb 9 oz	0.0	0.1	0.1	No	WIRE FAILURE

PROJECT ENGR. F. KEISTER

TEST STRESS-RUPTURE DURING CONDITIONS OF HEAT STERILIZATION (N2 atmosphere) 145°C

TYPE OF JOINT STRANDED CONDUCTOR TO CINCH CONNECTOR CUP

TESTED BY F. Keister

DATE Last Calibrated on May 11, 1965
Next calibration due Nov. 11, 1965

#11 Hanging of 8913 Hours - light off

CONRAD Temperature - Altitude Chamber
Holland, Mich. Model No. FH8-3-3
Serial No. 7268

Time Meter readings

	SPECIMEN NUMBER	WEIGHT (POUNDS)	INITIAL TIME (T_i)	FINAL TIME (T_f)	TOTAL TIME in hours (T_f-T_i)	CREEP OBSERVED	
	147	1lb 10oz	891.3	—	—	— *	SEE NOTE ATTACHED
	148	3lb 2oz	891.2	[illegible]	0.8	—	JOINT FAILURE
	149	4lb 10oz	746.3	[illegible]	0.9	—	JOINT FAILURE
	150	6lb 2oz	890.9	[illegible]	0.6	—	JOINT FAILURE
	151	7lb 10oz	891.0	[illegible]	0.6	—	JOINT FAILURE
	152	9lb 2oz	527.8	[illegible]	0.6	—	JOINT FAILURE
	153	10lb 8oz	520.2	[illegible]	0.6	—	JOINT FAILURE
	154	12lb 1oz	132.2	[illegible]	0.4	No	WIRE FAILURE
	155	13lb 9oz	0.7	[illegible]	0.1	No	WIRE FAILURE
	156	1lb 10oz	135.7	137.4	1.7	—	JOINT FAILURE
	157	3lb 2oz	135.7	137.4	1.7	—	JOINT FAILURE
	158	4lb 10oz	135.7	136.5	0.8	—	JOINT FAILURE
	159	6lb 2oz	135.7	136.3	0.6	—	JOINT FAILURE
	160	7lb 10oz	135.7	136.3	0.6	—	JOINT FAILURE
	161	9lb 2oz	135.7	136.3	0.6	—	JOINT FAILURE
	162	[illegible]	135.7	136.2	0.5	—	JOINT FAILURE **
	163	12lb 1oz	21.5	21.6	0.1	No	WIRE FAILURE
	164	[illegible]	0.1	0.1	0	No	WIRE FAILURE ***
1	165	1lb 10oz	891.3	896.5	5.2	—	Joint failure
2	166	3lb 2oz	892.1	895.3	3.2	—	Joint failure
3	167	4lb 10oz	747.3	749.8	2.5	—	Joint failure
4	[illegible]	6lb 2oz	891.6	894.1	2.5	—	Joint failure
5	[illegible]	7lb 10oz	891.6	894.1	2.5	—	Joint failure
6	[illegible]	9lb 2oz	528.4	530.6	2.2	—	Joint failure
7	171	10lb 8oz	520.8	523.2	2.4	No	wire failure at the joint.
8	172	12lb 1oz	132.7	133.6	0.9	No	wire failure at the joint.
9	173	13lb 9oz	000.8	000.8	≅5 minutes	No	wire failure
10	174	1lb 10oz	137.4	140.3	2.9	—	Joint Failure
11	175	3lb 2oz	137.4	139.9	2.5	—	Joint Failure
12	176	4lb 10oz	136.5	138.8	2.3	—	Joint Failure
13	177	6lb 2oz	136.3	138.5	2.2	—	Joint Failure
14	178	7lb 10oz	136.3	138.4	2.1	—	Joint Failure
15	179	9lb 2oz	136.3	138.4	2.1	—	Joint Failure
16	180	10lb 8oz	136.2	138.2	2.0	—	Joint Failure
17	181	12lb 1oz	21.6	23.7	2.1	—	Joint Failure
18	182	13lb 8oz	000.1	000.1	≅4 minutes	No	wire failure

Heat applied at time = 0
N2 backfill started at time = 0

Heat on after 2.1 hours of hanging. @ 3:45 pm
85°C @ 3:55 pm
105°C @ 4:10 pm
145°C @ 4:15 pm

Started on Aug. 31, 1965
Loaded cans with shot.

* Microswitch failed. Joint still o.k. after 0.8 hours.

PROJECT ENGR. F. KEISTER

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JPL CONTRACT 951069

TEST STRESS-RUPTURE @ Sterilization Time & Temperature

TYPE OF JOINT Solder Joint → Stranded conductor to BENDIX connector cup.

TESTED BY F. Keister

DATE 9-2-65 thru 9-13-65

SPECIMEN NUMBER 1.1.2	LOAD	PERCENT OF ULTIMATE STRENGTH	INITIAL TIME METER READING T_I	FINAL TIME METER READING T_F	TOTAL TIME (hours) $T_F - T_I = T_T$	$(T_T - 3.5 \text{ hr.})$ TIME AFTER 145°C TEMP. REACHED	TYPE OF FAILURE
147	68 gm = .15 lb.	1	1) 896.5	1015.3	118.8	115.3	NONE
148	136 gm = .30 lb.	2	2) 895.3	1014.1	118.8	115.3	NONE
149	204 gm = .45 lb.	3	3) 749.8	868.6	118.8	115.3	NONE
150	272 gm = .60 lb.	4	4) 894.1	1012.8	118.7	115.2	NONE
151	341 gm = .75 lb.	5	5) 894.1	940.5	46.4	42.9	JOINT
152	1 lb. 8 oz.	10	6) 530.6	552.0	21.4	17.9	JOINT
153	2 lb. 4 oz.	15	7) 523.2	526.7	3.5	0.0	JOINT
154	3 lb. 0 oz.	20	8) 133.6	137.3	3.7	0.2	JOINT
155	3 lb. 12 oz.	25	9) 000.8	5.3	4.5	1.0	JOINT
156	.15 lb.	1	10) 140.3	258.8	118.5	115.0	NONE
157	.30 lb.	2	11) 139.9	258.4	118.5	115.0	NONE
158	.45 lb.	3	12) 138.8	257.4	118.6	115.1	NONE
159	.60 lb.	4	13) 138.5	256.9	118.4	114.9	NONE
160	.75 lb.	5	14) 138.4	256.8	118.4	114.9	NONE
161	1 lb. 8 oz.	10	15) 138.4	148.0	9.6	6.1	JOINT
162	2 lb. 4 oz.	15	16) 138.2	145.6	7.4	3.9	JOINT
163	3 lb. 0 oz.	20	17) 23.7	27.6	3.9	0.4	JOINT
164	3 lb. 12 oz.	25	18) 000.2	003.7	3.5	0.0	JOINT
						$(T_T - 1.0 \text{ hr.})$	
165	0.30 lb.	1) 2	1015.3	1152.1	136.8	135.8	NONE
166	0.45 lb.	2) 3	1014.1	1150.9	136.8	135.8	NONE
167	0.60 lb.	3) 4	868.6	1005.4	136.8	135.8	NONE
168	0.75 lb.	4) 5	1012.8	1149.6	136.8	135.8	NONE
169	1.125 lb.	5) 7.5	940.5	1023.0	82.5	81.5	JOINT
170	1.50 lb.	6) 10	552.0	588.9	36.9	35.9	JOINT
171	2.25 lb.	7) 15	526.7	549.9	23.2	22.2	JOINT
172	3.00 lb.	8) 20	137.3	140.0	2.7	1.7	JOINT
173	3.75 lb.	9) 25	5.3	8.6	3.3	2.3	JOINT
174	0.30 lb.	10) 2	258.8	395.5	136.7	135.7	NONE
175	0.45 lb.	11) 3	258.4	395.1	136.7	135.7	NONE
176	0.60 lb.	12) 4	257.4	394.1	136.7	135.7	NONE
177	0.75 lb.	13) 5	256.9	393.6	136.7	135.7	NONE
178	1.125 lb.	14) 7.5	256.8	287.9	31.1	30.1	JOINT
179	1.50 lb.	15) 10	148.0	187.2	39.2	38.2	JOINT
180	2.25 lb.	16) 15	145.6	150.6	5.0	4.0	JOINT
181	3.00 lb.	17) 20	27.6	29.8	2.2	1.2	JOINT
182	3.75 lb.	18) 25	003.7	005.6	1.9	0.9	JOINT

Test started @ 11:30 am on 9-2-65

Heat applied after 3 hr. hanging. 145°C reached after 3½ hr. hanging.

Test started @ 8:45 pm on Tues., Sept. 7, 1965

145°C reached @ 4:45 approx.

PROJECT ENGR. F. KEISTER

JPL CONTRACT 951069

TEST Electrical Test during Vibration - Solder Joints

TYPE OF JOINT 1.1.1 , 1.1.2 , and 1.2

TESTED BY Kassebaum

DATE 7-30-65

Current input = 100 milliamperes ac

Stranded conductor to CINCH cup.

BEFORE HEAT				AFTER HEAT (8-10-65)			
SPECIMEN NUMBER 1.1.1	JOINT RESISTANCE	% CHANGE IN JOINT RESISTANCE		SPECIMEN NUMBER 1.1.1	JOINT RESISTANCE	% CHANGE IN JOINT RESISTANCE	
91			RESONANT FREQUENCY = 244 cps	101			
92	0.0009 Ω	0		102	0.0009 Ω	0	
93				103			
94				104			
95				105			
96	0.0009 Ω	0		106	0.009 Ω	0	
97				107			
98				108			
99	0.00045 Ω	0		109	0.00045 Ω	0	
100				110			

Stranded conductor to CINCH cup

Stranded conductor to BENDIX cup

No Heat				After Heat			
SPECIMEN NUMBER 1.1.2	JOINT RESISTANCE	% OF CHANGE		SPECIMEN NUMBER 1.1.2	JOINT RESISTANCE	% OF CHANGE	
91	.00026	0	RESONANCE 170 CPS	101			
92				102	.00052	0	
93				103			
94	.00052	0		104			
95				105			
96				106	.00052	0	
97				107			
98	.00052	0		108			
99				109	.00026	0	
100				110			

Stranded conductor to BENDIX cup

Stranded conductor to solder coated terminal

NO HEAT				AFTER HEAT			
SPECIMEN NUMBER 1.2	JOINT RESISTANCE	% OF CHANGE		SPECIMEN NUMBER 1.2	JOINT RESISTANCE	% OF CHANGE	
91			RESONANCE 140 CPS	101			
92	.0004 Ω	0		102	.0004	0	
93				103			
94				104			
95				105			
96	.0004 Ω	0		106	.0004	0	
97				107			
98				108			
99	.0002 Ω	0		109	.0002	0	
100				110			

Stranded conductor to solder coated terminal

PROJECT ENGR. F. KEISTER

JPL CONTRACT 951069

TEST VIBRATION - Solder Joints

TYPE OF JOINT 1.3.1, 1.3.2, and 1.3.3

TESTED BY Ka

DATE 7-30-65

Current input = 100 milliamperes ac

Gold plated copper to solder coated terminal

No Heat / After Heat

SPECIMEN NUMBER 1.3.1	JOINT RESISTANCE	% OF CHANGE		SPECIMEN NUMBER 1.3.1	JOINT RESISTANCE	% OF CHANGE	
91			RESONANCE 220 cps	101			
92	000145Ω	0		102	.00023Ω	0	
93				103			
94	.00023Ω	0		104			
95				105			
96				106	.00023Ω	0	
97				107			
98	.00023Ω	0		108			
99				109	.000145Ω	0	
100				110			

Gold plated copper to solder coated terminal

Solder coated copper to solder coated terminal

No Heat / After Heat

SPECIMEN NUMBER 1.3.2	JOINT RESISTANCE	% OF CHANGE		SPECIMEN NUMBER 1.3.2	JOINT RESISTANCE	% OF CHANGE	
91	000125Ω	0	RESONANCE 252 cps	101			
92				102	.00025Ω	0	
93				103			
94	.00025Ω	0		104			
95				105			
96				106	.00025Ω	0	
97				107			
98	.00025Ω	0		108			
99				109	.000125Ω	5	
100				110			

Solder coated copper to solder terminal

Gold plated Dumet to solder coated terminal

No Heat / After Heat

SPECIMEN NUMBER 1.3.3	JOINT RESISTANCE	% OF CHANGE		SPECIMEN NUMBER 1.3.3	JOINT RESISTANCE	% OF CHANGE	
91			RESONANCE 190 cps	101			
92	.0007Ω	0		102	.0007	0	
93				103			
94				104			
95				105			
96	.0007Ω	0		106	.0007	0	
97				107			
98				108			
99	.00035Ω	0		109	.00035	0	
100				110			

Gold plated Dumet to solder terminal

PROJECT ENGR. F. KEISTER

JPL CONTRACT 951069

TEST VIBRATION - Solder Joints

TYPE OF JOINT 1.3.4, 1.3.5, and 1.3.6

TESTED BY

DATE 7-30-65

Current input: 100 milliamperes ac

Gold plated Kovar to solder coated terminal

No Heat				After Heat			
SPECIMEN NUMBER 1.3.4	JOINT R	% OF RESISTANCE		SPECIMEN NUMBER 1.3.4	JOINT R	% OF R CHANGE	
91			RESONANCE 180 cps	101	.0003Ω	0	
92	.0006	0		102			
93				103			
94				104	.0006 →	0	
95				105			
96	.0006	0		106			
97				107			
98				108	.0006	0	
99	.0003	0		109			
100				110			

Gold plated nickel to solder coated terminal

No Heat				After Heat			
SPECIMEN NUMBER 1.3.5	JOINT RESISTANCE	CHANGE IN JOINT RESISTANCE		SPECIMEN NUMBER 1.3.5	JOINT RESISTANCE	% CHANGE IN JOINT RESISTANCE	
91			RESONANCE 205 cps	101			
92	.00027Ω	0		102	.00027	0	
93				103			
94				104			
95				105	MISSING		
96	.00027	0		106			
97				107	.00027	0	
98				108			
99	.00018Ω	0		109			
100	←	Broken on		110	.000065	0	
		extraction from fixture					

Bare nickel to solder coated terminal

No Heat				After Heat			
SPECIMEN NUMBER 1.3.6	JOINT RESISTANCE	% OF CHANGE		SPECIMEN NUMBER 1.3.6	JOINT RESISTANCE	% OF CHANGE	
91			RESONANCE 175 cps	101			
92	.0005Ω	0		102	.0005	0	
93				103			
94				104			
95				105			
96	.0005Ω	0		106	.0005	0	
97				107			
98				108			
99	.00025Ω	0		109	.00025	0	
100				110			

PROJECT ENGR. F. KEISTER

JPL CONTRACT 951069

TEST VIBRATION - Solder Joints

TYPE OF JOINT 1.4 and 1.5

TESTED BY

DATE 7-30-65

Current input: 100 milliamperes ac

Gold plated copper to gold plated terminal

No Heat SPECIMEN NUMBER 1.4	JOINT RESISTANCE	% OF CHANGE		After Heat SPECIMEN NUMBER 1.4	JOINT RESISTANCE	% OF CHANGE	
91	.00014Ω	0	RESONANCE 172 cps	101			
92				102	.00028	0	
93				103			
94	.00028Ω	0		104			
95				105			
96				106	.00028	0	
97				107			
98	.00028Ω	0		108			
99				109			
100				110	.00014	0	

Gold plated Copper to gold plated terminal

Resistor lead to solder coated terminal

No Heat SPECIMEN NUMBER 1.5	JOINT RESISTANCE	% OF CHANGE		After Heat SPECIMEN NUMBER 1.5	JOINT RESISTANCE	% OF CHANGE	
91			RESONANCE 212 cps	101			
92	.00019Ω	0		102	.00019	0	
93				103			
94				104			
95	.00010Ω	0		105			
96				106	.00010	0	
97				107			
98	.00019Ω	0		108			
99				109	.00019	0	
100				110			

Resistor lead to solder terminal

PROJECT ENGR. F. KEISTER

JPL CONTRACT 951069

TEST Electrical Test During Vibration - Weld Joint

TYPE OF JOINT Weld Joint - Bare nickel to Inco

TESTED BY

DATE 9-14-65

Current input = 100 milliamps DC

No heat			Sterilized		
SPECIMEN NUMBER	JOINT RESISTANCE	% CHANGE IN RESISTANCE DURING VIBRATION	SPECIMEN NUMBER	JOINT RESISTANCE	% CHANGE IN RESISTANCE DURING VIBRATION
1.1.91B			1.1.101B		
1.1.92B	.00055 Ω	0	1.1.102B	.00055 Ω	0
1.1.93B			1.1.103B		
1.1.94B			1.1.104B		
1.1.95B	.00028 Ω	0	1.1.105B		
1.1.96B			1.1.106B	.00055 Ω	0
1.1.97B			1.1.107B		
1.1.98B	.00055 Ω	0	1.1.108B		
1.1.99B			1.1.109B	.00028 Ω	0
1.1.100B			1.1.110B		
1.1.JPL3			1.1.JPL7		
1.1.JPL4	.00055 Ω	0	1.1.JPL8	.00055 Ω	0
1.1.JPL5			1.1.JPL9		
1.1.JPL6			1.1.JPL10		

RESONANT FREQUENCY = 420 cps

CURRENT: 100 mA

LIST OF EQUIPMENT USED:

1. VERTICAL VIBRATION SYSTEM, LING ELECTRONICS MODEL C-P3/4 S/N45 LAST CALIB - 8-16-65
2. ACCELEROMETER, ENDEVCO CORP. MODEL 2211 S/N E5641 LAST CALIB 5-14-65
3. WAVE ANALYZER, HEWLETT PACKARD MODEL 302A S/N 149-00127 LAST CALIB 5-28-65
4. ELECTRONIC COUNTER - HEWLETT PACKARD MODEL 522B S/N 1897 LAST CALIB 6-21-65
5. AUDIO SIGNAL GENERATOR - HEWLETT PACKARD MODEL 205AB S/N 6965 LAST CALIB 6-16-65

Include Model number, Serial number, Manufacturer, Date of last calibration, if any

6. V.T.V.M - HEWLETT PACKARD MODEL 400H S/N 1197 LAST CALIB 6-2-65
7. A.C CURRENT PROBE, HEWLETT PACKARD MODEL No 456A S/N 1C3-1939 LAST CALIB - 5-22-65
8. SLIP-SYNC CHADWICK-HELMUTH - MODEL #. S/N 103AR LAST CALIB —
9. Strobex, Chadwick-Helmuth, Model 121R
10. Sweep oscillator; Dynac Inc., Model DY-2200; Serial # 167; Last calib. 8/4/65

PROJECT ENGR. F. KEISTER

JPL CONTRACT 951069

TEST Electrical Test During Vibration - Weld Joints

TYPE OF JOINT Gold plated nickel to Inco (1.2) and Gold plated Kovar to Inco (1.3)

TESTED BY Kassebaum DATE 8-30-65

Current input = 100 milliamps ac

No heat				Sterilized			
SPECIMEN NUMBER	JOINT RESISTANCE	% CHANGE IN RESISTANCE DURING VIBRATION		SPECIMEN NUMBER	JOINT R	% OF CHANGE	
1.2.91B				1.2.101B			
1.2.92B	.0005Ω	0		1.2.102B	.0005Ω	0	
1.2.93B				103B			
1.2.94B				104B			
1.2.95B				105B	.00025Ω	0	
1.2.96B	.0005Ω	0		106B			
1.2.97B				107B			
1.2.98B				108B	.0005Ω	0	
1.2.99B				109B			
1.2.100B	.0005Ω	0		110B			
1.2.JPL3				1.2.JPL 7			
1.2.JPL4				8	.0005Ω	0	
1.2.JPL5	.00025Ω	0		9			
1.2.JPL6				10			

RESONANT FREQUENCY = 420 cps

9/14/65

No heat				STERILIZED			
SPECIMEN NUMBER	JOINT RESISTANCE	% CHANGE IN RESISTANCE DURING VIBRATION		SPECIMEN #	JOINT R	% OF CHANGE	
1.3.91B				1.3.101B			
1.3.92B	.0010Ω	0		102B	.0010Ω	0	
1.3.93B				103B			
1.3.94B				104B			
1.3.95B				105B	.0005Ω	0	
1.3.96B	.0010Ω	0		106B			
1.3.97B				107B			
1.3.98B				108B	.0010Ω	0	
1.3.99B	.0005Ω	0		109B			
1.3.100B				110B			
1.3.JPL3				1.3.JPL 7			
1.3.JPL4	.00137Ω	0		8	.00137Ω	0	
1.3.JPL5				9			
1.3.JPL6				10			

RESONANT FREQUENCY = 41 cps

PROJECT ENGR. F.KEISTER

JPL CONTRACT 951069

TEST Electrical Test During Vibration - Weld Joint

TYPE OF JOINT Weld Joint - Gold plated Dumet to Inco (1.4)
Gold plated copper to Inco (1.5)

TESTED BY DATE 7-19-65

Current input: 100 milliamperes ac

No heat				Sterilized			
SPECIMEN NUMBER	JOINT RESISTANCE	% CHANGE IN RESISTANCE DURING VIBRATION		SPECIMEN #	JOINT R	% OF CHANGE	
1.4.91B				1.4.101B			
1.4.92B	.00048 Ω	0		102B	.00048 Ω	0	
1.4.93B				103 B			
1.4.94B				104B			
1.4.95B				105B	.00024 Ω	0	
1.4.96B	.00048 Ω	0		106 B			
1.4.97B				107B			
1.4.98B				108B	.00048 Ω	0	
1.4.99B	.00024 Ω	0		109B			
1.4.100B				110 B			
1.4.JPL3				1.4.JPL7			
1.4.JPL4	.000165 Ω			8	.000155	0	
1.4.JPL5	Samples [illegible] cut			9			
1.4.JPL6				10			
		RESONANT FREQUENCY = 418 cps					

No heat				Sterilized			
SPECIMEN NUMBER	JOINT RESISTANCE	% CHANGE IN RESISTANCE DURING VIBRATION		SPECIMEN #	JOINT R	% OF CHANGE	
1.5.91B				1.5.101B			
1.5.92B	.00024 Ω			102B	.00024 Ω	0	
1.5.93B				103B			
1.5.94B				104B			
1.5.95B				105B	.00012 Ω	0	
1.5.96B	.00024 Ω	0		[illegible]			
1.5.97B				[illegible]			
1.5.98B				[illegible]	[illegible] Ω	0	
1.5.99B	.00012 Ω	0		[illegible]			
1.5.100B				[illegible]			
1.5.JPL3				JPL [illegible]			
1.5.JPL4	.00027 Ω	0		[illegible]	.00027 Ω	0	
1.5.JPL5				[illegible]			
1.5.JPL6				[illegible]			
		RESONANT FREQUENCY = 320 cps					

PROJECT ENGR. F. KEISTER

JPL CONTRACT 951069

TEST Electrical Test During Vibration - Weld Joints

TYPE OF JOINT Weld Joint - Solder coated copper to Inco (1.6) and Kovar foil to Kovar foil (2.)

TESTED BY

DATE 2 [illegible] 65

No heat			STERILIZED		
SPECIMEN NUMBER	JOINT RESISTANCE	% CHANGE IN RESISTANCE DURING VIBRATION	SPECIMEN #	JOINT R	% OF CHANGE
1.6.91B			1.6.101B		
1.6.92B	.00028 Ω	0	102B	.00028 Ω	0
1.6.93B			103B		
1.6.94B			104B		
1.6.95B			105B	.00014 Ω	0
1.6.96B	.00028 Ω	0	106B		
1.6.97B			107B		
1.6.98B			108B	.00028 Ω	0
1.6.99B	.00014 Ω	0	109B		
1.6.100B			110B		
1.6.JPL3			JPL 7		
1.6.JPL4	.00024 Ω	0	JPL 8	.00024 Ω	0
1.6.JPL5			JPL 9		
1.6.JPL6			JPL 10		

RESONANT FREQUENCY = 478 cps

NO HEAT			STERILIZED		
SPECIMEN NUMBER	JOINT RESISTANCE	PERCENTAGE CHANGE IN RESISTANCE DURING VIBRATION	SPECIMEN NUMBER	JOINT RESISTANCE	% CHANGE IN RESISTANCE DURING VIBRATION
2.91B			2.101B		
2.92B	.0046 Ω	0	2.102B	.0046 Ω	0
2.93B			2.103B		
2.94B			2.104B		
2.95B			2.105B		
2.96B	.0046 Ω	0	2.106B	.0046 Ω	0
2.97B			2.107B		
2.98B			2.108B		
2.99B	** .0023 Ω	0	2.109B	.0023 Ω	0
2.100B			2.110B		

RESONANT FREQUENCY = 280 cps

** Damaged prior to vibration, but showed no ill effects

Note: These joints were all of a very high resistance

PROJECT ENGR. F. KEISTER

JPL CONTRACT 951069

TEST Ultimate Strength after Vibration

TYPE OF JOINT Solder Joints – Various types

TESTED BY John C. Holberton
Research Lab Analyst C

DATE Sept. 7, 1965

W= Wire failure
J= Joint failure

Stranded conductor to CINCH cup
STRANDED CONDUCTOR TO CINCH CUP
Gold plated copper wire to solder coated terminal

SPECIMEN NUMBER	STRENGTH (pounds) BEFORE HEAT	SPECIMEN NUMBER	STRENGTH (pounds) AFTER HEAT	SPECIMEN NUMBER	STRENGTH (pounds) BEFORE HEAT	SPECIMEN NUMBER	STRENGTH (pounds) AFTER HEAT
1.1.1.91	14.5 w	1.1.1.101	14.5 w	1.3.1.91	11.0 w	1.3.1.101	11.0 w
1.1.1.92	14.5 w	1.1.1.102	14.5 w	1.3.1.92	11.0 w	1.3.1.102	11.5 w
1.1.1.93	14.5 w	1.1.1.103	14.5 w	1.3.1.93	10.5 w	1.3.1.103	11.0 w
1.1.1.94	14.5 w	1.1.1.104	14.5 w	1.3.1.94	10.5 w	1.3.1.104	11.5 w
1.1.1.95	*	1.1.1.105	14.5 w	1.3.1.95	11.0 w	1.3.1.105	10.5 w
1.1.1.96	14.5 w	1.1.1.106	14.5 w	1.3.1.96	10.5 w	1.3.1.106	11.5 w
1.1.1.97	14.5 w	1.1.1.107	15.0 w	1.3.1.97	11.0 w	1.3.1.107	11.0 w
1.1.1.98	14.5 w	1.1.1.108	14.5 w	1.3.1.98	10.5 w	1.3.1.108	11.5 w
1.1.1.99	14.5 w	1.1.1.109	14.5 w	1.3.1.99	11.0 w	1.3.1.109	11.0 w
1.1.1.100	14.5 w	1.1.1.110	14.5 w	1.3.1.100	11.0 w	1.3.1.110	11.0 w

Stranded conductor to BENDIX cup
STRANDED CONDUCTOR TO BENDIX CUP
Solder coated copper wire to solder coated terminal

1.1.2.91	14.5 w	1.1.2.101	14.5 w	1.3.2.91	11.5 w	1.3.2.101	11.5 w
1.1.2.92	14.5 w	1.1.2.102	14.5 w	1.3.2.92	11.5 w	1.3.2.102	11.5 w
1.1.2.93	14.5 w	1.1.2.103	14.5 w	1.3.2.93	12.0 w	1.3.2.103	12.0 w
1.1.2.94	14.5 w	1.1.2.104	14.5 w	1.3.2.94	11.5 J	1.3.2.104	11.5 w
1.1.2.95	15.0 w	1.1.2.105	14.5 w	1.3.2.95	12.0 w	1.3.2.105	11.5 w
1.1.2.96	14.5 w	1.1.2.106	14.5 w	1.3.2.96	11.5 w	1.3.2.106	11.5 w
1.1.2.97	14.5 w	1.1.2.107	14.5 w	1.3.2.97	5.5 J	1.3.2.107	12.0 w
1.1.2.98	14.5 w	1.1.2.108	14.5 w	1.3.2.98	10.0 J	1.3.2.108	12.0 w
1.1.2.99	14.5 w	1.1.2.109	14.5 w	1.3.2.99	12.0 w	1.3.2.109	11.5 w
1.1.2.100	14.5 w	1.1.2.110	14.5 w	1.3.2.100	11.0 J	1.3.2.110	12.0 w

Stranded conductor to Solder coated terminal
STRANDED CONDUCTOR TO SOLDER COATED TERMINAL
Gold plated Dumet wire to solder coated terminal

1.2.91	14.5 w	1.2.101	14.0 J&W	1.3.3.91	20.5 J	1.3.3.101	26.0 w
1.2.92	14.5 w	1.2.102	15.5 w	1.3.3.92	13.5 J	1.3.3.102	22.5 J
1.2.93	14.5 w	1.2.103	14.5 w	1.3.3.93	25.5 w	1.3.3.103	19.5 J
1.2.94	14.5 w	1.2.104	14.5 w	1.3.3.94	21.0 J	1.3.3.104	26.5 w
1.2.95	11.5 J	1.2.105	14.0 w	1.3.3.95	26.0 w	1.3.3.105	25.5 w
1.2.96	14.5 w	1.2.106	14.5 w	1.3.3.96	19.0 J	1.3.3.106	26.0 w
1.2.97	14.5 w	1.2.107	13.5 J	1.3.3.97	26.5 w	1.3.3.107	25.0 J
1.2.98	14.5 w	1.2.108	14.5 J	1.3.3.98	25.5 w	1.3.3.108	8.5 J
1.2.99	14.5 w	1.2.109	14.0 J	1.3.3.99	24.5 J	1.3.3.109	22.5 J
1.2.100	14.5 w	1.2.110	15.0 w	1.3.3.100	25.5 w	1.3.3.110	13.0 J

* SAMPLE RUINED DURING VIBRATION

PROJECT ENGR. F. KEISTER

JPL CONTRACT 951069

TEST ULTIMATE STRENGTH AFTER VIBRATION

TYPE OF JOINT SOLDER JOINTS – VARIOUS TYPES

TESTED BY JOHN C. HOLBERTON
RESEARCH LAB ANALYST C

DATE SEPT 7, 1965

W = WIRE FAILURE
J = JOINT FAILURE

	SPECIMEN NUMBER	STRENGTH (POUNDS) BEFORE HEAT	SPECIMEN NUMBER	STRENGTH (POUNDS) AFTER H
GOLD PLATED KOVAR TO SOLDER COATED TERMINAL	1.3.4. 91	17.5 J	1.34.101	23.0 J
	1.3.4. 92	230 W	1.34.102	19.5 J
	1.3.4 93	22.5 J	1.34.103	23.0 W
	1.3.4 94	23.5 W	1.34.109	29.0 W
	1.3.4 95	18.0 J	1.34. 105	23.0 J
	1.3.4 96	21.5 J	1.34. 106	22.5 J
	1.3.4 97	18.0 J	1.34. 107	19.0 J
	1.34 98	23.5 W	1.34. 108	13.5 J
	1.34 99	23.0 W	1.34. 109	14.5 J
	1.3.4. 100	29.5 J	1.34.110	23.0 W
GOLD PLATED NICKEL TO SOLDER COATED TERMINAL	1.3.5. 91	24.5 J	1.3.5.101	21.0 J
	1.3.5 92	21.0 J	1.3.5.102	29.0 J
	1.3.5 93	25.5 J	1.3.5.103	38.0 W
	1.3.5 94	26.5 J	1.3.5.104	27.0 J
	1.3.5 95	18.5 J	1.3.5.105	LOST
	1.3.5 96	24.5 J	1.3.5.106	24.5 J
	1.3.5 97	24.0 J	1.3.5.107	25.0 J
	1.3.5 98	37.5 W	1.3.5.108	28.5 J
	1.3.5 99	32.5 J	1.3.5.109	25.0 J
	1.3.5 100	*	1.3.5.110	32.5 J
BARE NICKEL TO SOLDER COATED TERMINAL	1.3.6. 91	27.5 J	1.3.6.101	29.0 J
	1.3.6. 92	27.0 J	1.3.6. 102	23.5 J
	1.3.6. 93	25.0 J	1.3.6. 103	31.0 J
	1.3.6. 94	36.5 J	1.3.6. 104	35.5 J
	1.3.6. 95	40.0 J	1.3.6. 105	25.0 J
	1.3.6. 96	27.5 J	1.3.6. 106	40.0 J
	1.3.6. 97	27.0 J	1.36. 107	31.5 J
	1.3.6. 98	30.5 J	1.36. 108	21.0 J
	1.3.6. 99	28.5 J	1.36. 109	25.0 J
	1.36. 100	29.5 J	1.3.6. 110	30.5 J

	SPECIMEN NUMBER	STRENGTH (POUNDS) BEFORE HEAT	SPECIMEN NUMBER	STRENGTH (POUNDS) AFTER HEAT
GOLD PLATED COPPER TO GOLD PLATED TERMINAL				11.0 W
	1.4. 91	10.5 W	1.4. 101	11.0 W
	1.4. 92	10.5 W	1.4. 102	11.0 W
	1.4. 93	11.0 W	1.4. 103	11.0 W
	1.4. 94	11.0 W	1.4. 104	11.5 W
	1.4. 95	11.0 W	1.4. 105	8.5 J
	1.4. 96	11.0 W	1.4. 106	11.0 W
	1.4. 97	11.0 W	1.4. 107	11.5 W
	1.4. 98	11.0 W	1.4. 108	12.0 W
	1.4. 99	11.0 W	1.4. 109	11.5 W
	1.4. 100	11.0 W	1.4. 110	
RESISTOR LEAD TO SOLDER COATED TERMINAL			1.5. 101	22.5 W
	1.5. 91	20.5 J	1.5. 102	27.0 W
	1.5. 92	22.0 W	1.5. 103	21.0 W
	1.5. 93	19.0 W	1.5. 104	18.0 J
	1.5. 94	24.5 W	1.5. 105	21.0 J
	1.5. 95	18.5 W	1.5. 106	23.5 W
	1.5. 96	25.0 W	1.5. 107	19.0 W
	1.5. 97	20.0 W	1.5. 108	19.5 W
	1.5. 98	21.5 W	1.5. 109	19.5 W
	1.5. 99	23.5 W	1.5. 110	19.5 J
	1.5. 100	23.0 W		

* SAMPLE RUINED IN VIBRATION

PROJECT ENGR. F. KEISTER

JPL CONTRACT 951069

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TEST Ultimate Strength after Vibration

TYPE OF JOINT weld Joints - various types

TESTED BY Manning

DATE 9-14-65

Bare nickel to Inco | Gold plated Kovar to Inco

9-15-65 | 9-15-65

SPECIMEN NUMBER	STRENGTH (pounds) BEFORE HEAT	SPECIMEN NUMBER	STRENGTH (pounds) AFTER HEAT	SPECIMEN NUMBER	STRENGTH (pounds) BEFORE HEAT	SPECIMEN NUMBER	STRENGTH (pounds) AFTER HEAT
1.1.91B	11.0 W2	1.1.101B	11.0 W2	1.3.91B	14.0 R2	1.3.101B	14.5 R2
1.1.92B	10.5 W2	1.1.102B	11.5 W2	1.3.92B	16.5 R2	1.3.102B	14.0 R2
1.1.93B	11.0 W2	1.1.103B	12.0 W2	1.3.99B	13.5 R2	1.3.103B	14.0 R2
1.1.94B	12.0 W2	1.1.104B	11.5 W2	1.3.94B	16.5 R2	1.3.104B	19.5 R2
1.1.95B	11.0 W2	1.1.105B	12.0 W2	1.3.95B	14.0 R2	1.3.105B	14.5 R2
1.1.96B	8.5 W2	1.1.106B	11.0 W2	1.3.96B	17.0 R2	1.3.106B	14.5 R2
1.1.97B	11.5 W2	1.1.107B	12.0 W2	1.3.97B	13.5 R2	1.3.107B	15.0 R2
1.1.98B	11.5 W2	1.1.108B	12.5 W2	1.3.98B	17.0 R2	1.3.108B	17.5 R2
1.1.99B	11.5 W2	1.1.109B	12.5 W2	1.3.99B	16.5 R2	1.3.109B	14.0 R2
1.1.100B	11.0 W2	1.1.110B	11.5 W2	1.3.100B	15.5 R2	1.3.110B	14.0 R2
1.1.JPL3	8.5 W2	1.1.JPL7	10.0 W2	1.3.JPL3	17.5 R2	1.3.JPL7	19.0 R2
1.1.JPL4	10.0 W2	1.1.JPL8	10.5 W2	1.3.JPL4	17.0 R2	1.3.JPL8	18.5 WS
1.1.JPL5	8.0 W2	1.1.JPL9	10.5 W2	1.3.JPL5	16.0 R2	1.3.JPL9	17.5 R2
1.1.JPL6	10.0 WS	1.1.JPL10	9.5 W2	1.3.JPL6	17.0 R2	1.3.JPL10	17.0 R2
	BARE NICKEL TO INCO						

Au plated nickel to Inco | Gold plated Dumet to Inco

1.2.91B	13.5 W2	1.2.101B	13.5 W2	1.4.91B	19.0 W2	1.4.101B	12.5 R2
1.2.92B	11.5 W2	1.2.102B	14.0 W2	1.4.92B	18.5 W2	1.4.102B	18.5 W2
1.2.93B	13.0 W2	1.2.103B	12.5 W2	1.4.93B	17.5 W2	1.4.103B	19.0 W2
1.2.94B	12.0 W2	1.2.104B	14.5 WB	1.4.94B	13.5 R2	1.4.104B	17.5 W2
1.2.95B	13.0 W2	1.2.105B	14.5 WI	1.4.95B	18.5 R2	1.4.105B	14.5 R2
1.2.96B	12.0 W2	1.2.106B	10.5 WS	1.4.96B	13.0 R2	1.4.106B	19.5 W2
1.2.97B	14.0 W2	1.2.107B	13.5 W2	1.4.97B	18.5 R2	1.4.107B	19.0 W2
1.2.98B	12.0 W2	1.2.108B	13.0 W2	1.4.98B	12.5 R2	1.4.108B	19.0 R2
1.2.99B	14.0 W2	1.2.109B	12.0 W2	1.4.99B	18.5 W2	1.4.109B	19.5 R2
1.2.100B	13.0 WS	1.2.110B	13.0 W2	1.4.100B	13.5 R2	1.4.110B	19.0 R2
1.2.JPL3	11.5 W2	1.2.JPL7	12.5 W2	1.4.JPL3	15.0 W2	1.4.JPL7	12.0 R2
1.2.JPL4	11.5 W2	1.2.JPL8	11.5 W2	1.4.JPL4	*	1.4.JPL8	13.0 R2
1.2.JPL5	12.0 W2	1.2.JPL9	13.0 W2	1.4.JPL5	12.5 R2	1.4.JPL9	15.5 W2
1.2.JPL6	11.0 W2	1.2.JPL10	12.0 W2	1.4.JPL6	*	1.4.JPL10	16.5 W2
	GOLD PLATED NICKEL TO INCO						

* Specimens ruined in mounting on vibration table.

PROJECT ENGR. F. KEISTER

JPL CONTRACT 951069

TEST Ultimate Strength after Vibration

TYPE OF JOINT Weld Joints - various types

TESTED BY J. Manning

DATE 9-15-65

W2 = Wire broke adjacent to weld
R2 = Ribbon " " " "
WS = weld separation

WB = Wire broke away from weld
RB = Ribbon " " " "

Gold plated copper to Inco

SPECIMEN NUMBER	STRENGTH (pounds) BEFORE HEAT	SPECIMEN NUMBER	STRENGTH (pounds) AFTER HEAT
1.5.91B	9.5 W2	1.5.101B	8.5 W2
1.5.92B	9.5 W2	1.5.102B	9.5 W2
1.5.93B	9.0 W2	1.5.103B	9.0 W2
1.5.94B	10.0 W2	1.5.104B	9.5 W2
1.5.95B	9.5 W2	1.5.105B	9.5 W2
1.5.96B	10.5 W2	1.5.106B	9.0 W2
1.5.97B	9.0 W2	1.5.107B	8.5 W2
1.5.98B	10.0 W2	1.5.108B	9.0 W2
1.5.99B	9.0 W2	1.5.109B	9.5 W2
1.5.100B	10.0 W2	1.5.110B	8.5 W2
1.5.JPL3	9.0 W2	1.5.JPL7	9.0 W2
1.5.JPL4	9.0 W2	1.5.JPL8	9.0 W2
1.5.JPL5	9.0 W2	1.5.JPL9	9.0 W2
1.5.JPL6	9.0 W2	1.5.JPL10	9.0 W2

GOLD PLATED COPPER TO INCO

Gold plated Kovar foil to gold plated Kovar foil

SPECIMEN NUMBER	STRENGTH (pounds) BEFORE HEAT	SPECIMEN NUMBER	STRENGTH (pounds) AFTER HEAT
2.91B	3.5 W2	2.101B	3.2 W2
2.92B	4.5 W2	2.102B	3.7 W2
2.93B	3.7 W2	2.103B	3.2 R2
2.94B	3.2 R2	2.104B	3.7 W2
2.95B	3.5 R2	2.105B	3.0 R2
2.96B	4.0 R2	2.106B	3.5 R2
2.97B	3.2 R2	2.107B	4.0 W2
2.98B	4.2 R2	2.108B	4.2 W2
2.99B	*	2.109B	3.0 R2
2.100B	4.0 R2	2.110B	3.5 W2

* Specimen destroyed in disassembly from vibration table.

Solder coated copper to Inco

SPECIMEN NUMBER	STRENGTH (pounds) BEFORE HEAT	SPECIMEN NUMBER	STRENGTH (pounds) AFTER HEAT
1.6.91B	8.0 W2	1.6.101B	8.5 W2
1.6.92B	8.0 WS	1.6.102B	8.0 W2
1.6.93B	8.0 WS	1.6.103B	8.0 W2
1.6.94B	8.0 WS	1.6.104B	8.0 W2
1.6.95B	8.5 W2	1.6.105B	8.0 W2
1.6.96B	8.0 WS	1.6.106B	8.5 WS
1.6.97B	8.5 W2	1.6.107B	8.0 W2
1.6.98B	8.0 WS	1.6.108B	8.5 W2
1.6.99B	7.5 WS	1.6.109B	7.5 WS
1.6.100B	8.0 WS	1.6.110B	8.0 W2
1.6.JPL3	7.5 WS	1.6.JPL7	9.0 W2
1.6.JPL4	8.5 W2	1.6.JPL8	8.5 W2
1.6.JPL5	8.5 W2	1.6.JPL9	8.5 W2
1.6.JPL6	9.0 W2	1.6.JPL10	8.0 W2

SOLDER COATED COPPER TO INCO

PROJECT ENGR. F. KEISTER

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ATTACHMENT 3

PHOTOMICROGRAPHS OF METALLOGRAPHIC SPECIMENS

1. Solder Joints: Figures 1 - 22
2. Weld Joints: Figures 23 - 48

ATTACHMENT 3

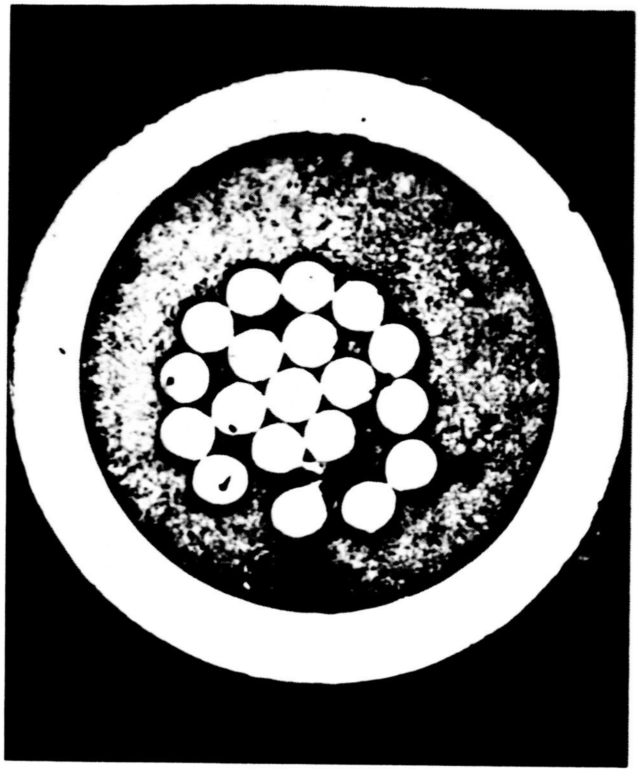


Figure 1. Solder joint 1. 1. 1. 83 stranded conductor to cinch connector cup; not sterilized; 60x magnification; potassium dichromate etch (02344).

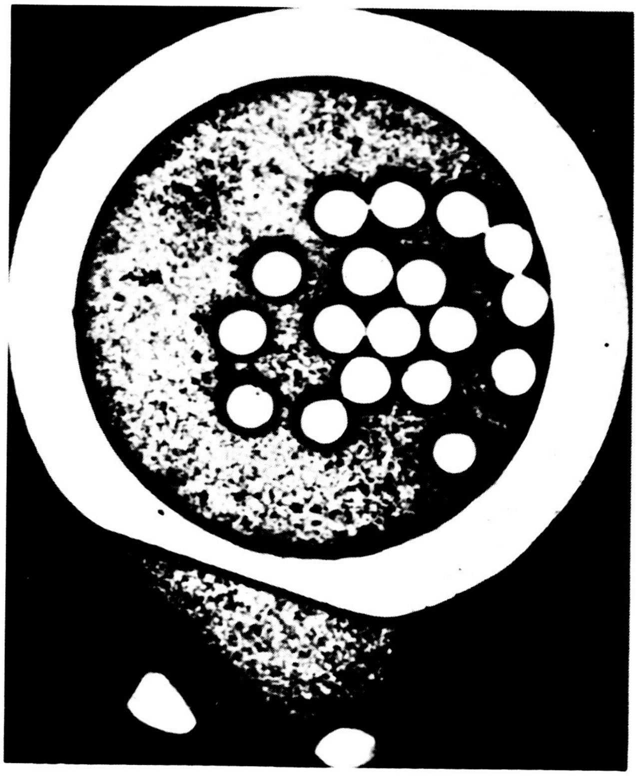


Figure 2. Solder joint 1. 1. 1. 89 stranded conductor to cinch connector cup; sterilized; 60x magnification; potassium dichromate etch (02345).

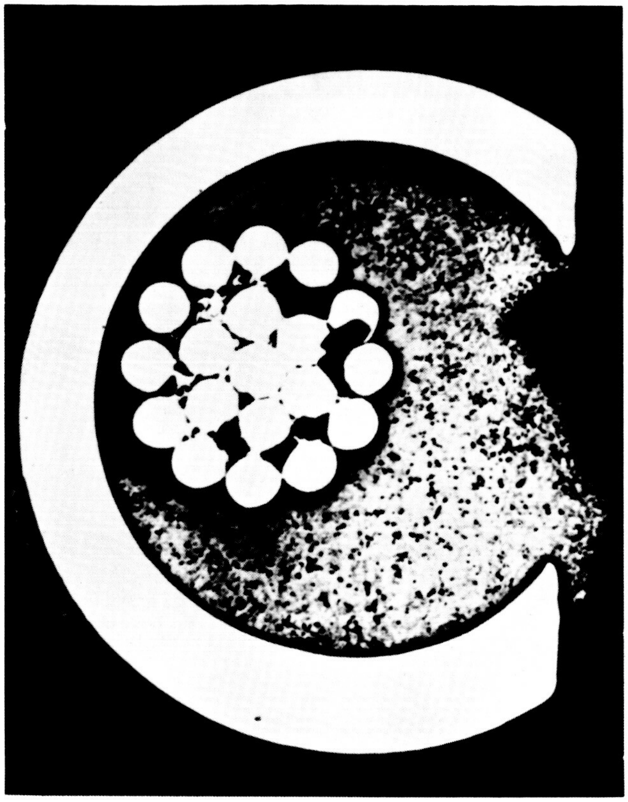


Figure 3. Solder joint 1. 1. 2. 83; stranded conductor to Bendix connector cup; not sterilized; 60x magnification; potassium dichromate etch (02346).

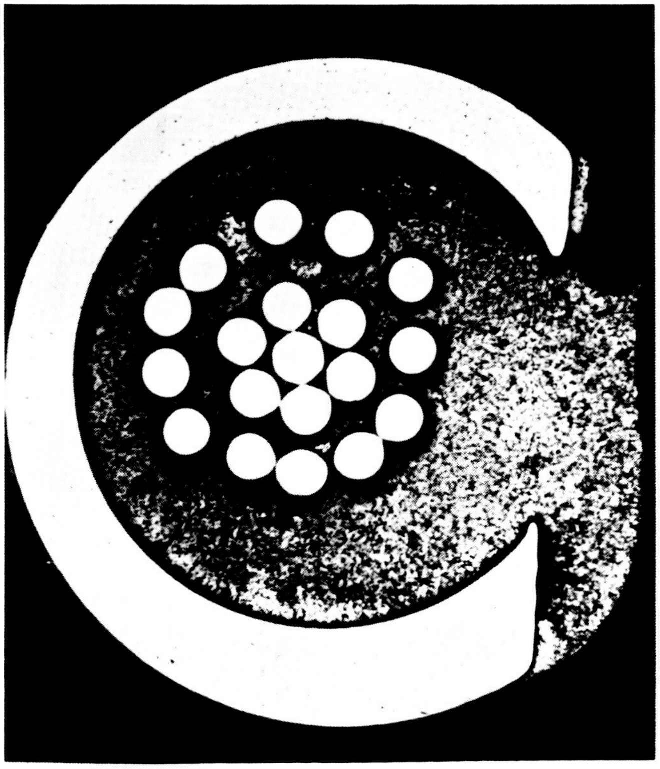


Figure 4. Solder joint 1. 1. 2. 88; stranded conductor to Bendix connector cup; sterilized; 60x magnification; potassium dichromate etch (02347).

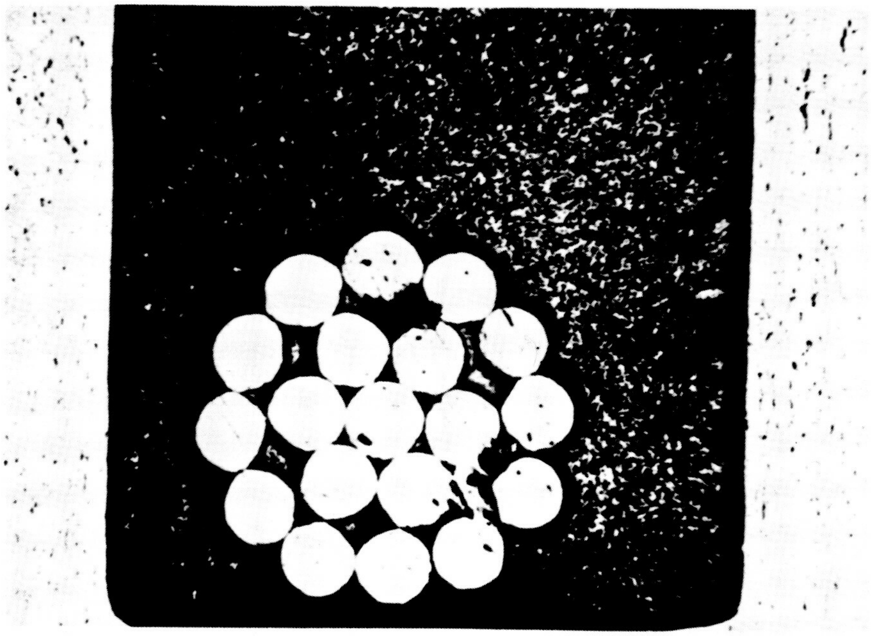


Figure 5. Solder joint 1.2.82; stranded conductor to solder coated bifurcated terminal; not sterilized; 100x magnification; potassium dichromate etch (02348).

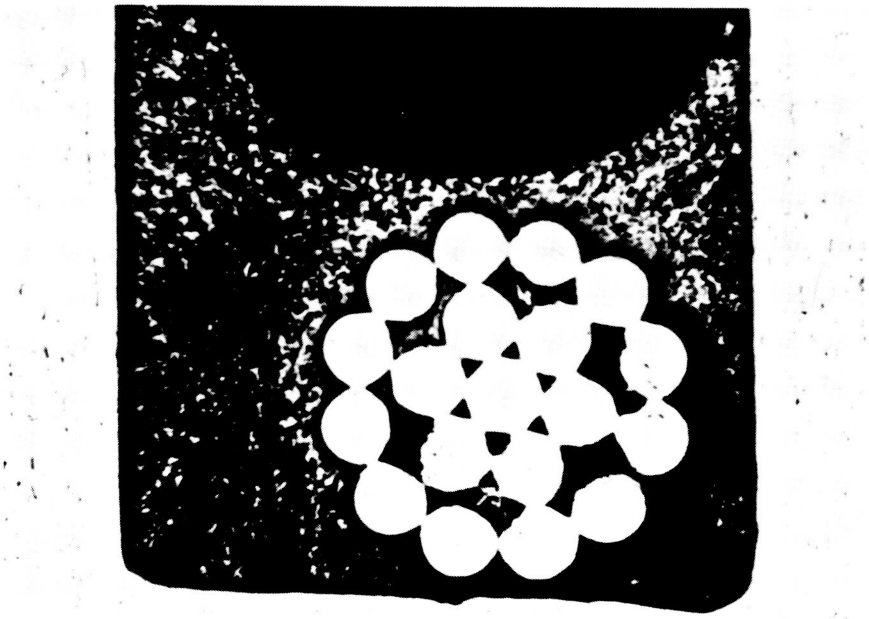


Figure 6. Solder joint 1.2.87; stranded conductor to solder coated bifurcated terminal; sterilized; 100x magnification; potassium dichromate etch (02349).

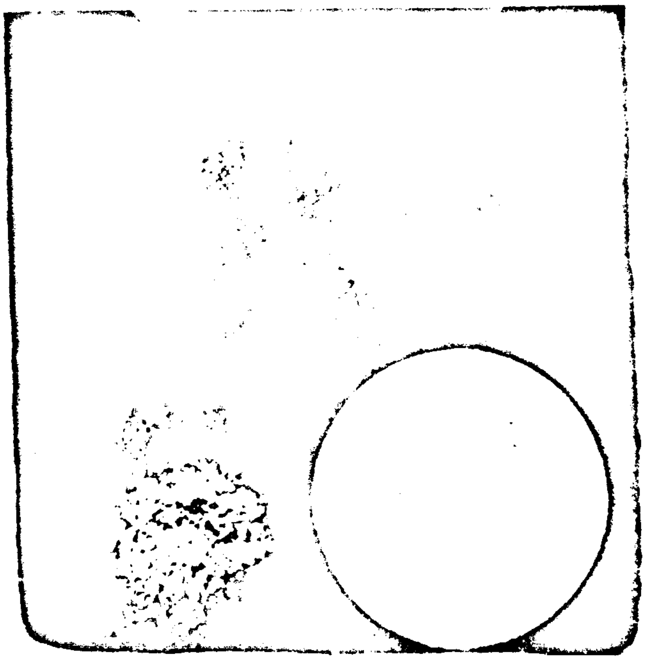


Figure 7. Solder joint 1. 3. 1. 84; gold plated copper conductor to solder coated bifurcated terminal; not sterilized; 100x magnification; potassium dichromate etch (02350).

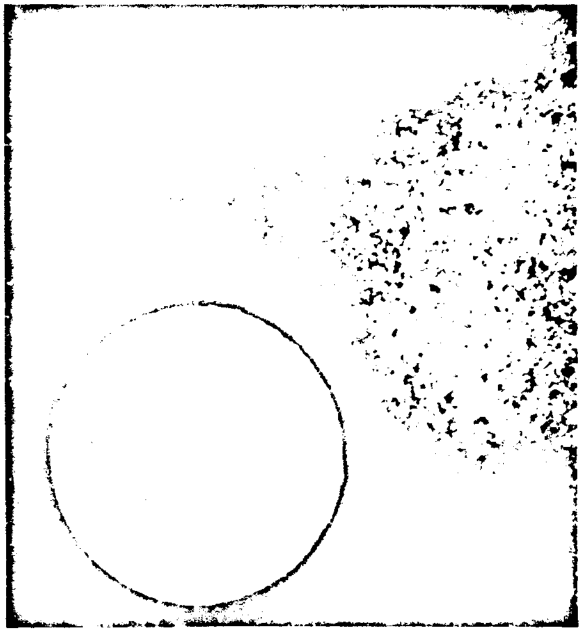


Figure 8. Solder joint 1. 3. 1. 86; gold plated copper conductor to solder coated bifurcated terminal; sterilized; 100x magnification; potassium dichromate etch (02351).

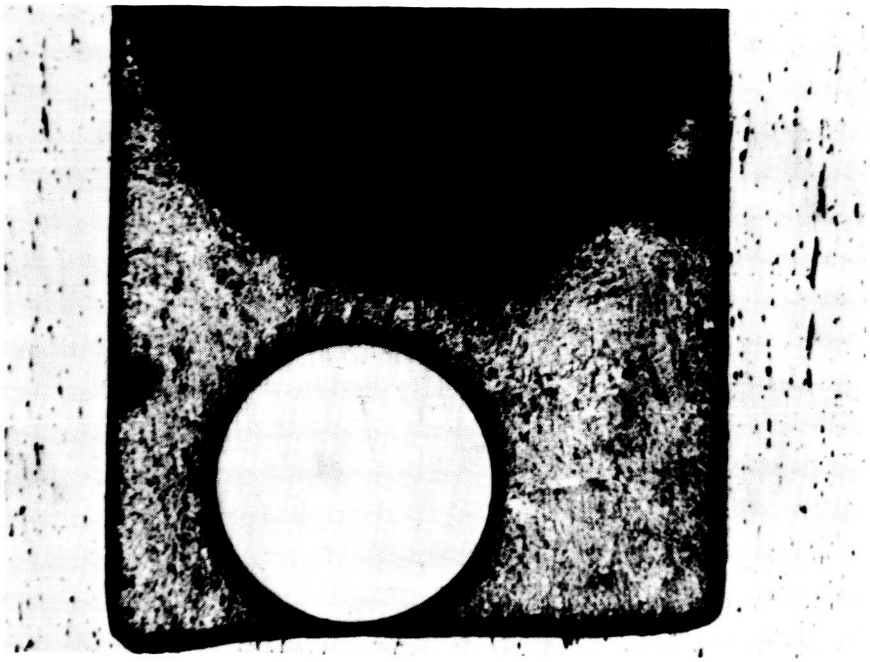


Figure 9. Solder joint 1.3.2.81; solder coated copper conductor to solder coated bifurcated terminal; not sterilized; 100x magnification; potassium dichromate etch (02352).

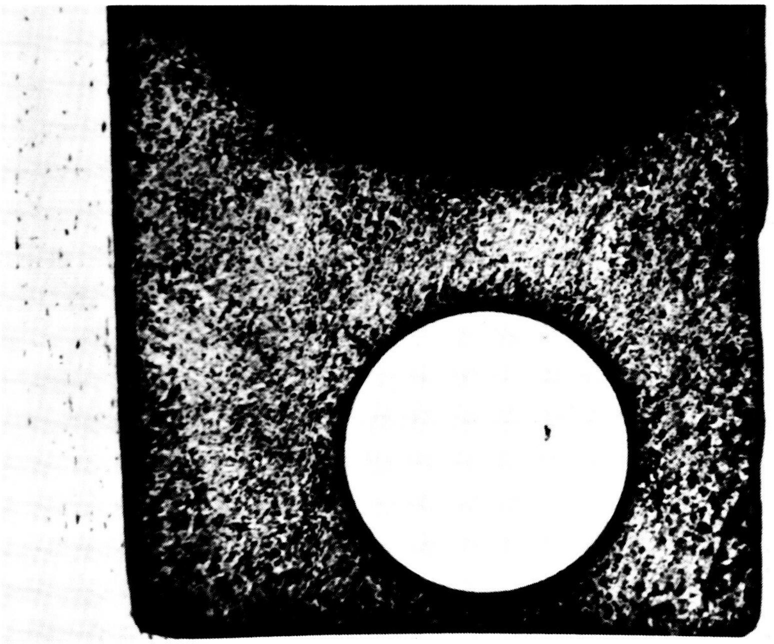


Figure 10. Solder joint 1.3.2.87; solder coated conductor to solder coated bifurcated terminal; sterilized; 100x magnification; potassium dichromate etch (02353).

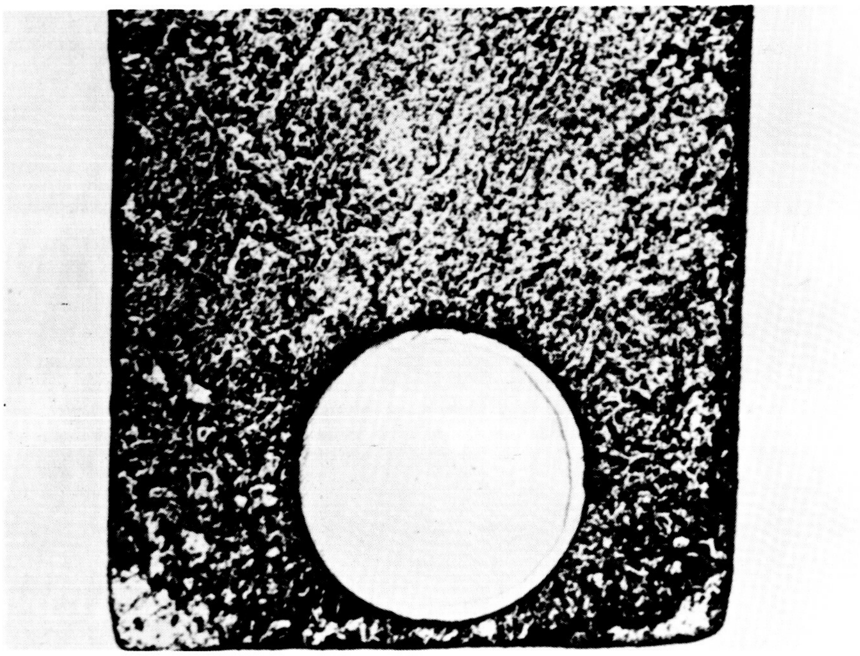


Figure 11. Solder joint 1.3.3.83; gold plated Dumet conductor to solder coated bifurcated terminal; not sterilized; 100x magnification; potassium dichromate etch (02354).

Figure 12. Solder joint 1.3.3.86; gold plated Dumet conductor to solder coated bifurcated terminal; sterilized; 100x magnification; potassium dichromate etch (02355).

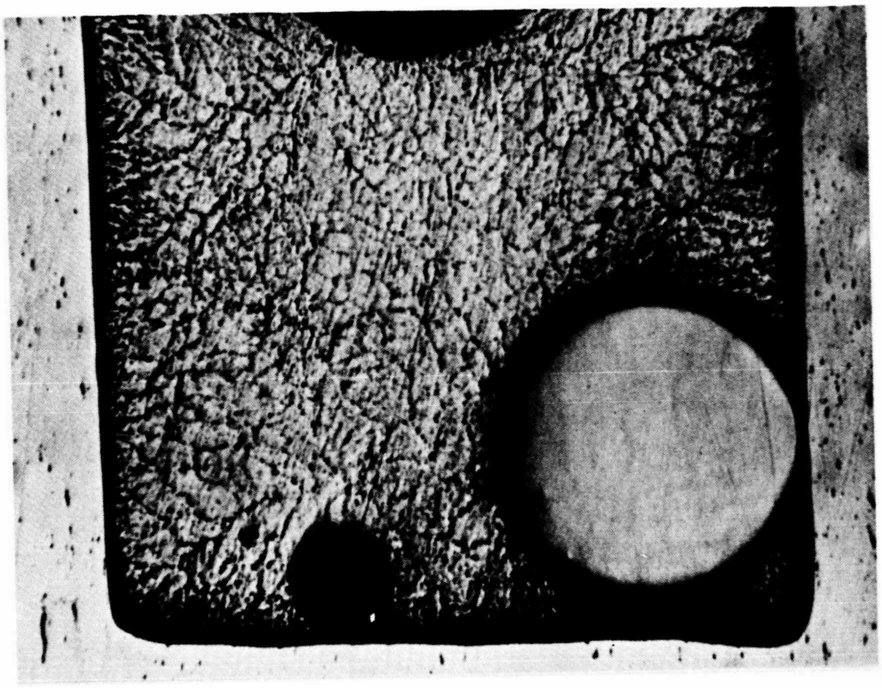


Figure 13. Solder joint 1.3.4.83; gold plated Kovar conductor to solder coated bifurcated terminal; not sterilized; 100x magnification; potassium dichromate etch (02356).

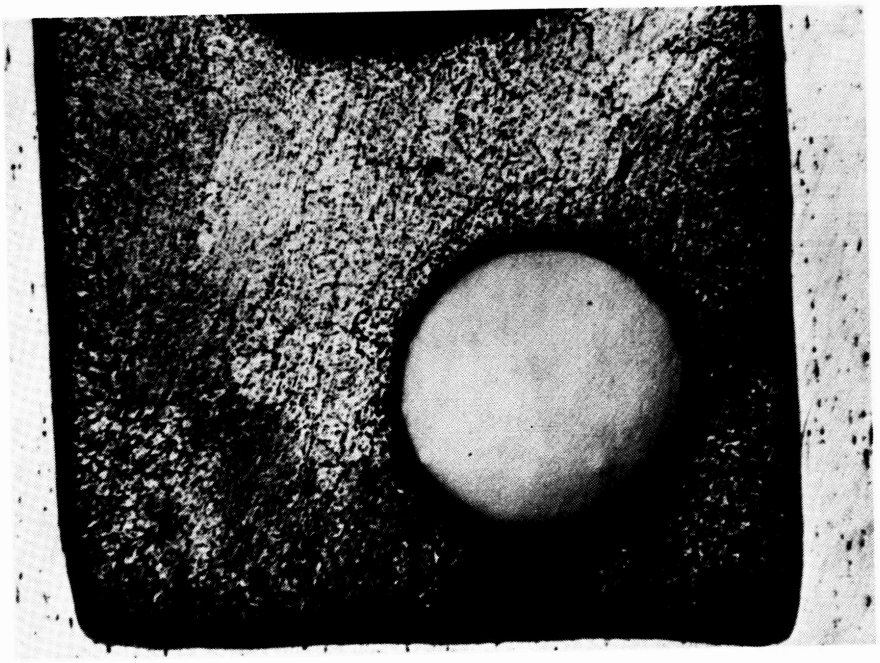


Figure 14. Solder joint 1.3.4.89; gold plated Kovar conductor to solder coated bifurcated terminal; sterilized; 100 magnification; potassium dichromate etch (02357).

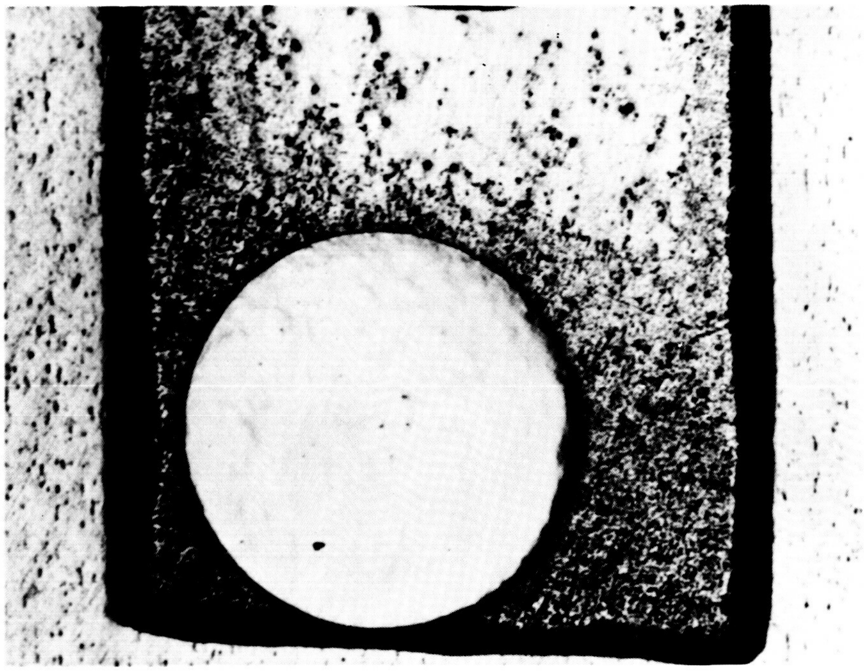


Figure 15. Solder joint 1.3.5.84; gold plated nickel conductor to solder coated bifurcated terminal; not sterilized; 100x magnification; potassium dichromate etch (02358).

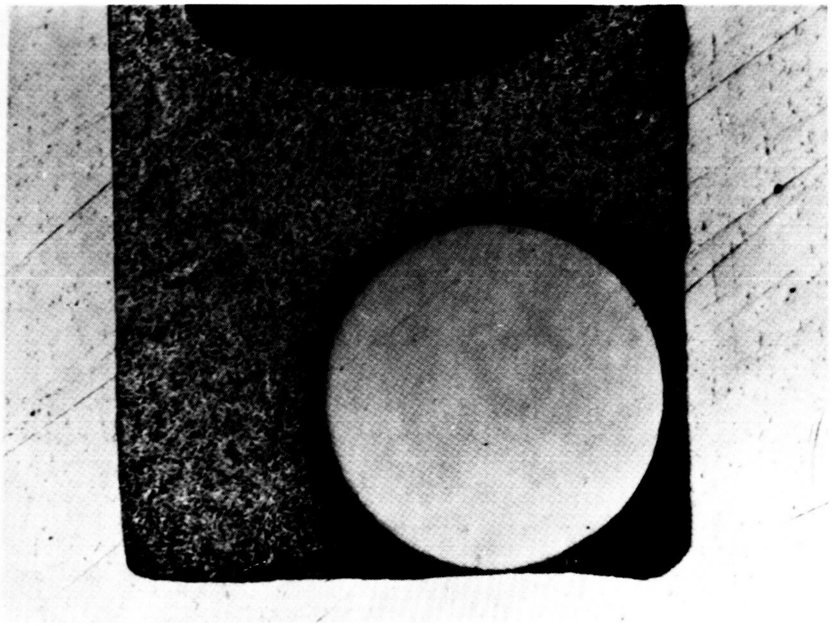


Figure 16. Solder joint 1.3.5.88; gold plated nickel conductor to solder coated bifurcated terminal: sterilized 100x magnification; potassium dichromate etch (02359).

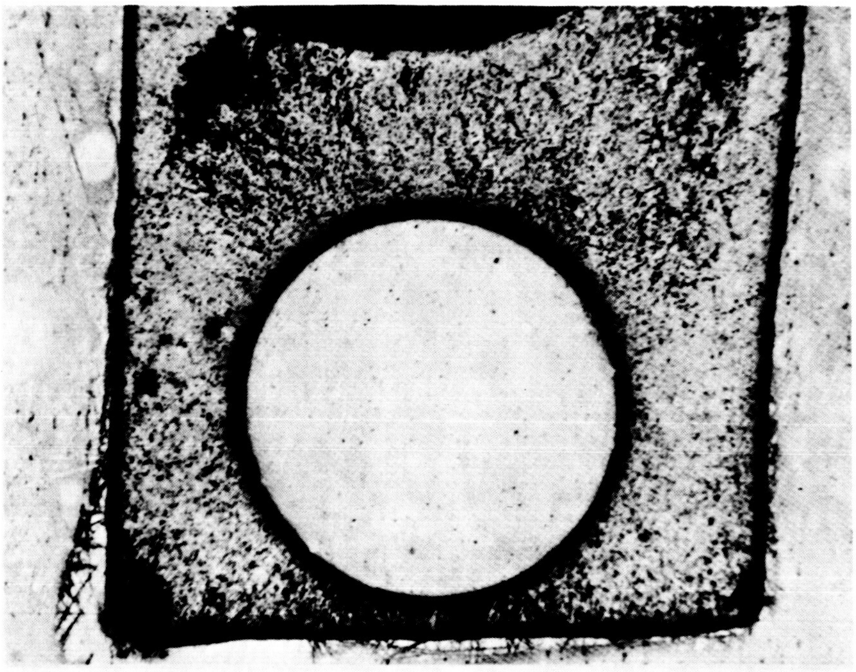


Figure 17. Solder joint 1.3.6.84; bare nickel conductor to solder coated bifurcated terminal; not sterilized; 100x magnification; potassium dichromate etch (02360).

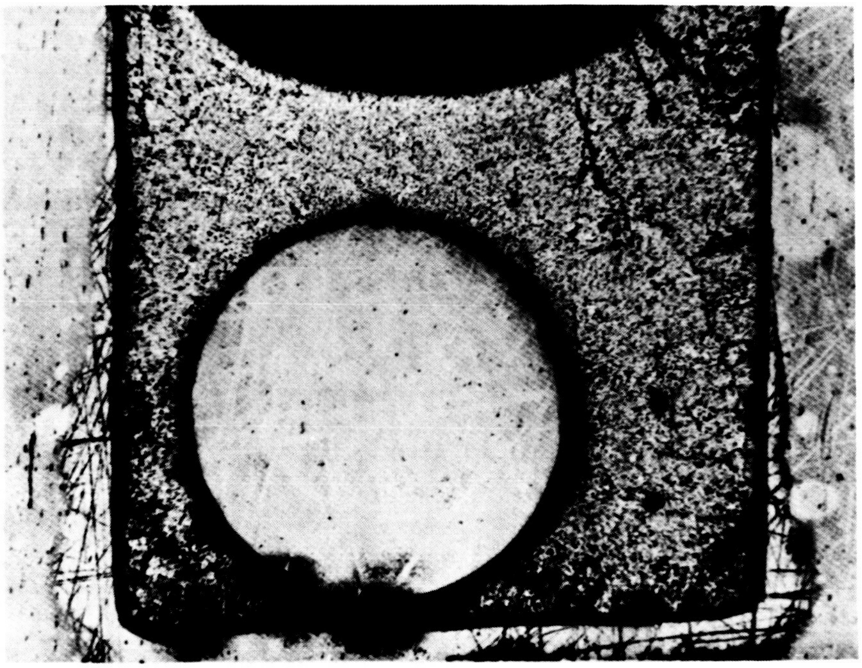


Figure 18. Solder joint 1.3.6.87; bare nickel conductor to solder coated bifurcated terminal; sterilized; 100x magnification; potassium dichromate etch (02361).

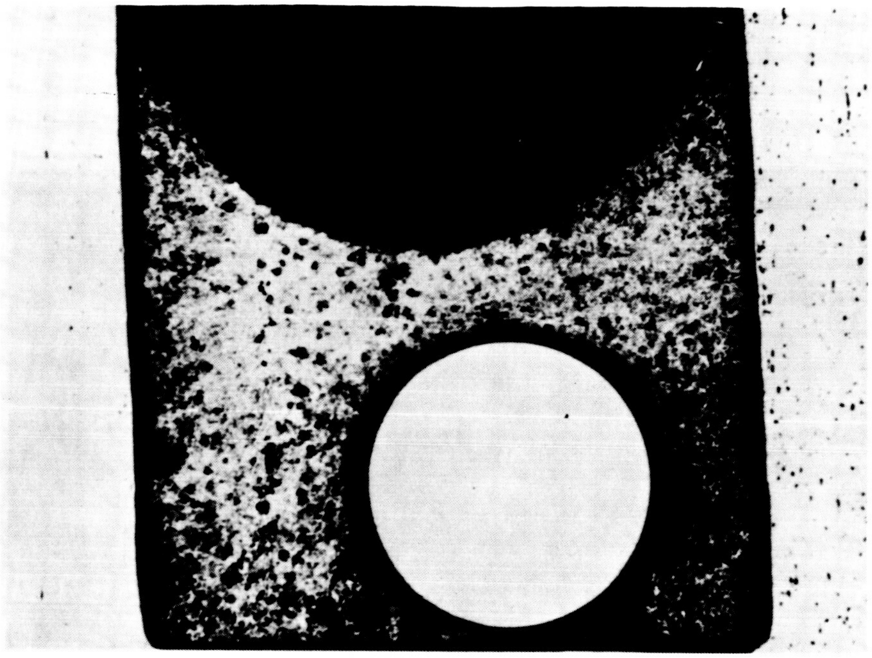


Figure 19. Solder joint 1.4.83; gold plated copper conductor to gold plated bifurcated terminal; not sterilized; 100x magnification; potassium dichromate etch (02362).

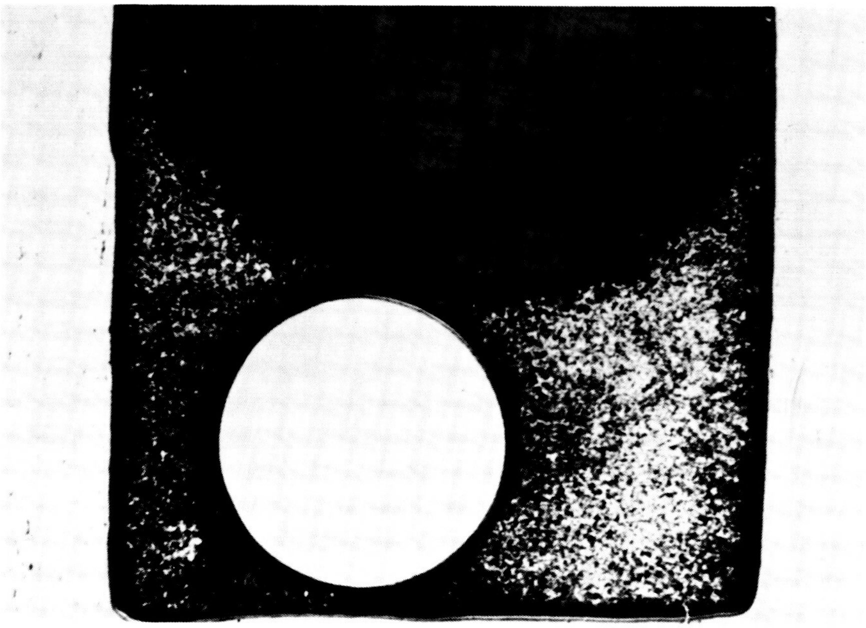


Figure 20. Solder joint 1.4.90; gold plated copper conductor to gold plated bifurcated terminal; sterilized; 100x magnification; potassium dichromate etch (02363).

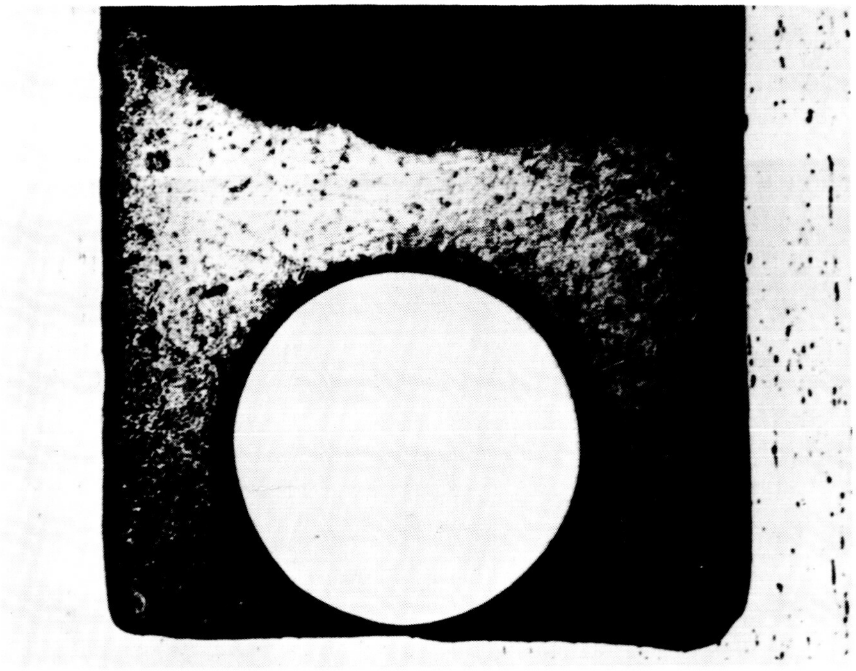


Figure 21. Solder joint 1.5.85; resistor lead to solder coated bifurcated terminal; not sterilized; 100x magnification; potassium dichromate etch (02364).

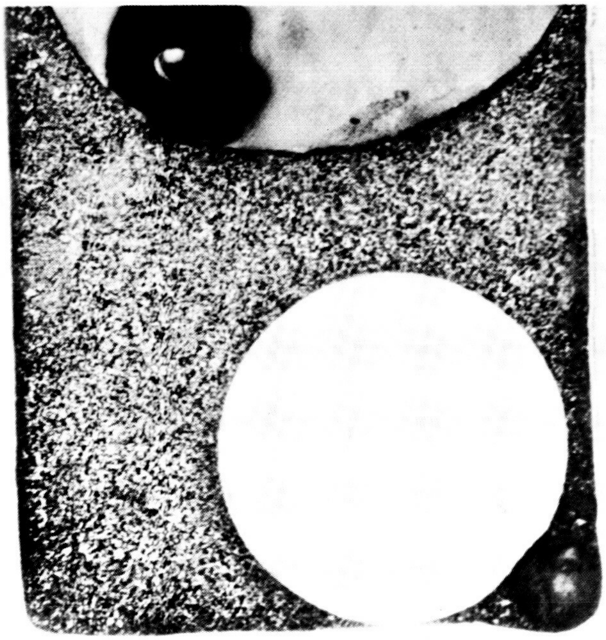


Figure 22. Solder joint 1.5.89; resistor lead to solder coated bifurcated terminal; sterilized; 100x magnification; potassium dichromate etch (02365).

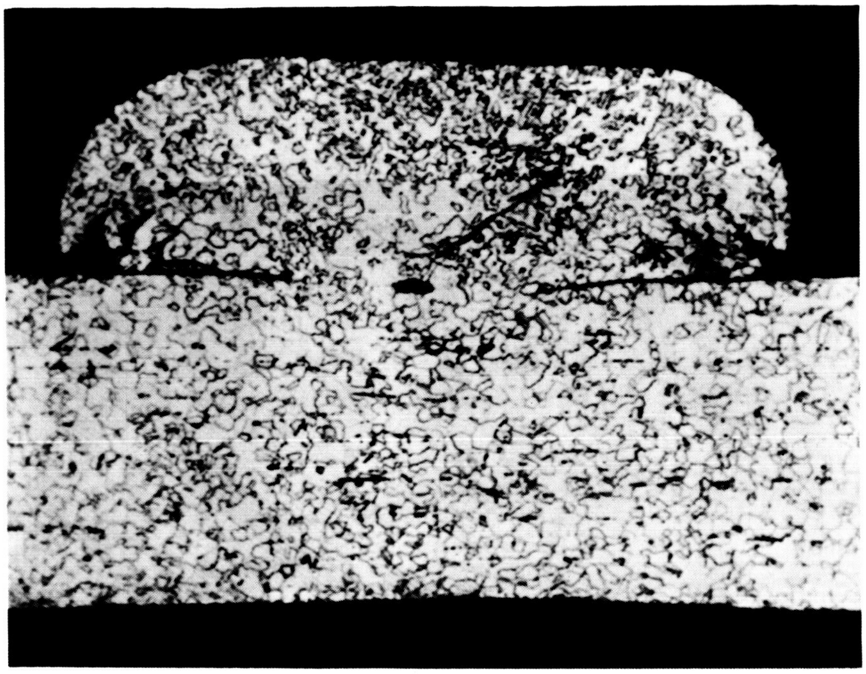


Figure 23. Weld joint 1. 1. 81; bare nickel wire to Inco ribbon; not sterilized; 150x magnification; nitric-acetic etch (02316)

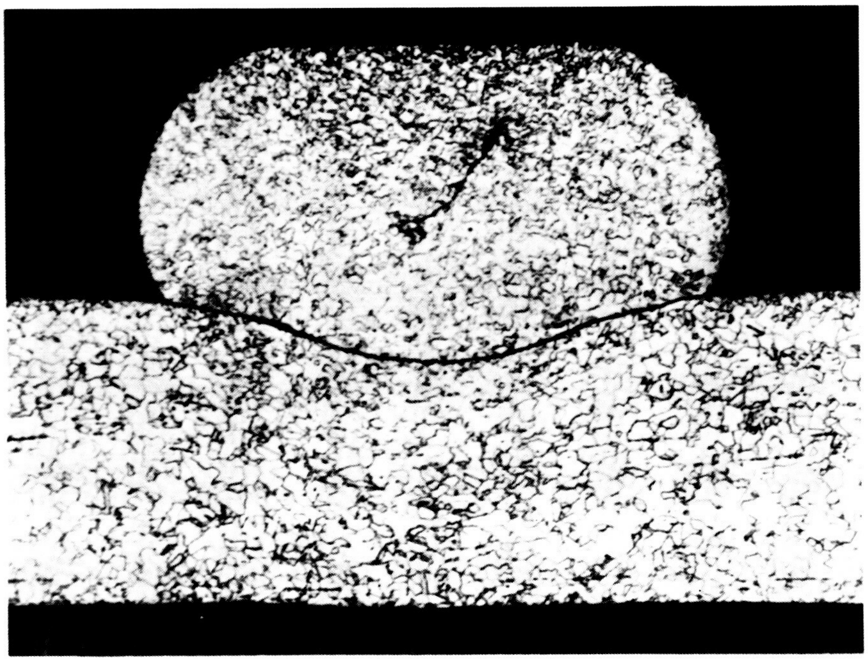


Figure 24. Weld joint 1. 1. 86; bare nickel wire to Inco ribbon; sterilized; 150x magnification; nitric-acetic etch (02319).

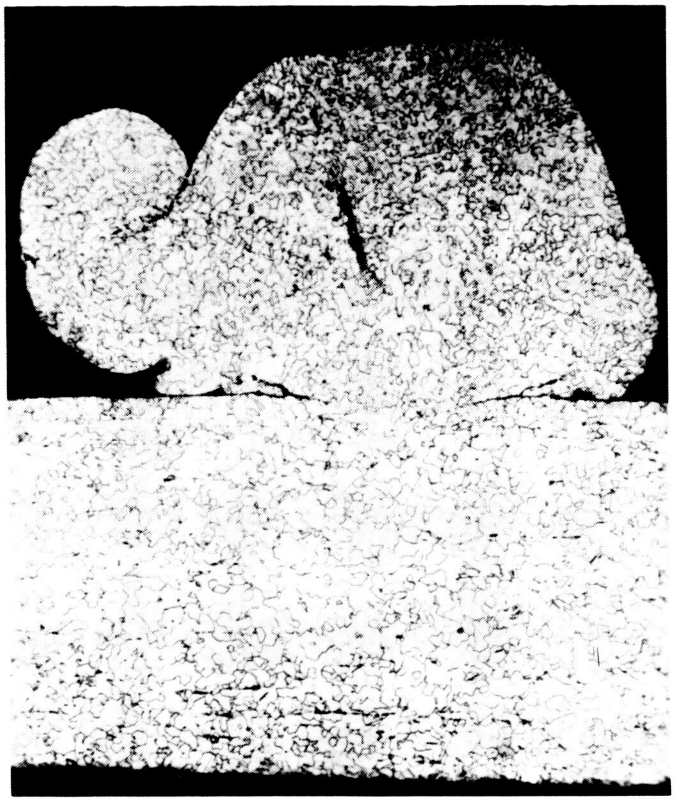


Figure 25. Weld joint 1.1. JPL 1; bare nickel wire to Inco ribbon; not sterilized; 150x magnification; nitric-acetic etch (02317).

Figure 26. Weld joint 1.1. JPL 2; bare nickel wire to Inco ribbon; sterilized; 150x magnification; nitric-acetic etch (02318).

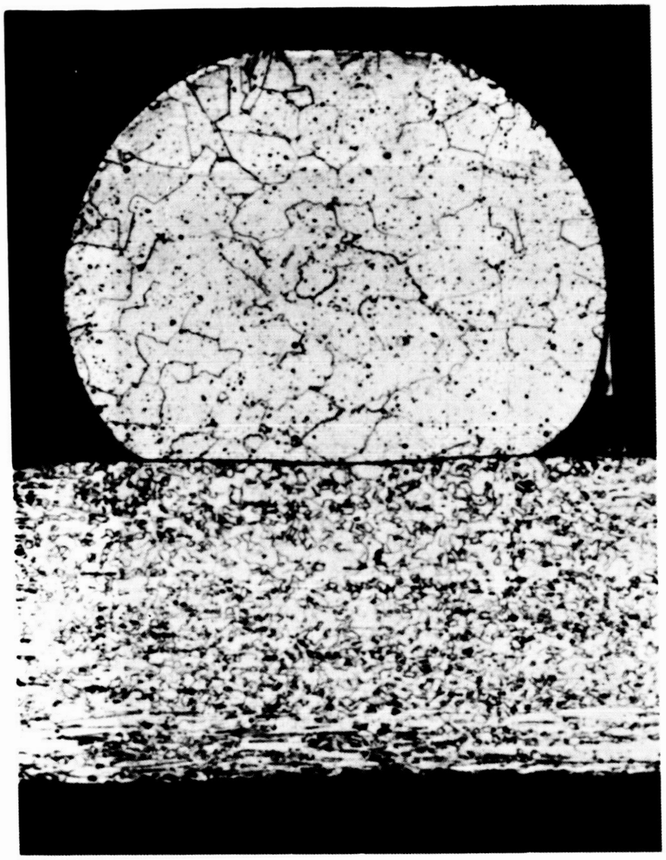


Figure 27. Weld joint 1. 2. 81; gold plated nickel wire to Inco ribbon; not sterilized; 150x magnification; nitric-acetic etch (02320).

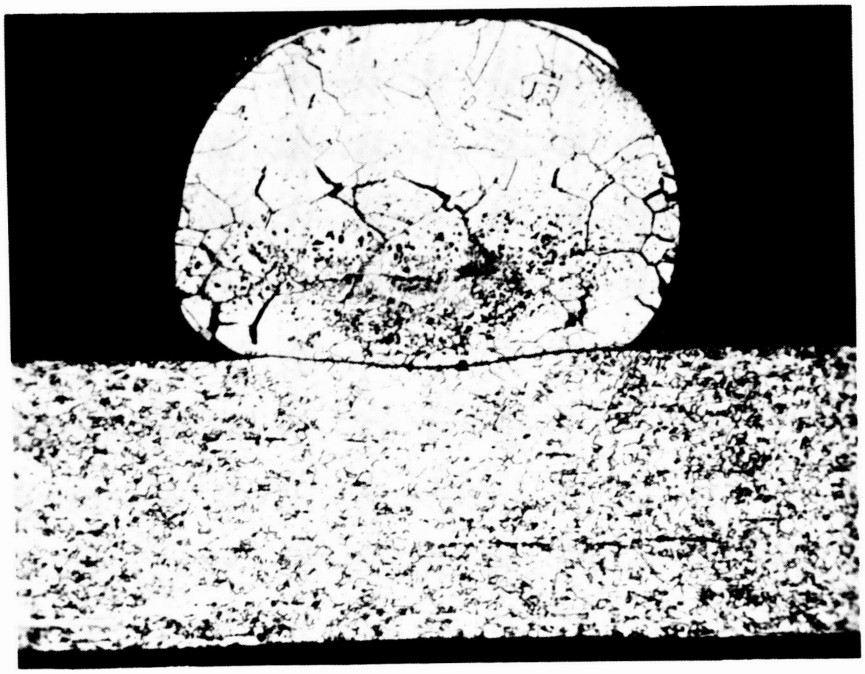


Figure 28. Weld joint 1. 2. 87; gold plated nickel wire to Inco ribbon; sterilized; 150x magnification; nitric-acetic etch (02323).

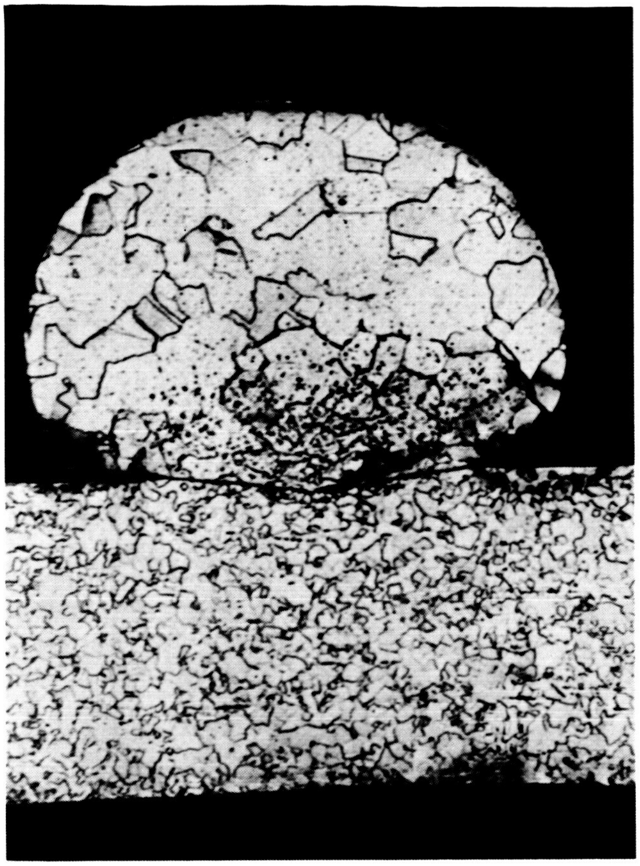


Figure 29. Weld joint 1.2. JPL 1; gold plated nickel wire to Inco ribbon; not sterilized; 150x magnification; nitric-acetic etch (02321).

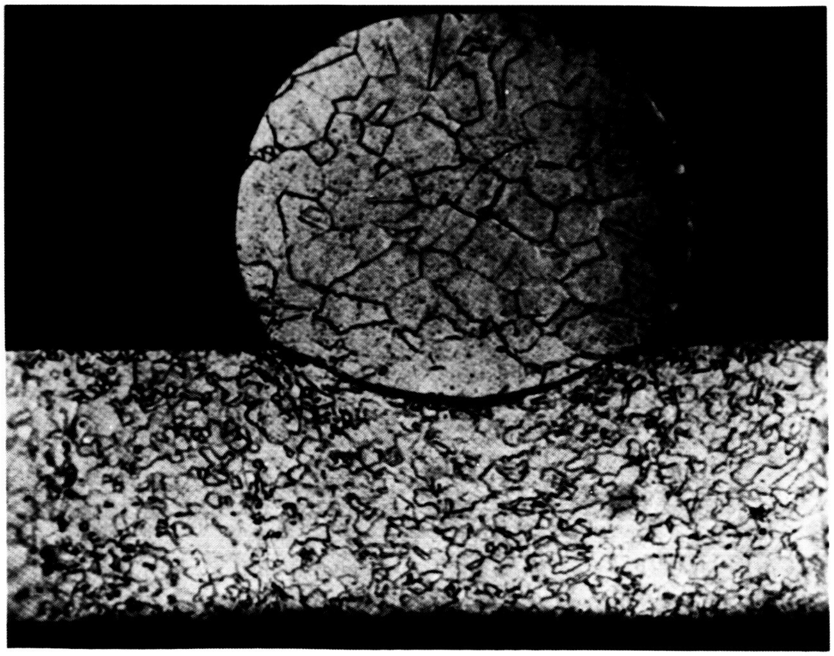


Figure 30. Weld joint 1.2. JPL 2; gold plated nickel wire to Inco ribbon; sterilized; 150x magnification; nitric-acetic etch (02322).

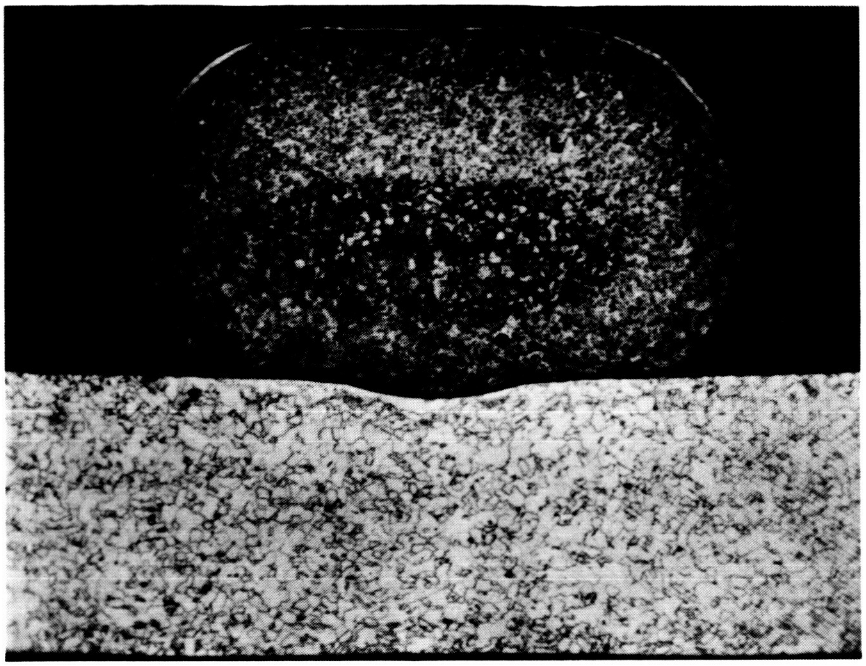


Figure 31. Weld joint 1. 3. 85; gold plated Kovar wire to Inco ribbon; not sterilized; 150x magnification; Carapella + nitric-acetic etch (02324).

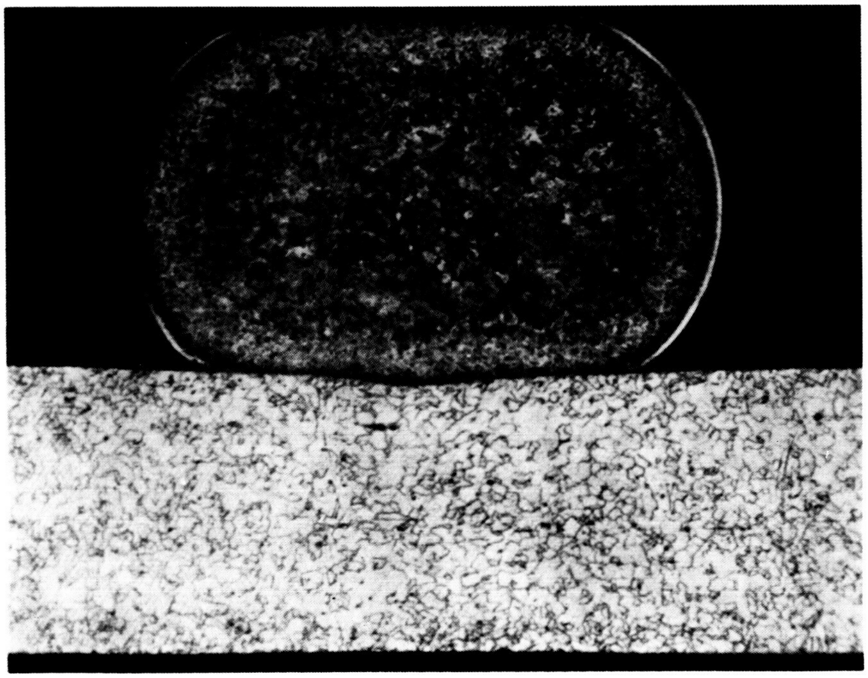


Figure 32. Weld joint 1. 3. 86; gold plated Kovar wire to Inco ribbon; sterilized; 150x magnification; Carapella + nitric-acetic etch (02324).

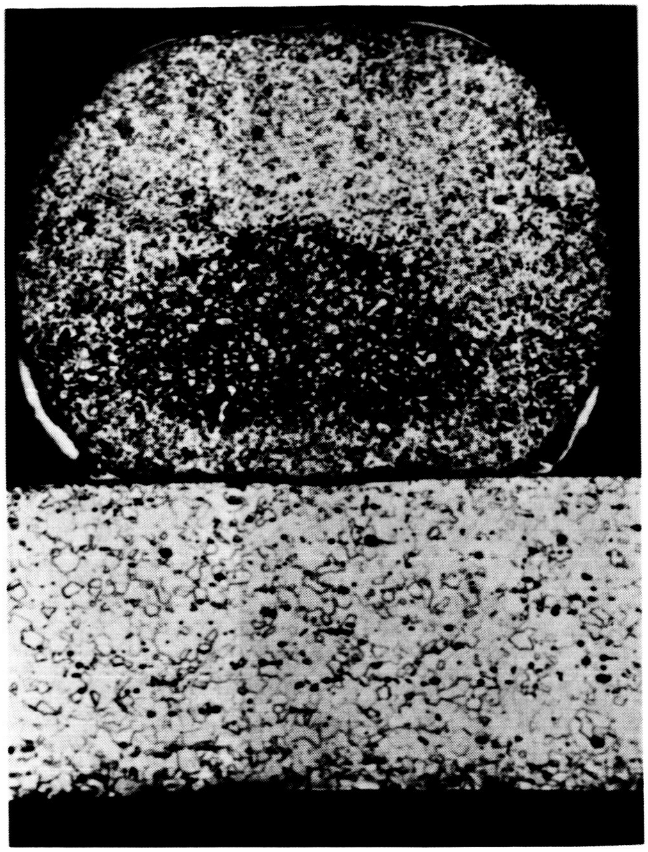


Figure 33. Weld joint 1. 3. JPL 2; gold plated Kovar wire to Inco ribbon; not sterilized; 150x magnification; Carapella + nitric-acetic etch (02325).

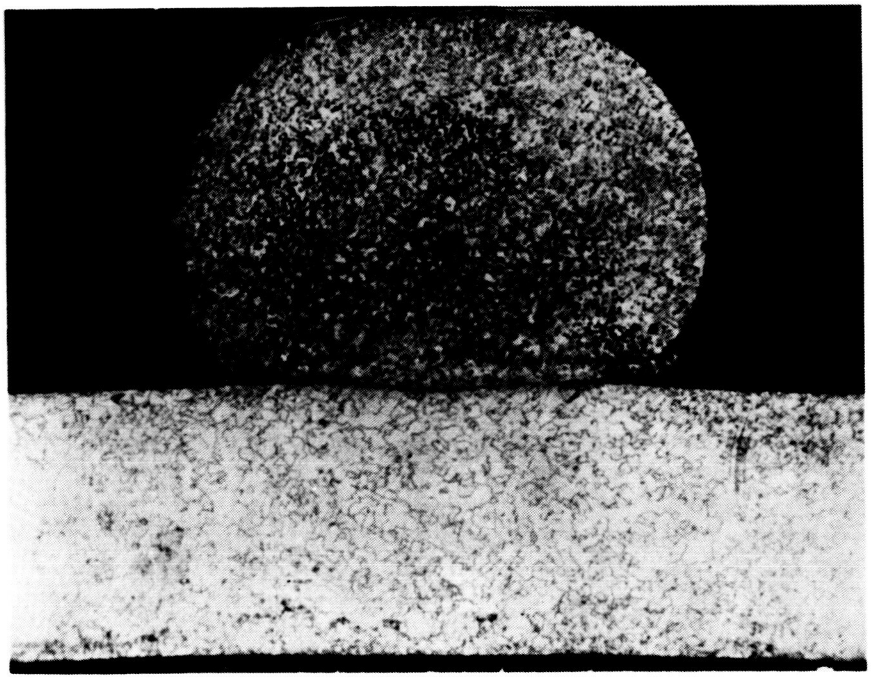


Figure 34. Weld joint 1. 3. JPL 2; gold plated Kovar wire to Inco ribbon; sterilized; 150x magnification; Carapella + nitric-acetic etch (02326).

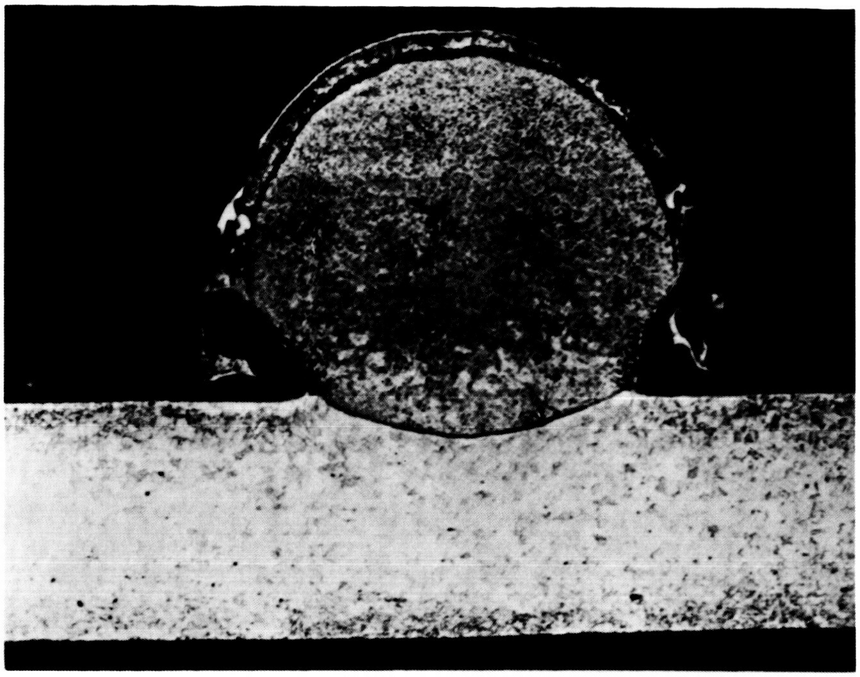


Figure 35. Weld joint 1.4.84; gold plated Dumet wire to Inco ribbon; not sterilized; 150x magnification; Carapella etch (02328).

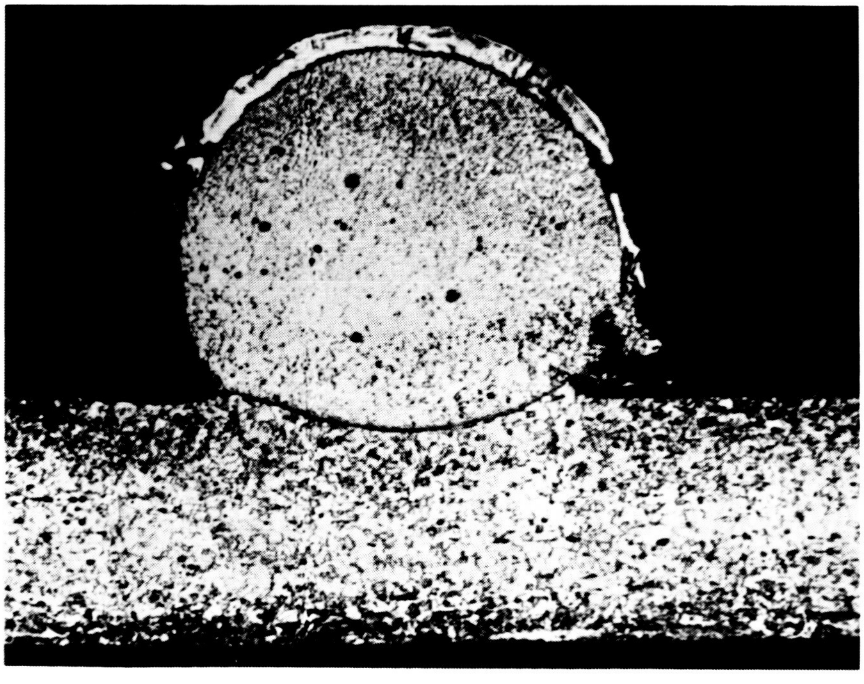


Figure 36. Weld joint 1.4.87; gold plated Dumet wire to Inco ribbon; sterilized; 150x magnification; Carapella etch (02331).

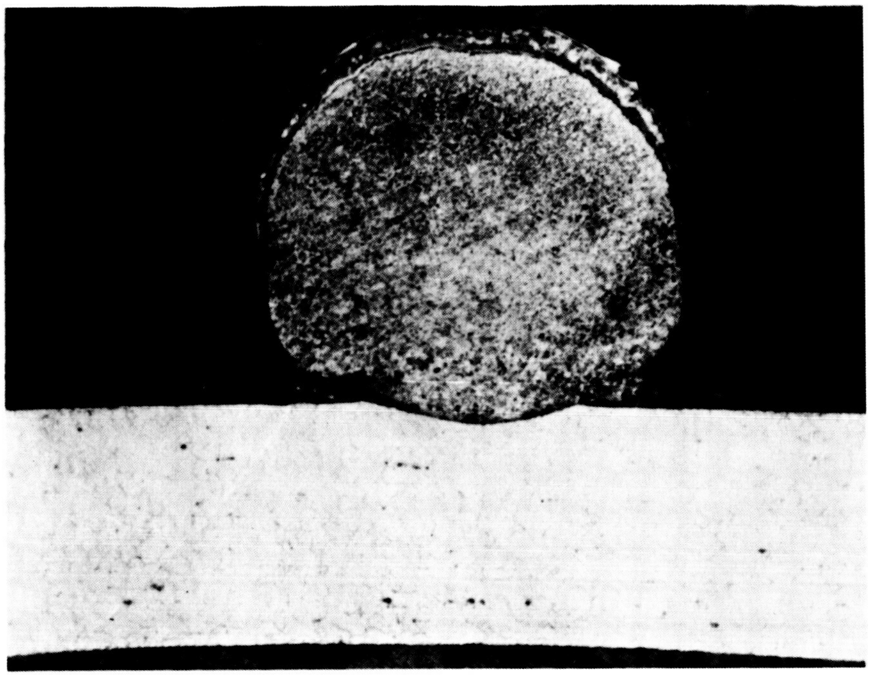


Figure 37. Weld joint 1.4. JPL 2; gold plated Dumet wire to Inco ribbon; not sterilized; 150x magnification; Carapella etch (02324).

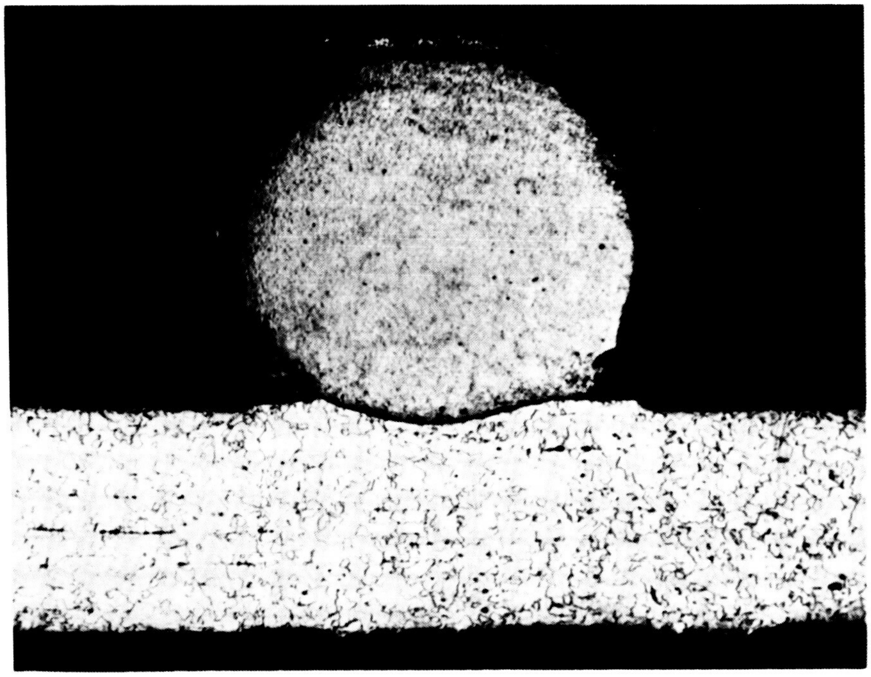


Figure 38. Weld joint 1.4. JPL 2; gold plated Dumet wire to Inco ribbon; sterilized; 150x magnification; Carapella etch (02330).

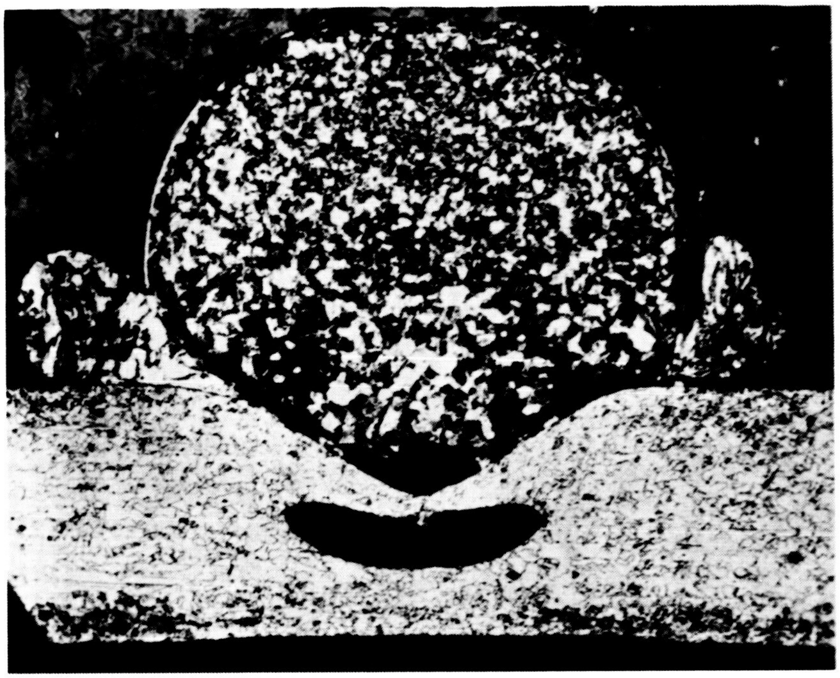


Figure 39. Weld joint 1.5.81; gold plated copper wire to Inco ribbon; not sterilized; 150x magnification; nitric-acetic etch (02332).

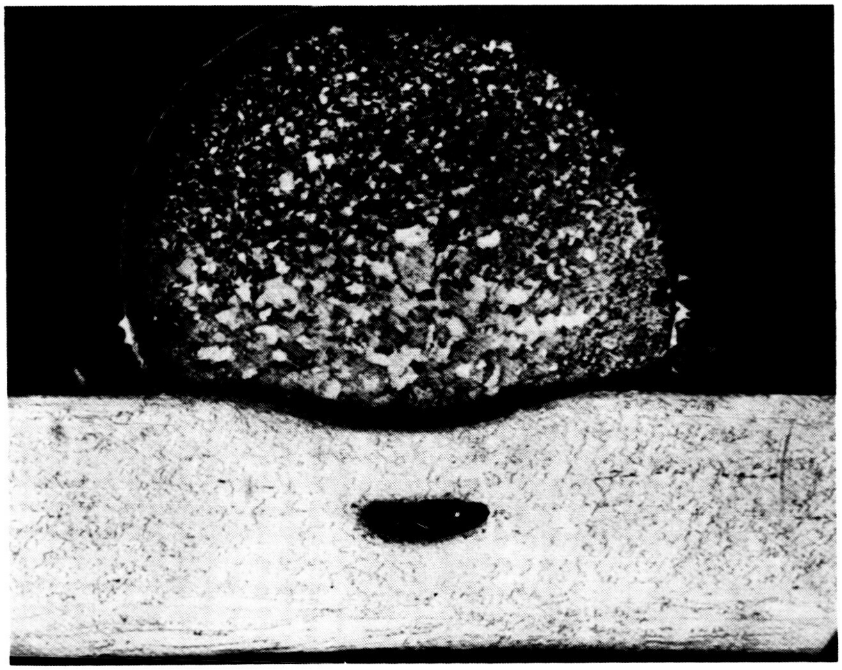


Figure 40. Weld joint 1.5.88; gold plated copper wire to Inco ribbon; sterilized; 150x magnification; nitric-acetic etch (02335).

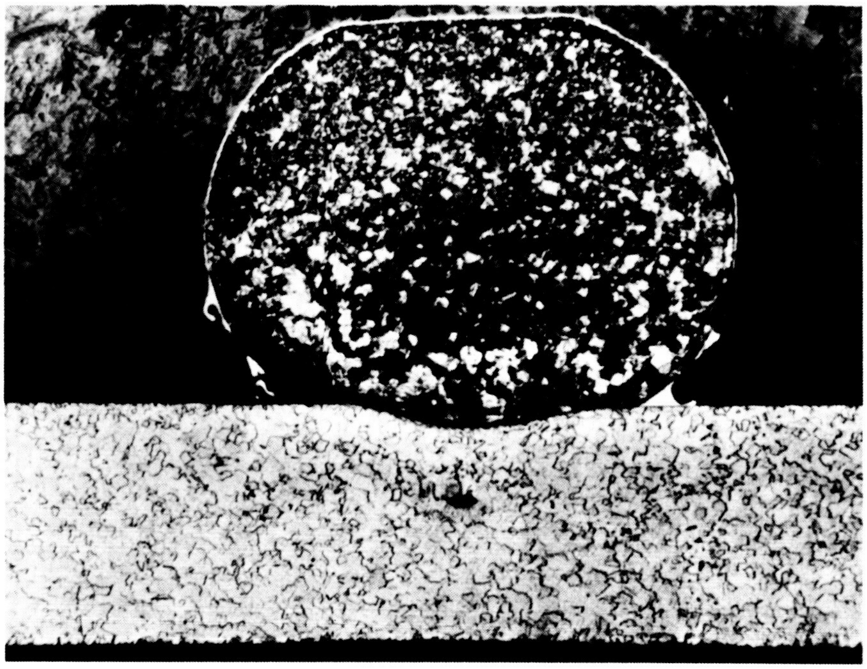


Figure 41. Weld joint 1.5. JPL 1; gold plated copper wire to Inco ribbon; not sterilized; 150x magnification; nitric-acetic etch (02333).

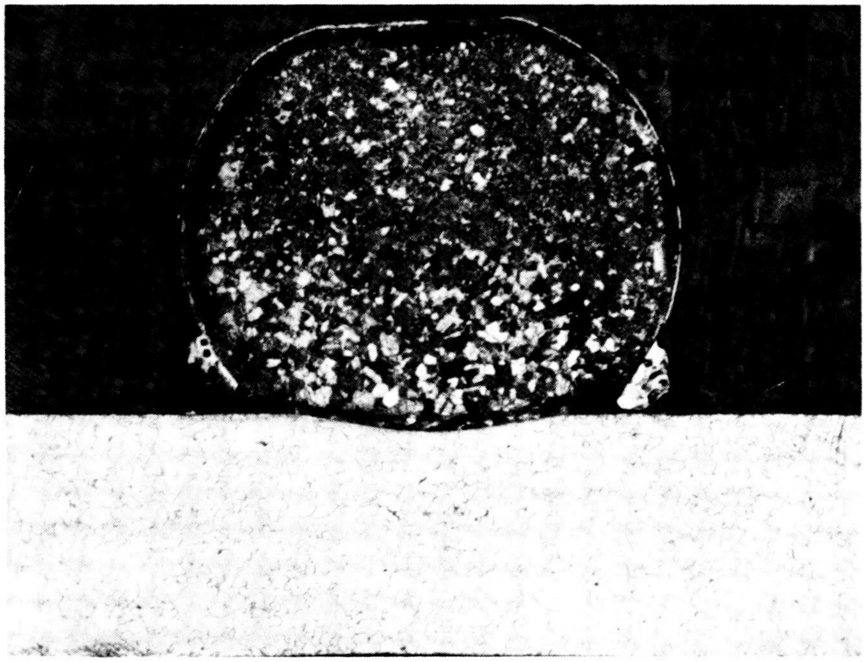


Figure 42. Weld joint 1.5. JPL 2; gold plated copper wire to Inco ribbon; sterilized; 150x magnification; nitric-acetic etch (02334).

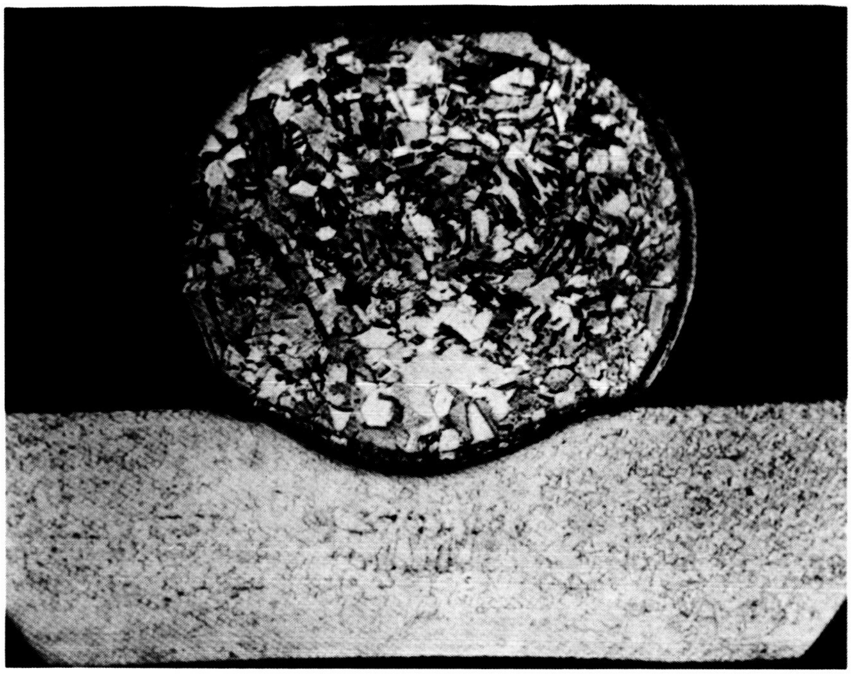


Figure 43. Weld joint 1. 6. 82; solder coated copper wire to Inco ribbon; not sterilized; 150x magnification; nitric-acetic etch (02336).

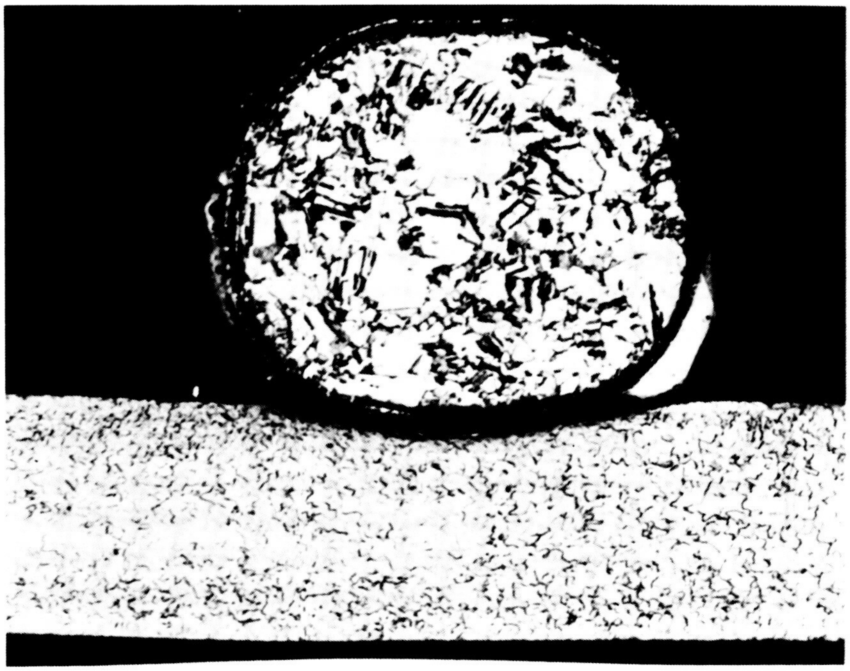


Figure 44. Weld joint 1. 6. 90; solder coated copper wire to Inco ribbon; sterilized; 150x magnification; nitric-acetic etch (02339).

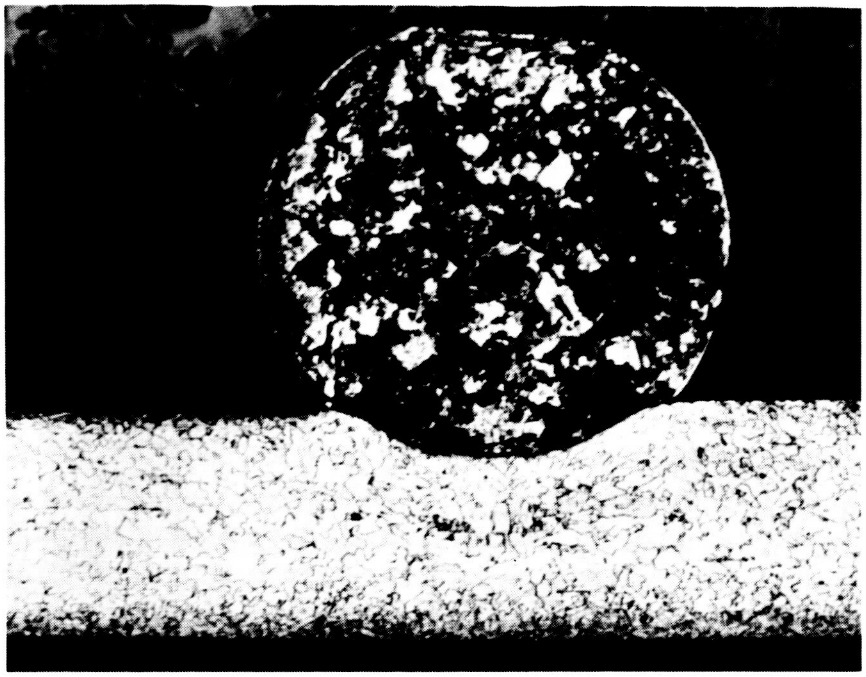


Figure 45. Weld joint 1.6. JPL 1; solder coated copper wire to Inco ribbon; not sterilized; 150x magnification; nitric-acetic etch (02337).

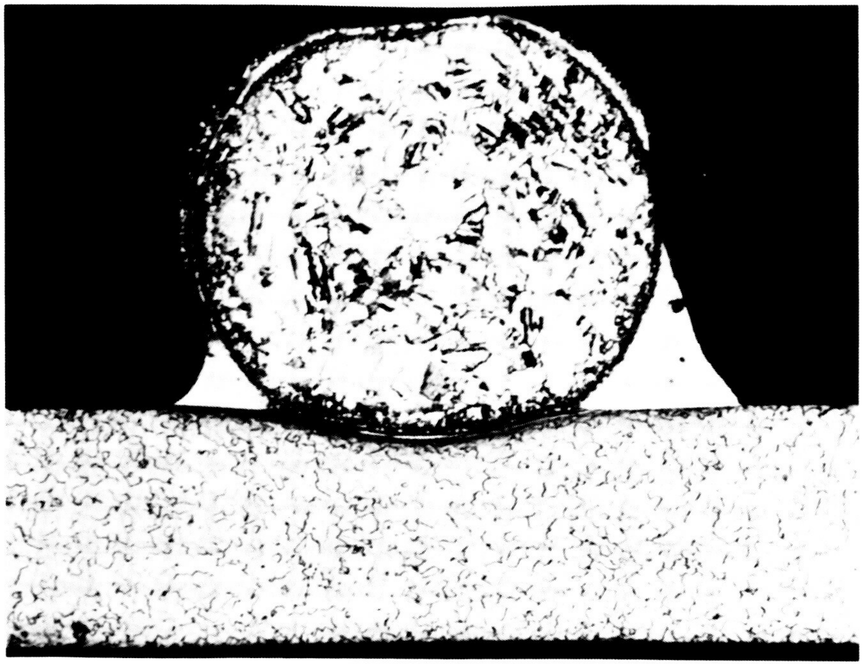


Figure 46. Weld joint 1.6. JPL 2; solder coated copper wire to Inco ribbon; sterilized; 150x magnification; nitric-acetic etch (02338).

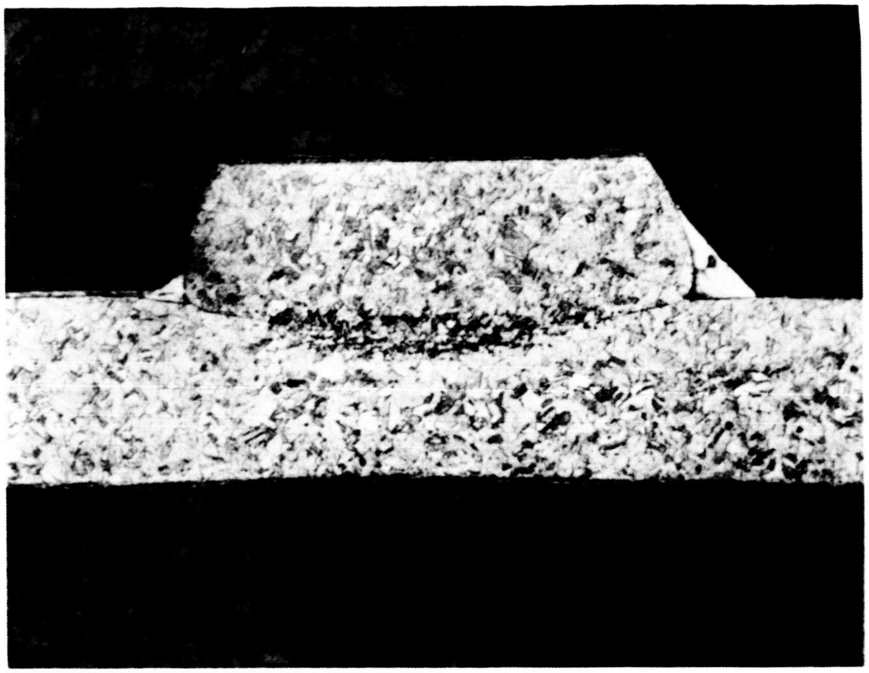


Figure 47. Weld joint 2.83; gold plated Kovar foil to itself; not sterilized; 150x magnification; Carapella etch (02340).

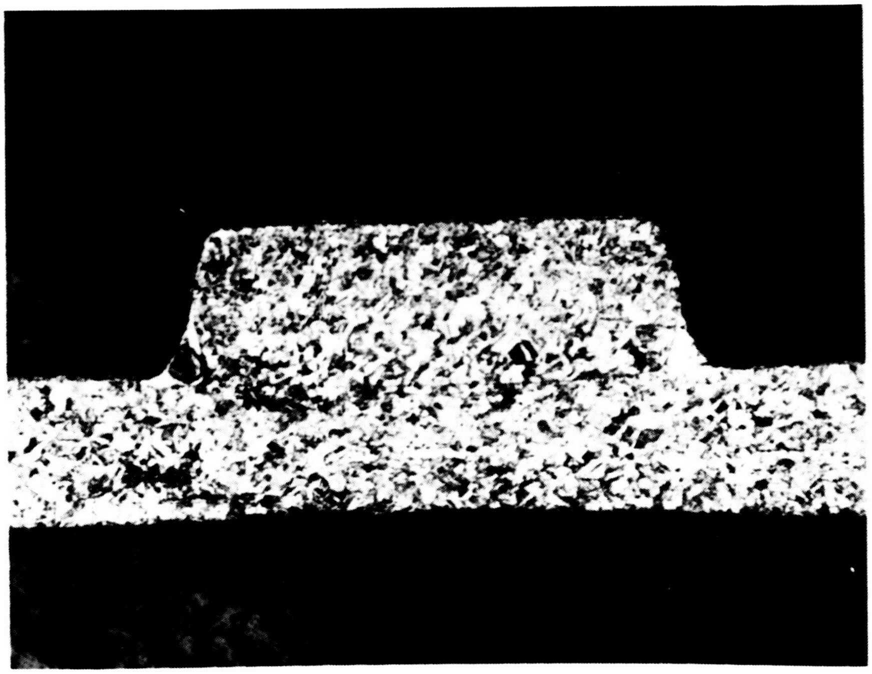


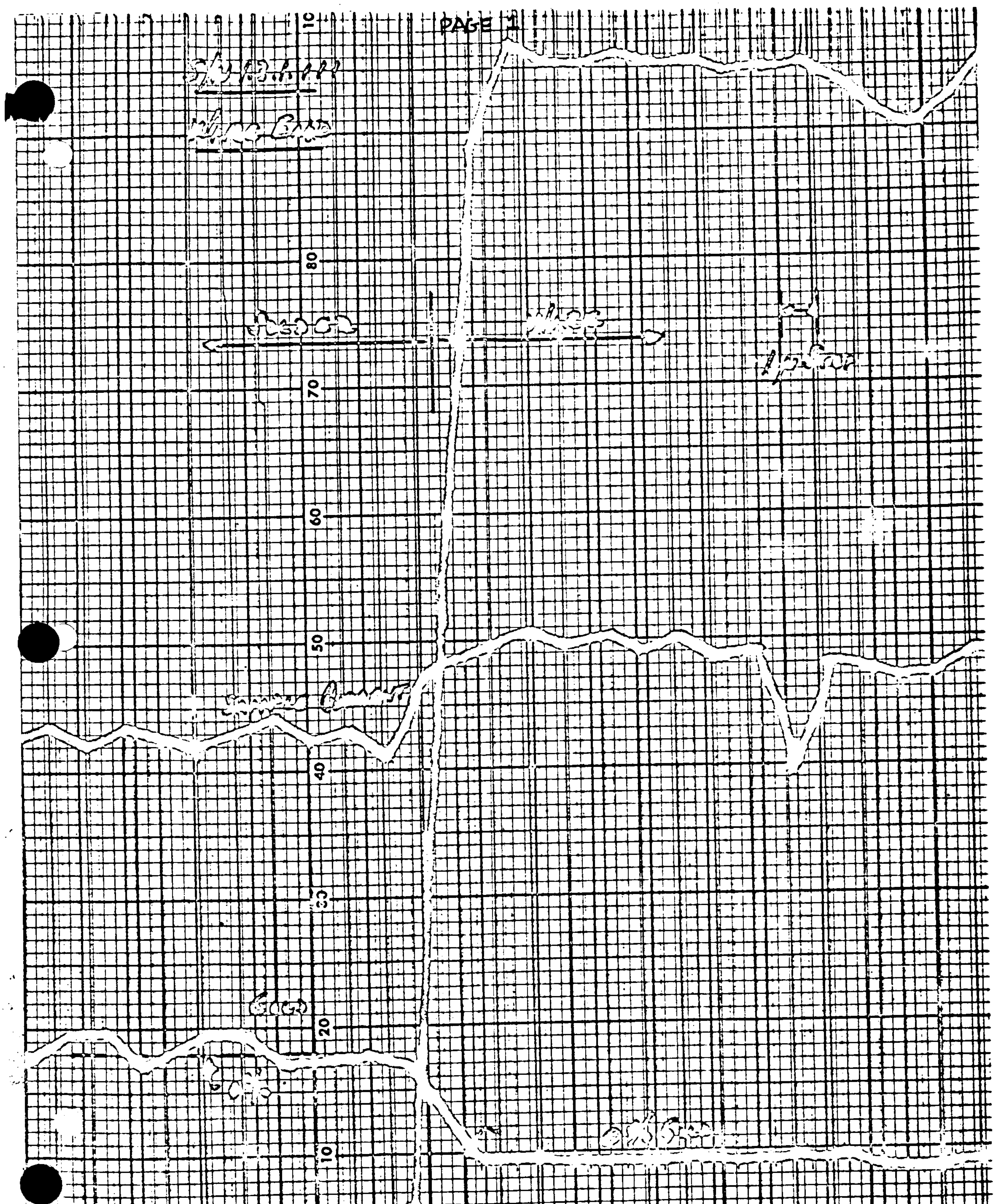
Figure 48. Weld joint 2.86; gold plated Kovar foil to itself; sterilized; 150x magnification; Carapella etch (02343).

ATTACHMENT 4

ELECTRON PROBE MICROANALYSIS CHARTS FOR SOLDERED AND WELDED JOINTS

Solder Joint 1.3.1: Pages 1 - 8
Solder Joint 1.4: Pages 9 - 16
Weld Joint 1.5: Pages 17 - 24

ATTACHMENT 4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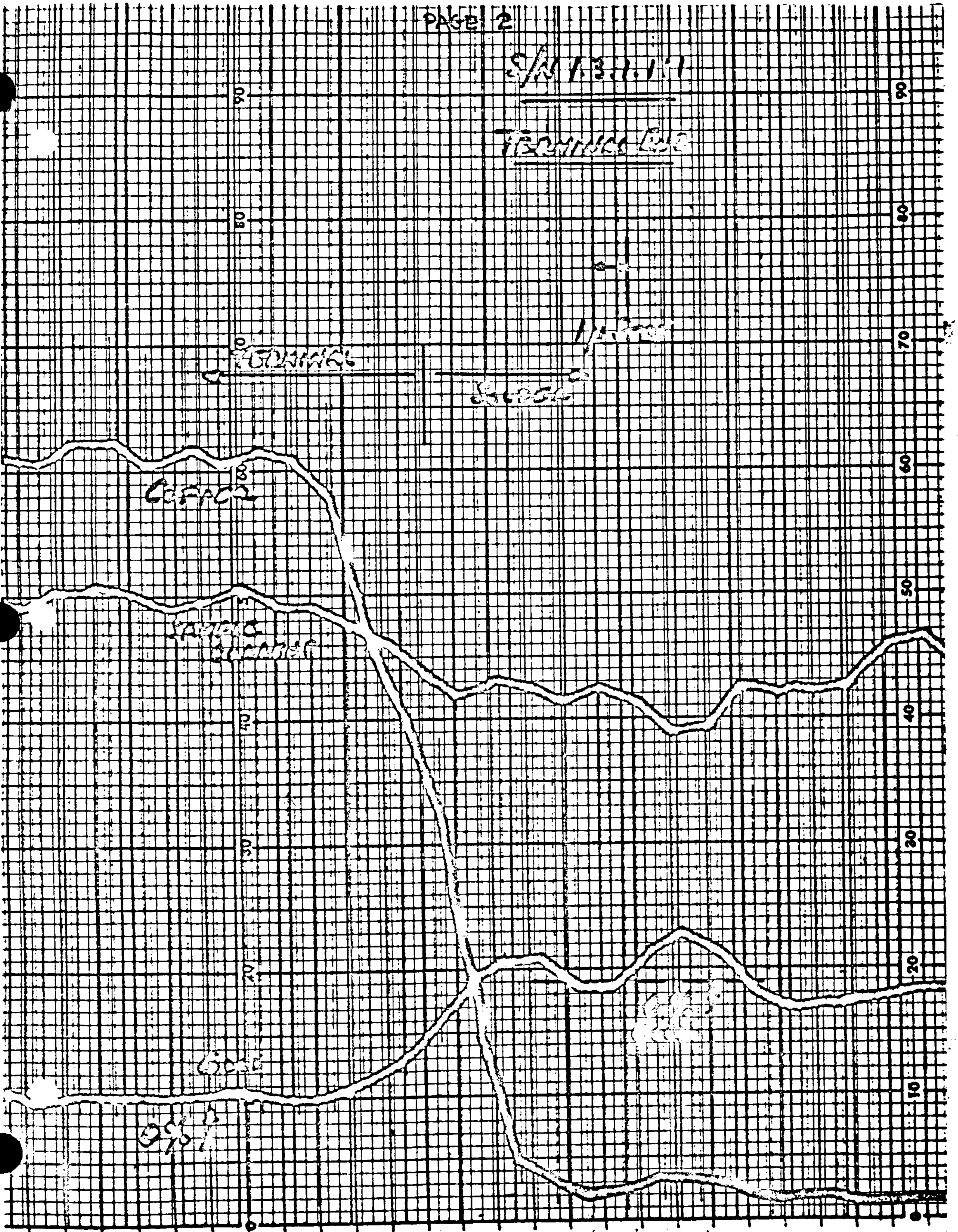
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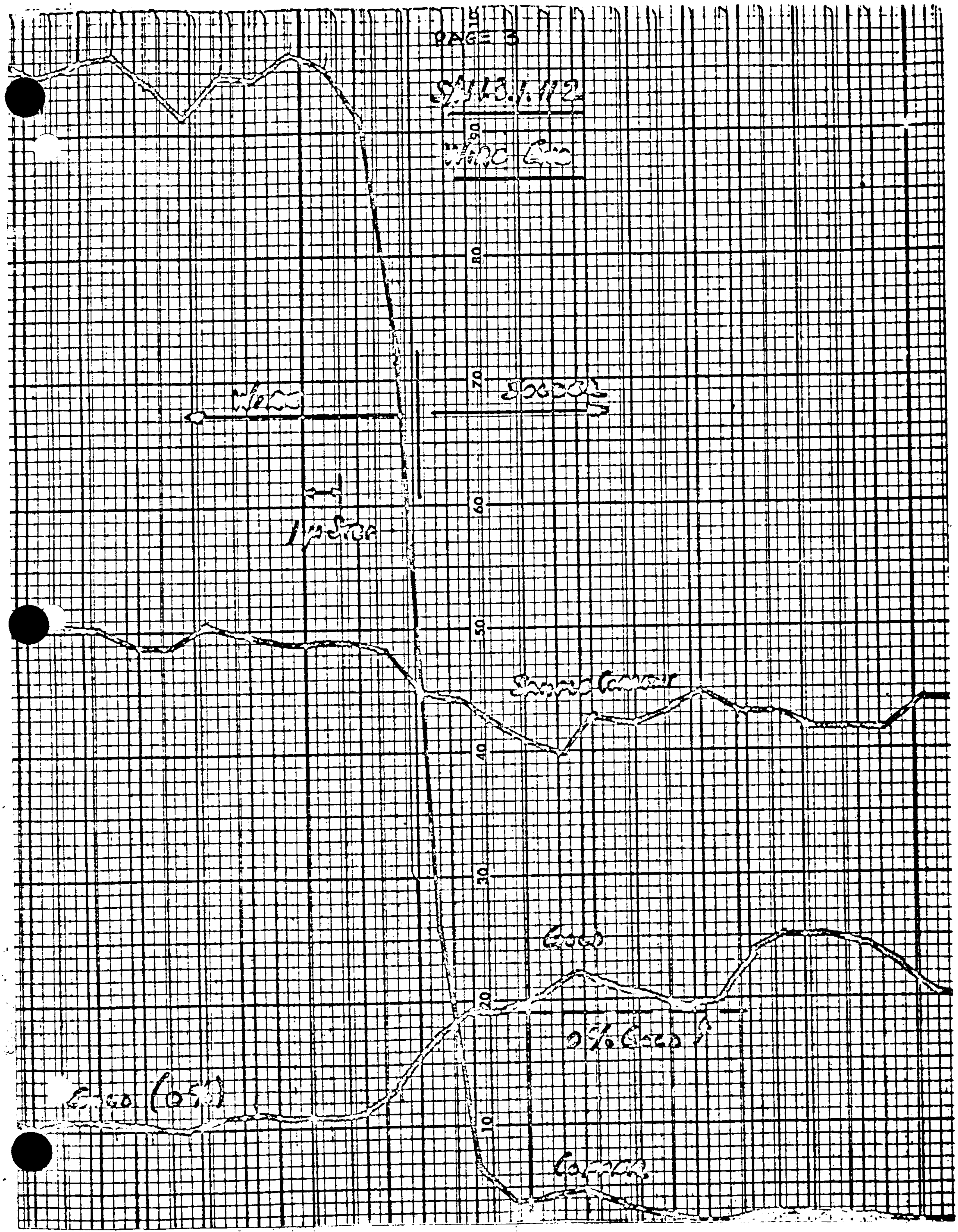
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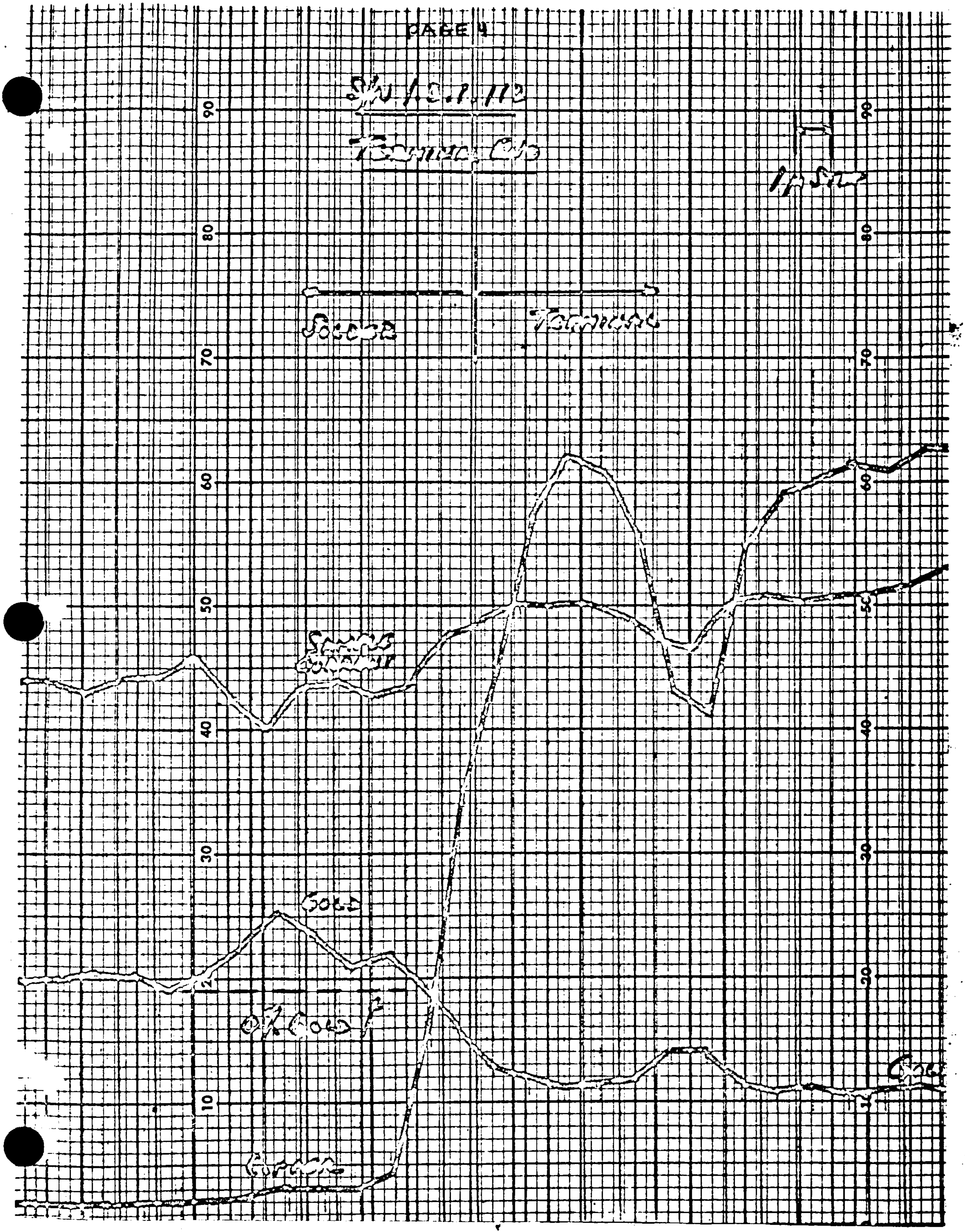
10
1 μ Sec
0% Good ?
(0%)


Second
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Gold
% Gold F
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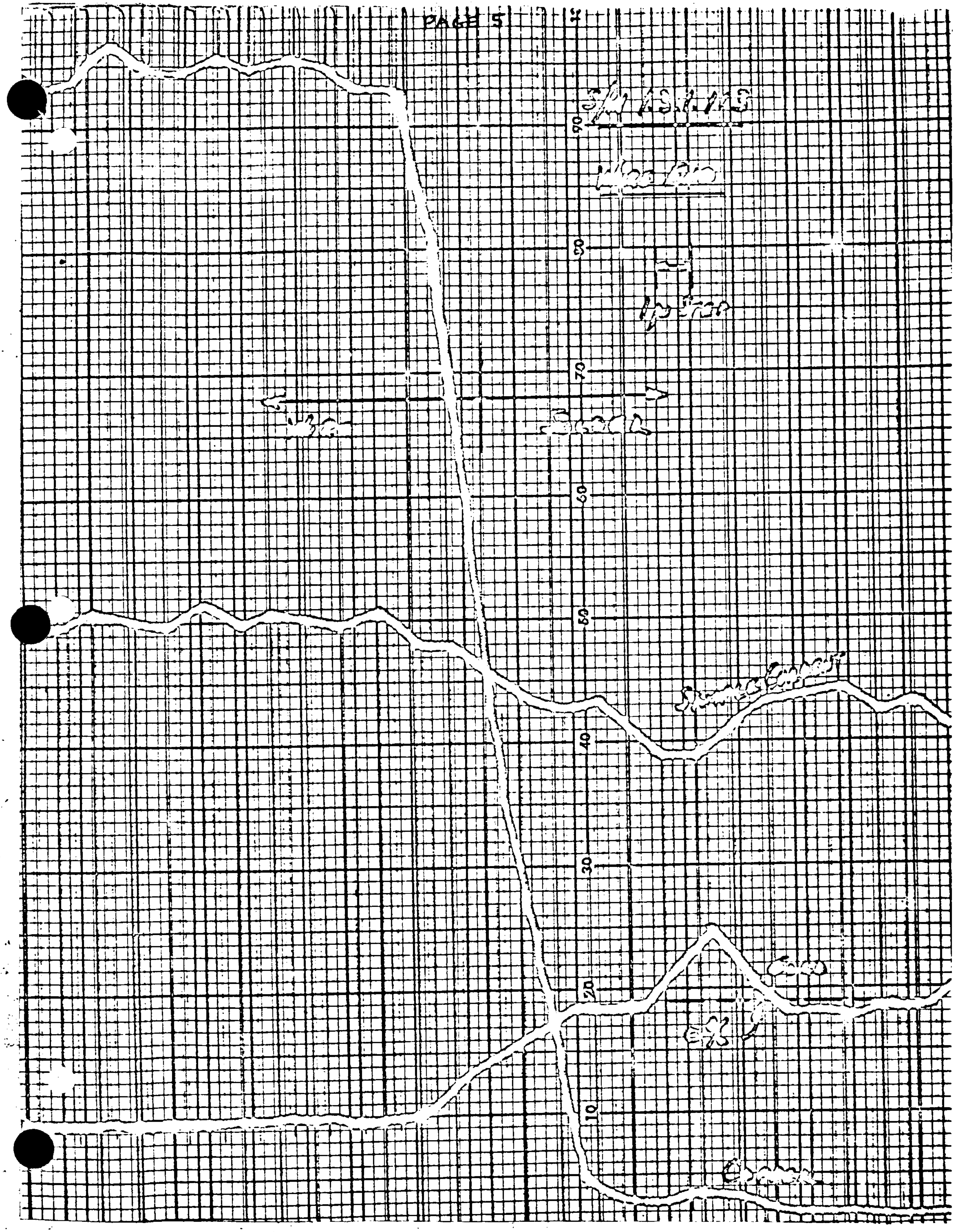
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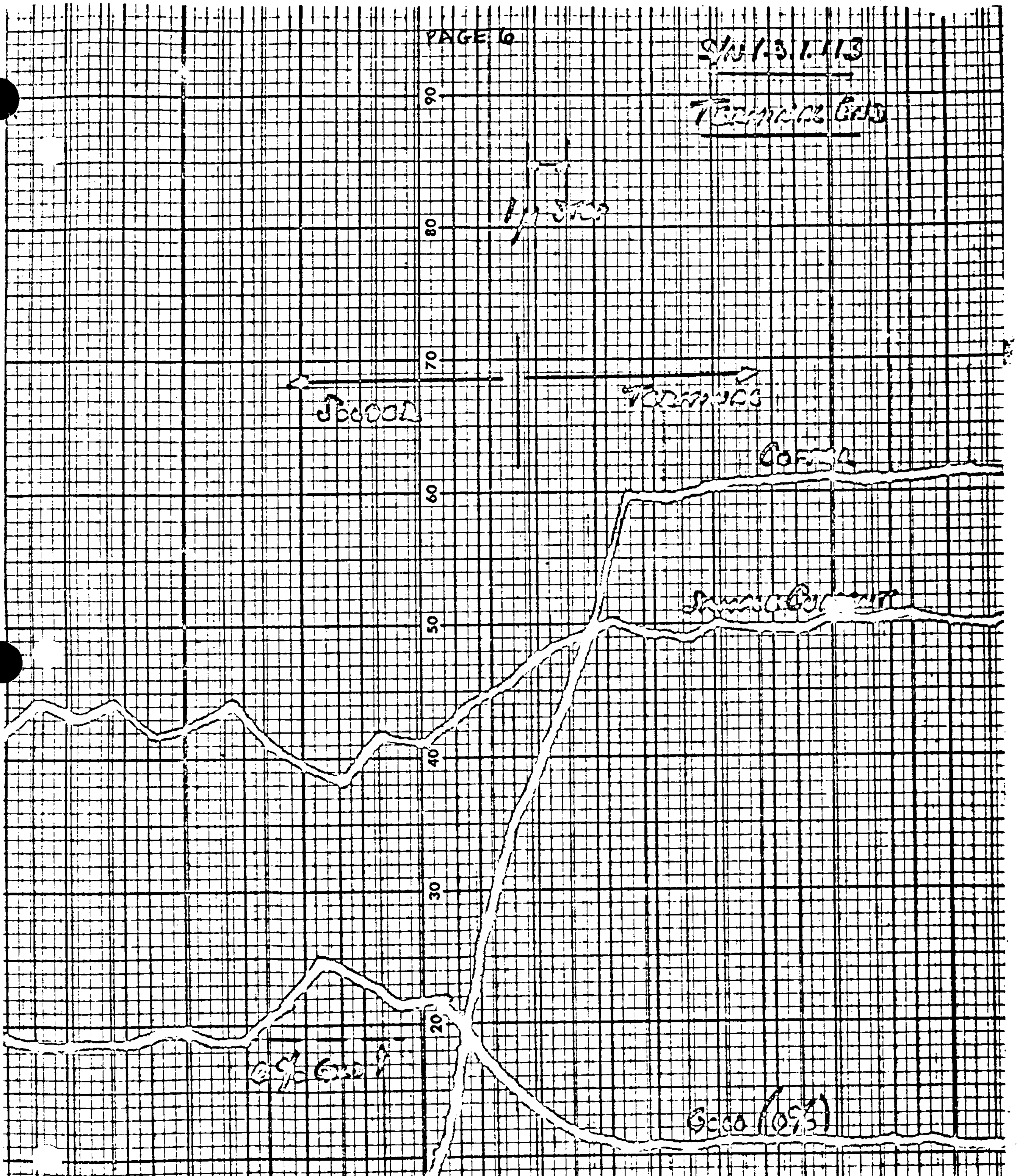
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Terminal Gas
1/2 Step
Second
Terminals
Coral
Sulphur Content
Gold (0%)
0% Gold ?
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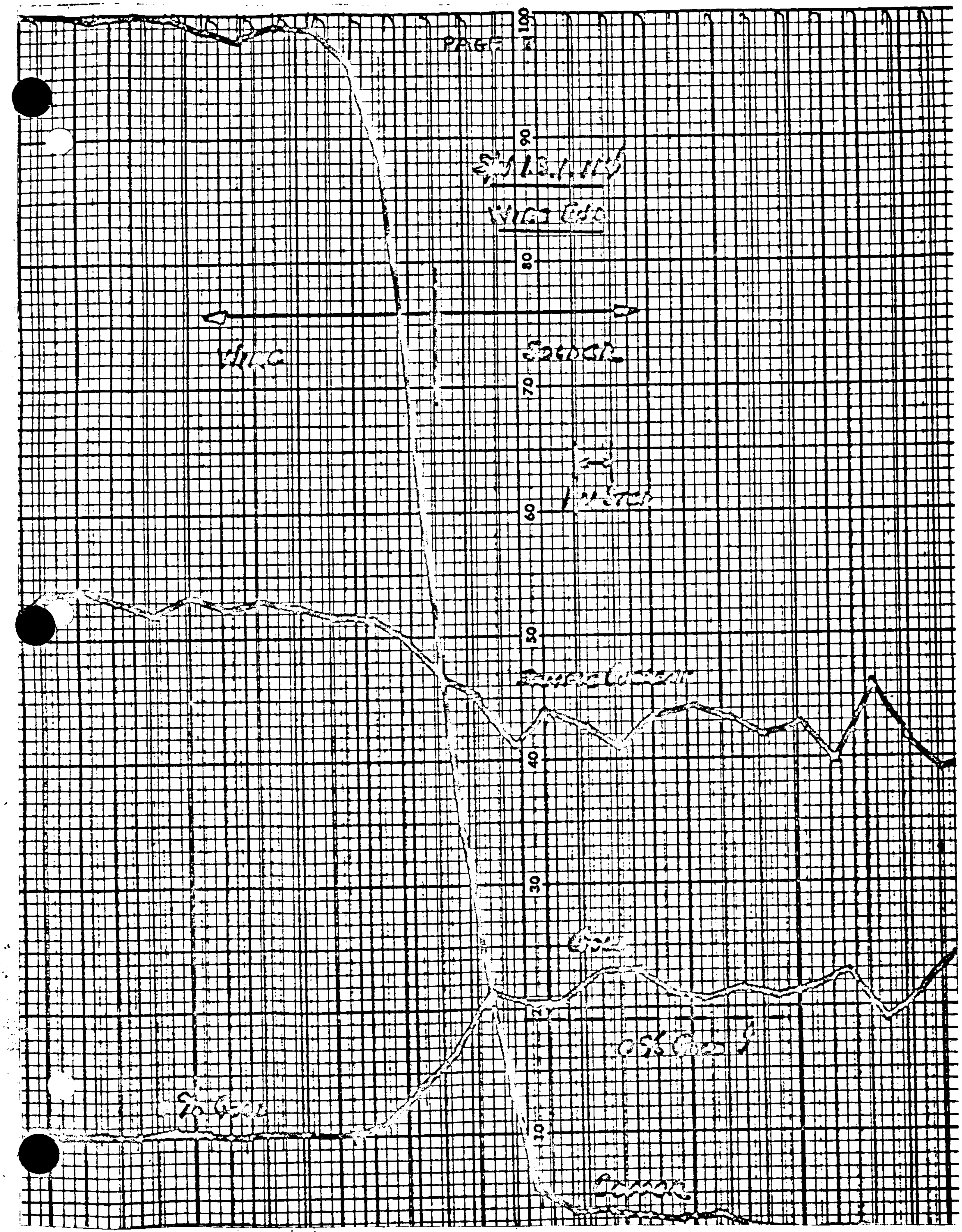
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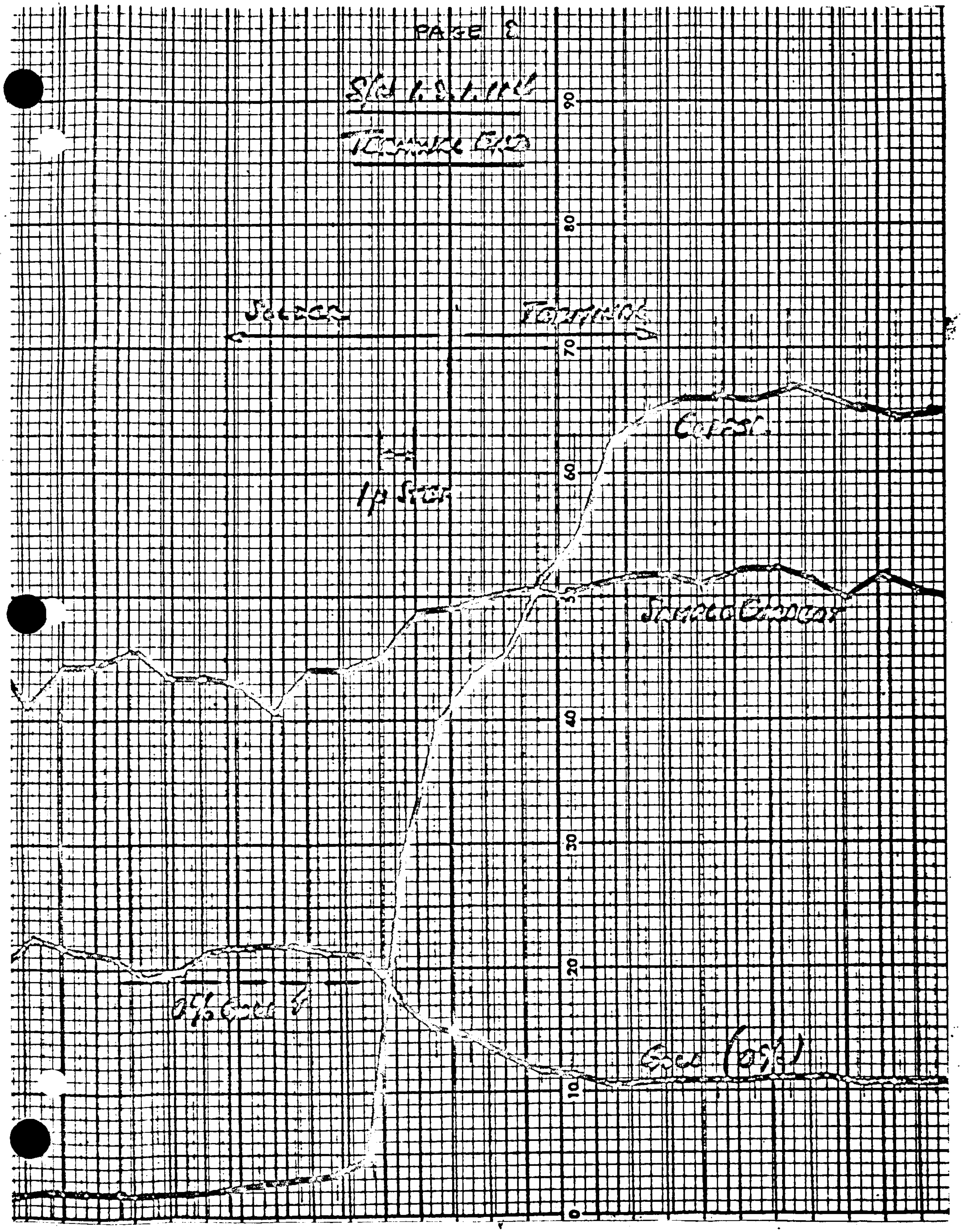
80
Wire
Stock
70
60
50
40
30
Gold
20
% Gold
10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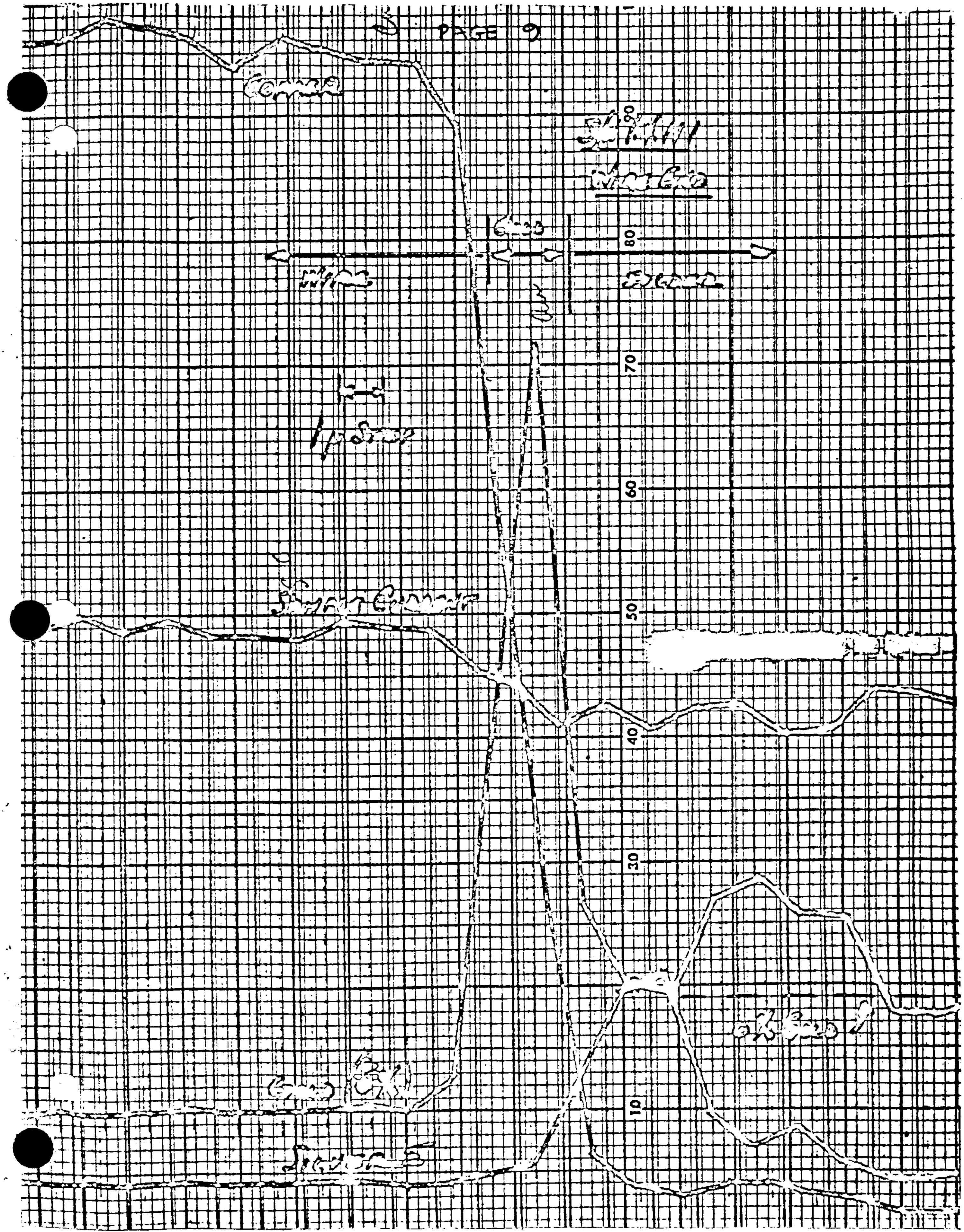
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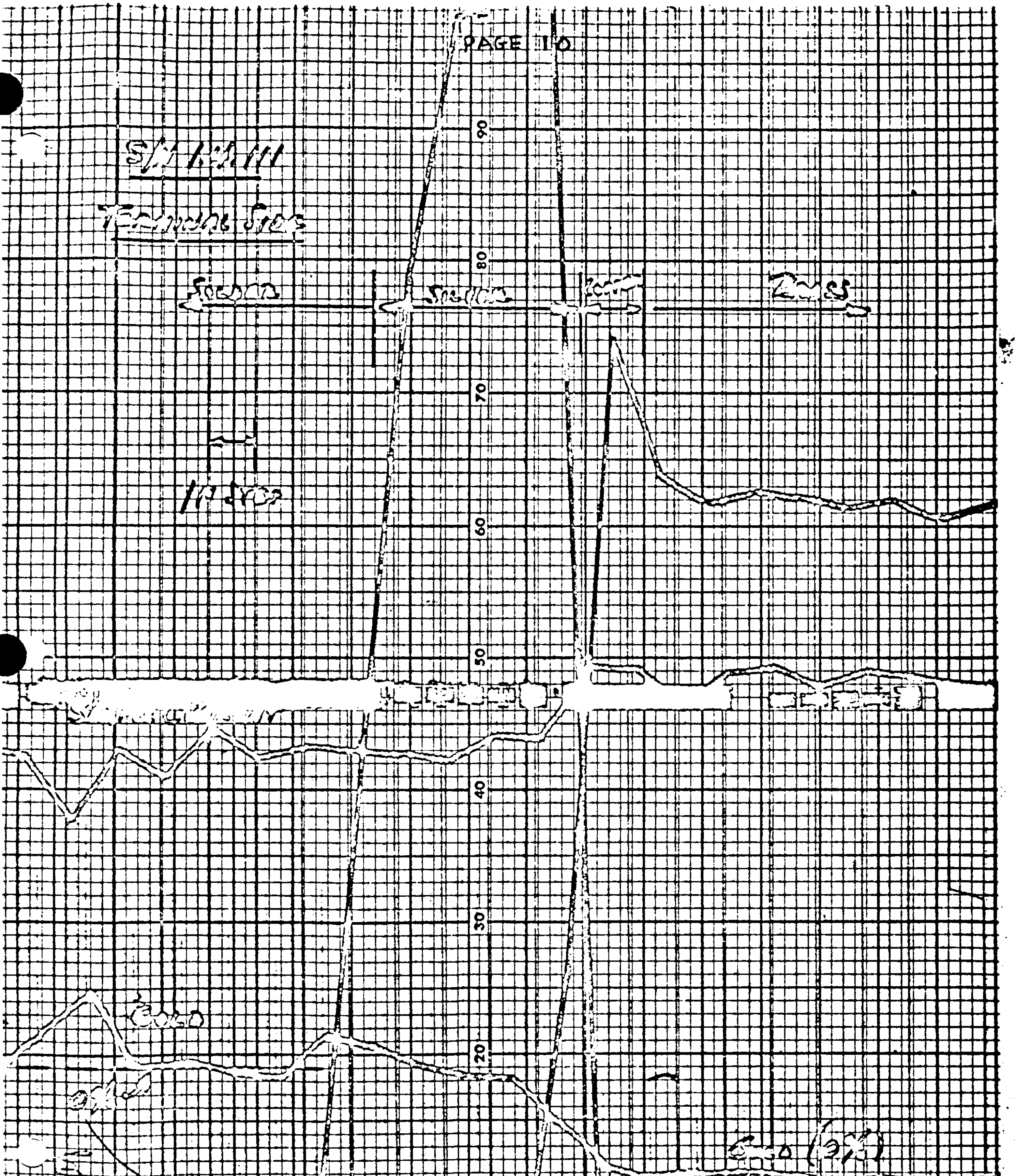
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Silver
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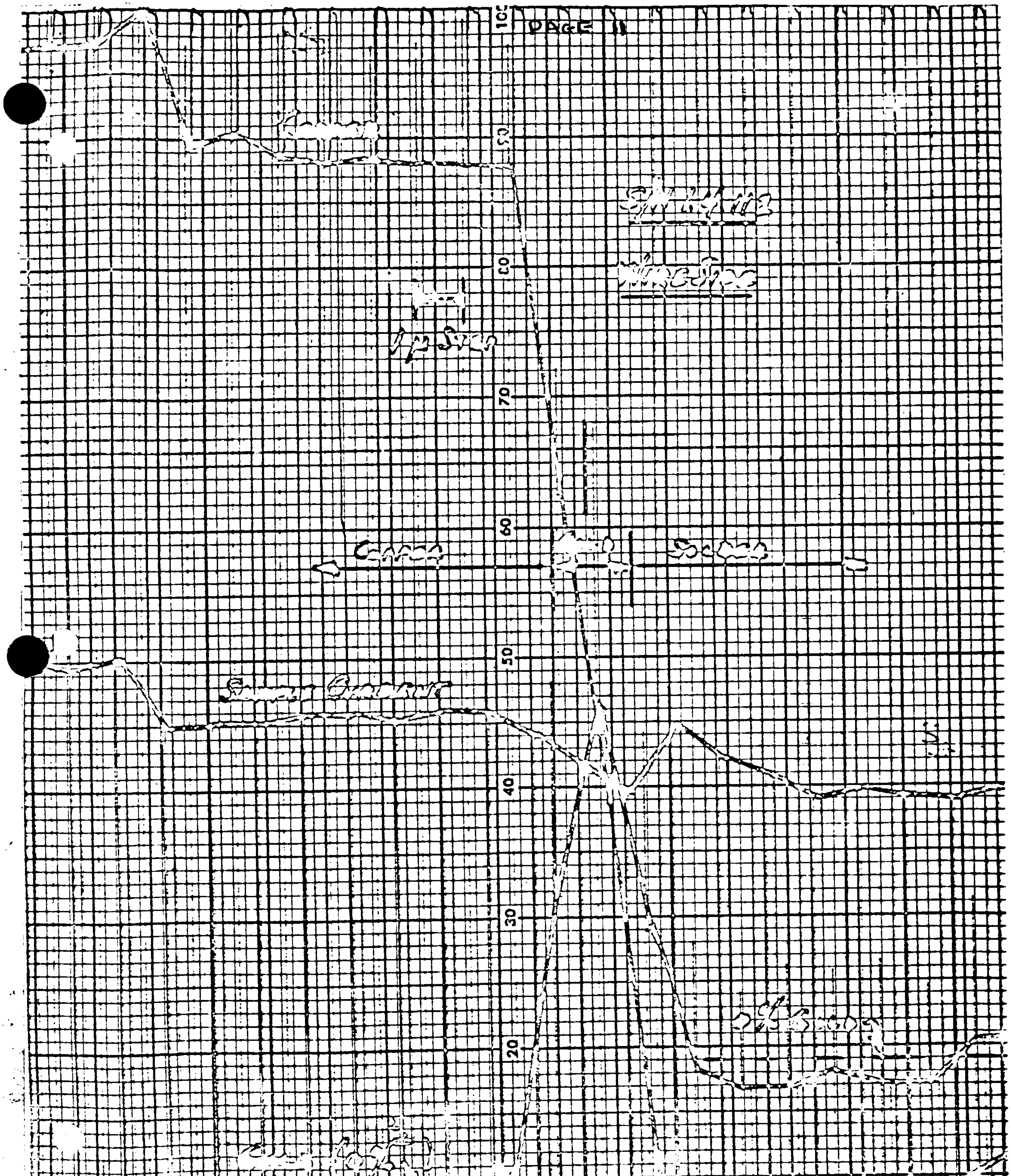
60
50
40
30
20
10
Gold
Silver
Copper
Gold (3X)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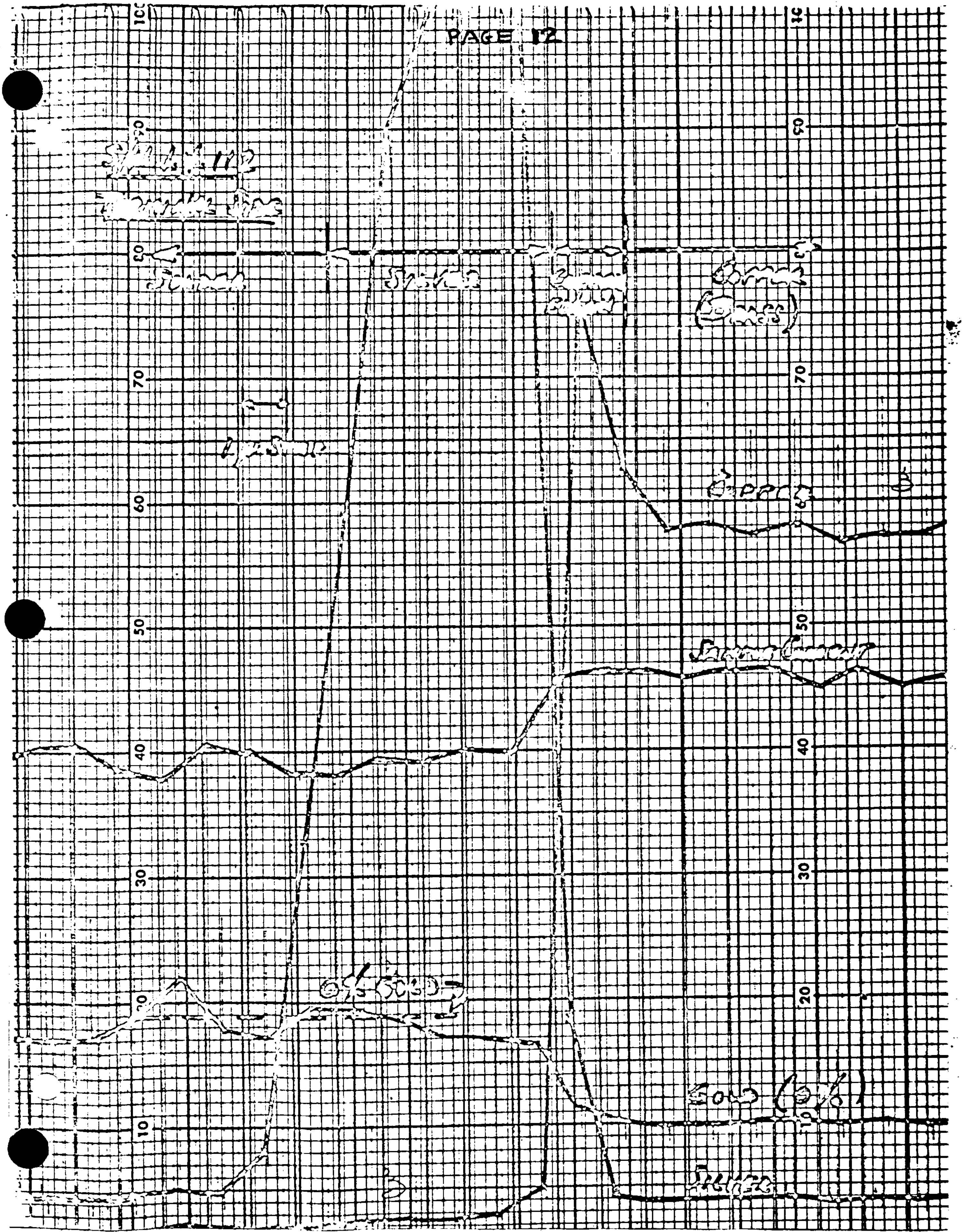
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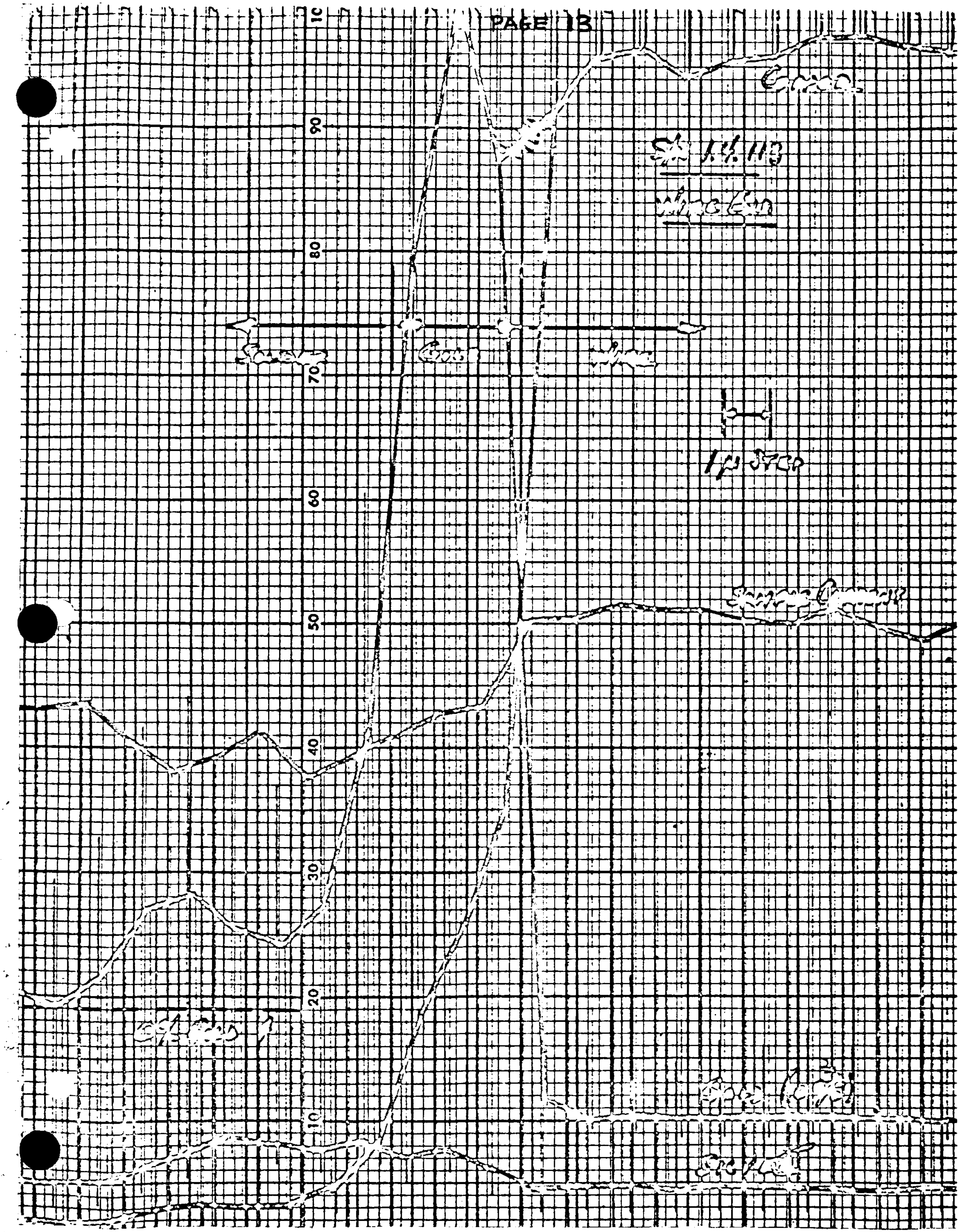
80
70
60
50
40
30
20
10
Copper
Gold (9%)
6% (Gold)
Silver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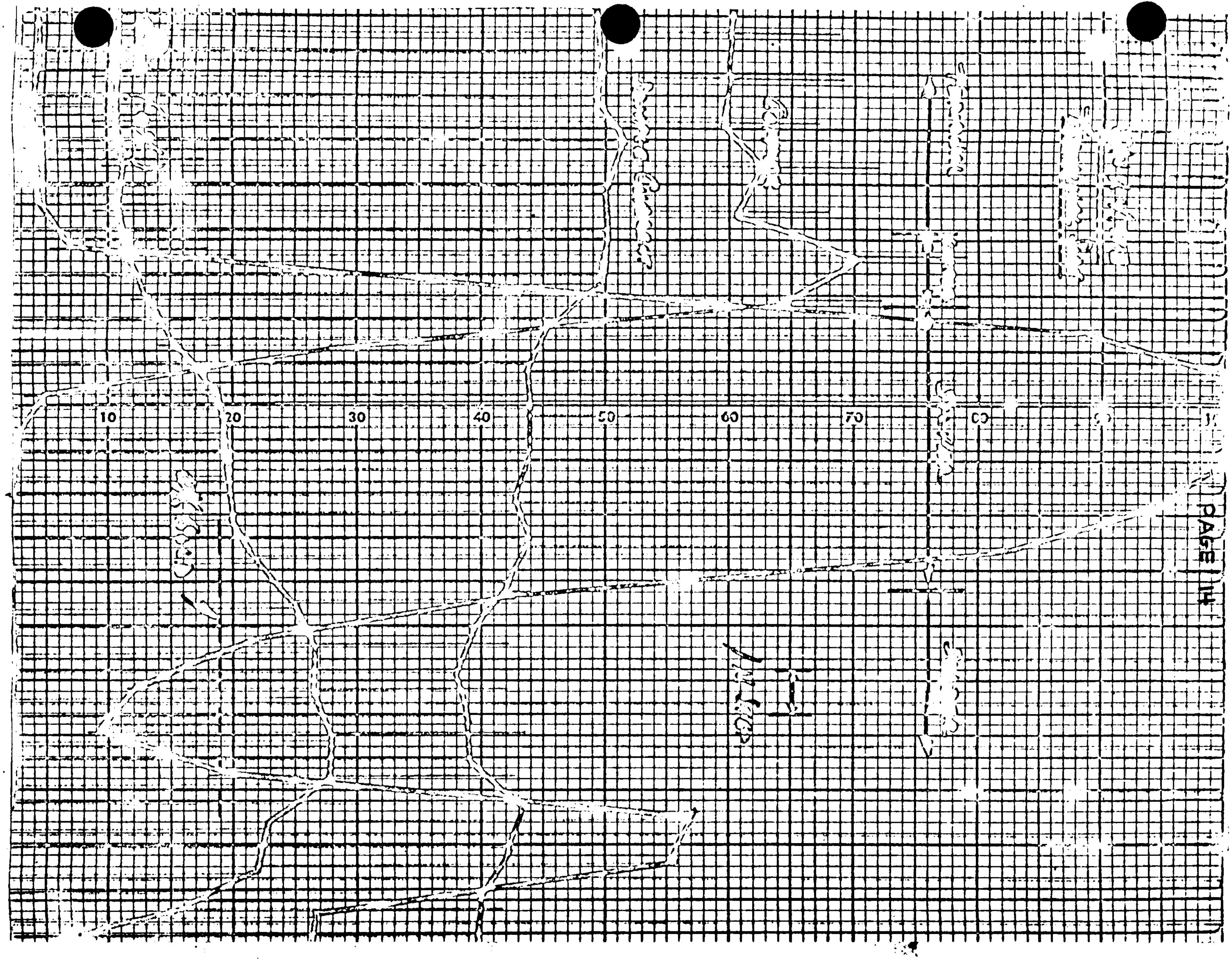
90
80
70
60
50
40
30
20
10
Green
White
Screen
Green
White
1μ Sec
Screen Current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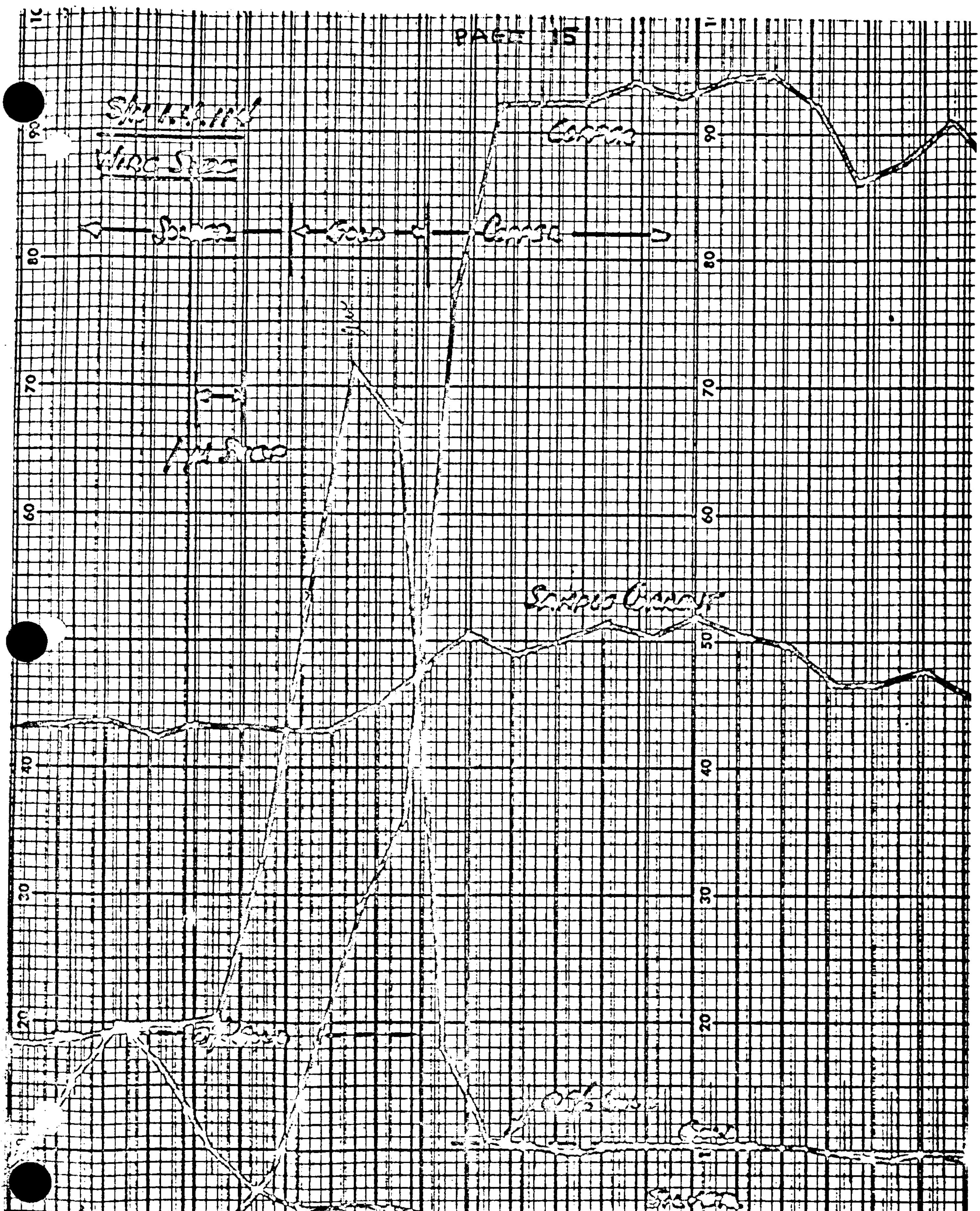
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Sample Change
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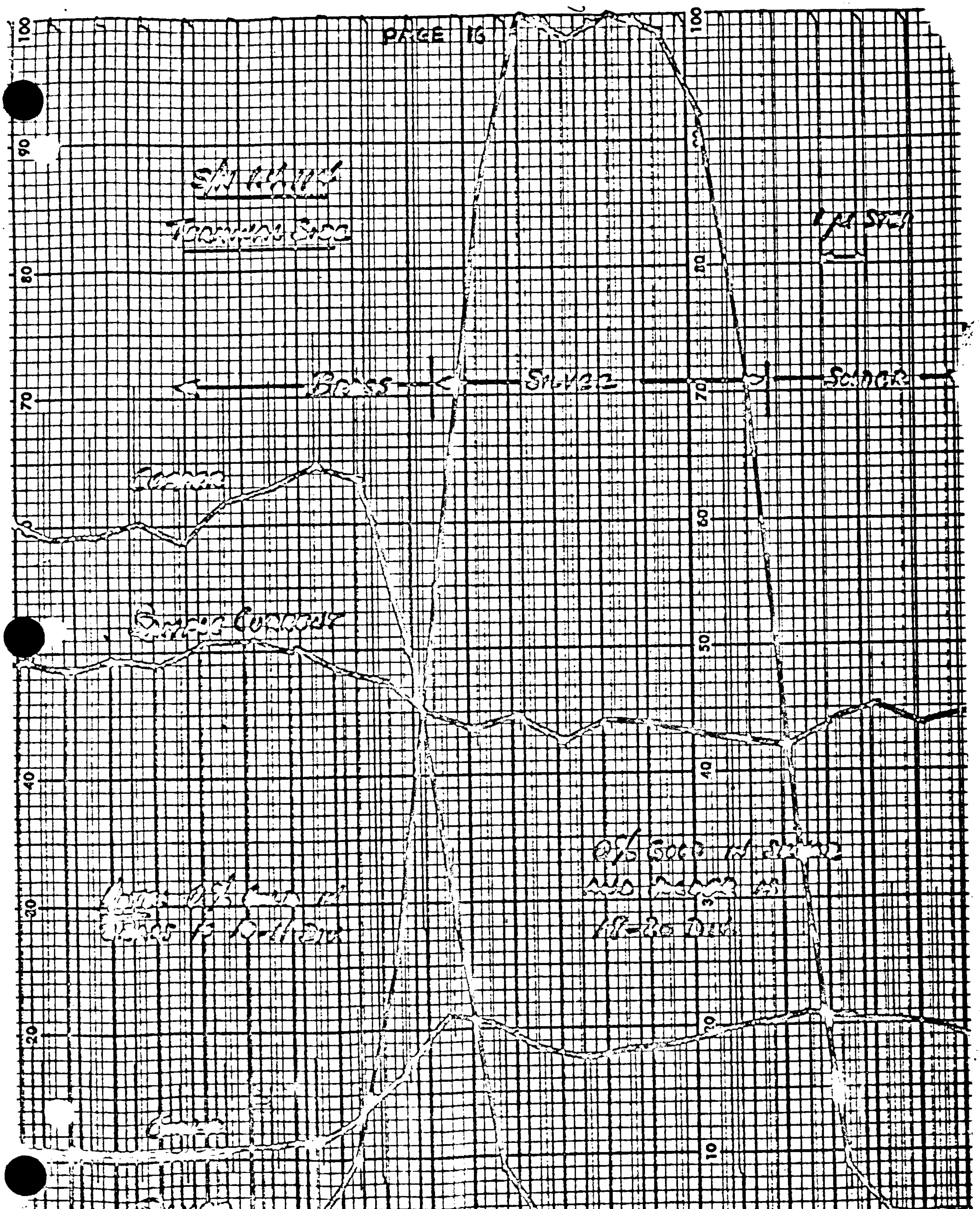
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TARGET SIDE
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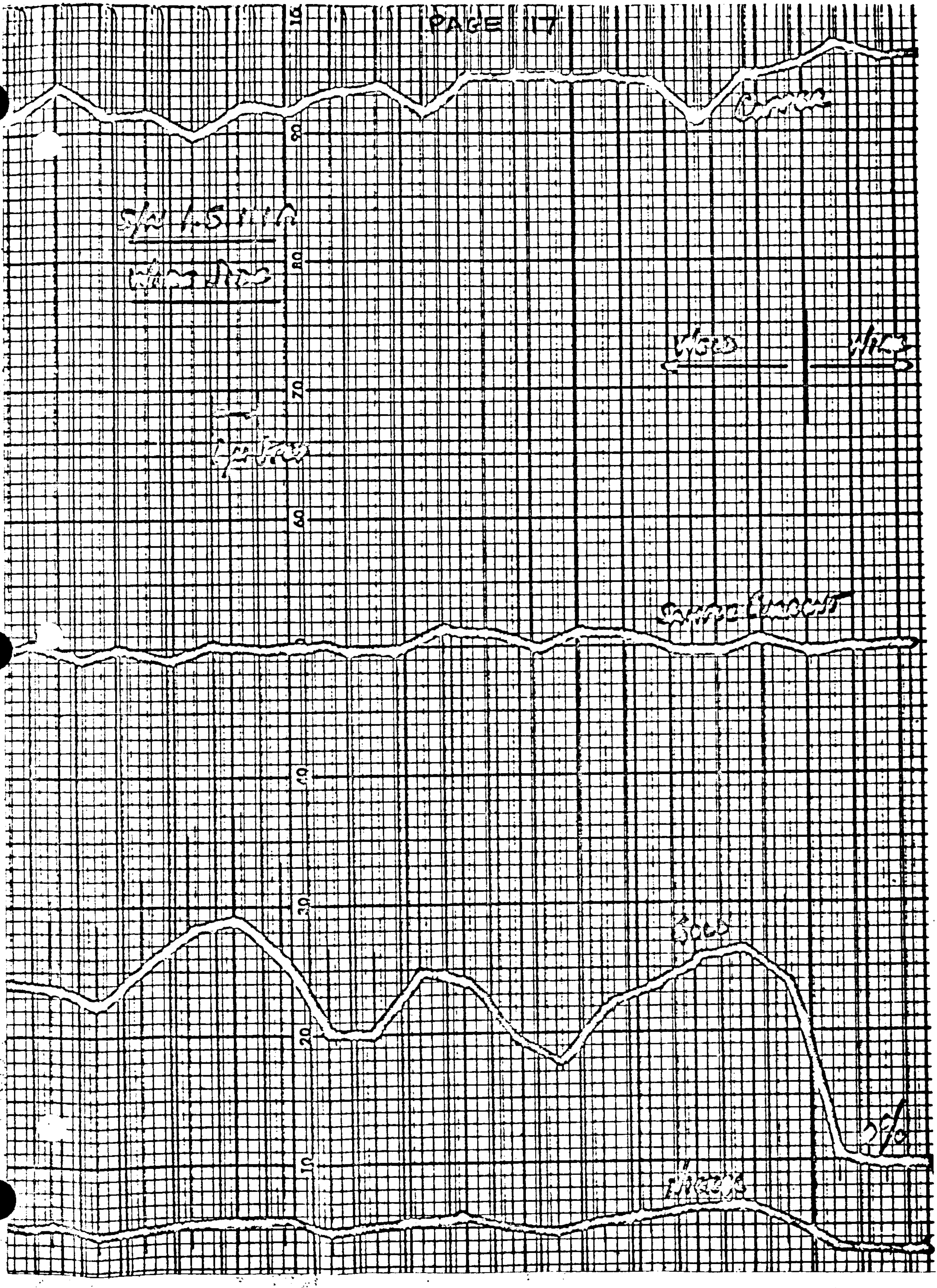
BRASS
SILVER
SOLDER
COPPER
BRASS CONTACT
0% GOLD IN SILVER
AND SOLDER AT
18-20 DIV
APPROX 0.% COPPER IN
SILVER AT 10-11 DIV
GOLD
SILVER


90
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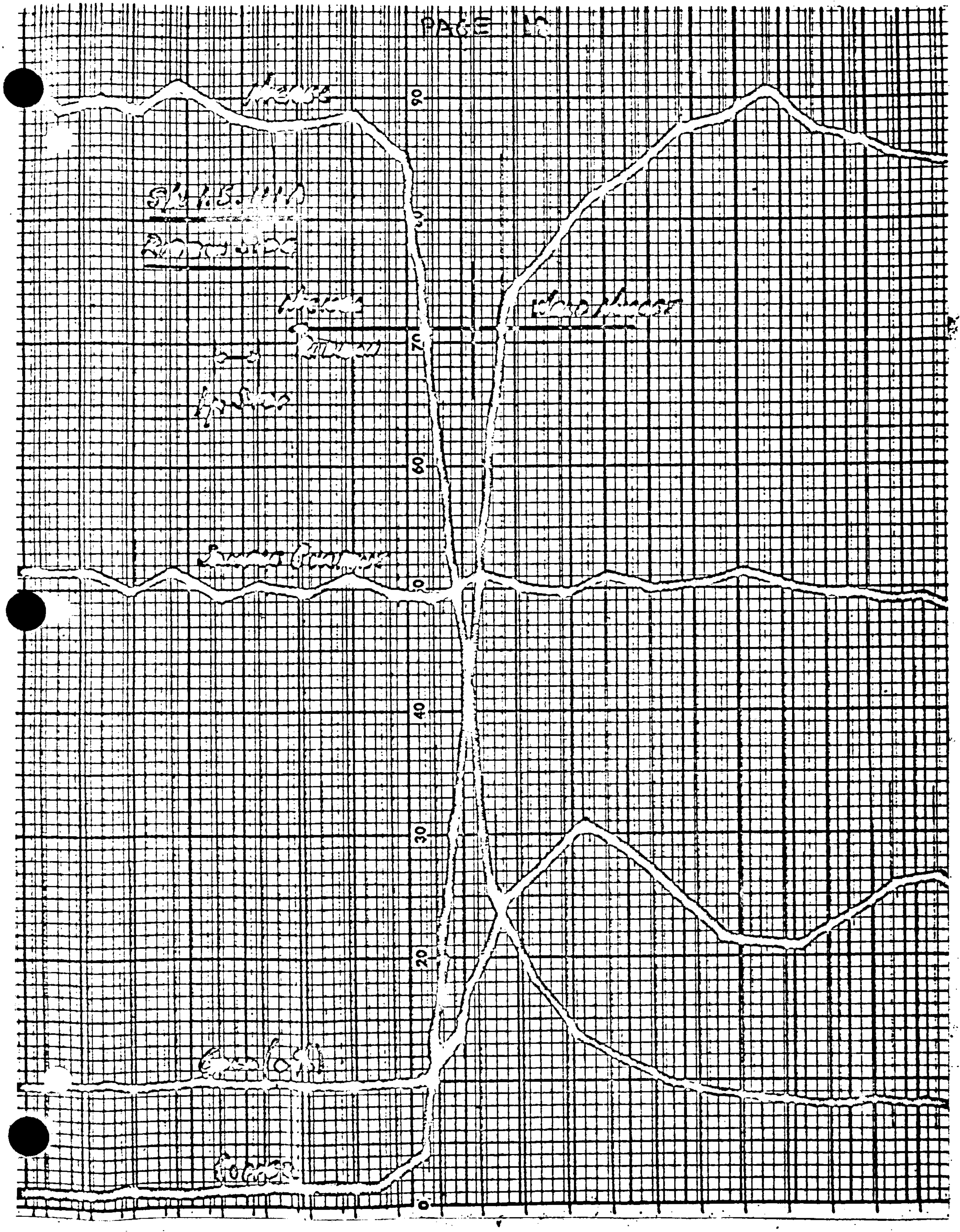
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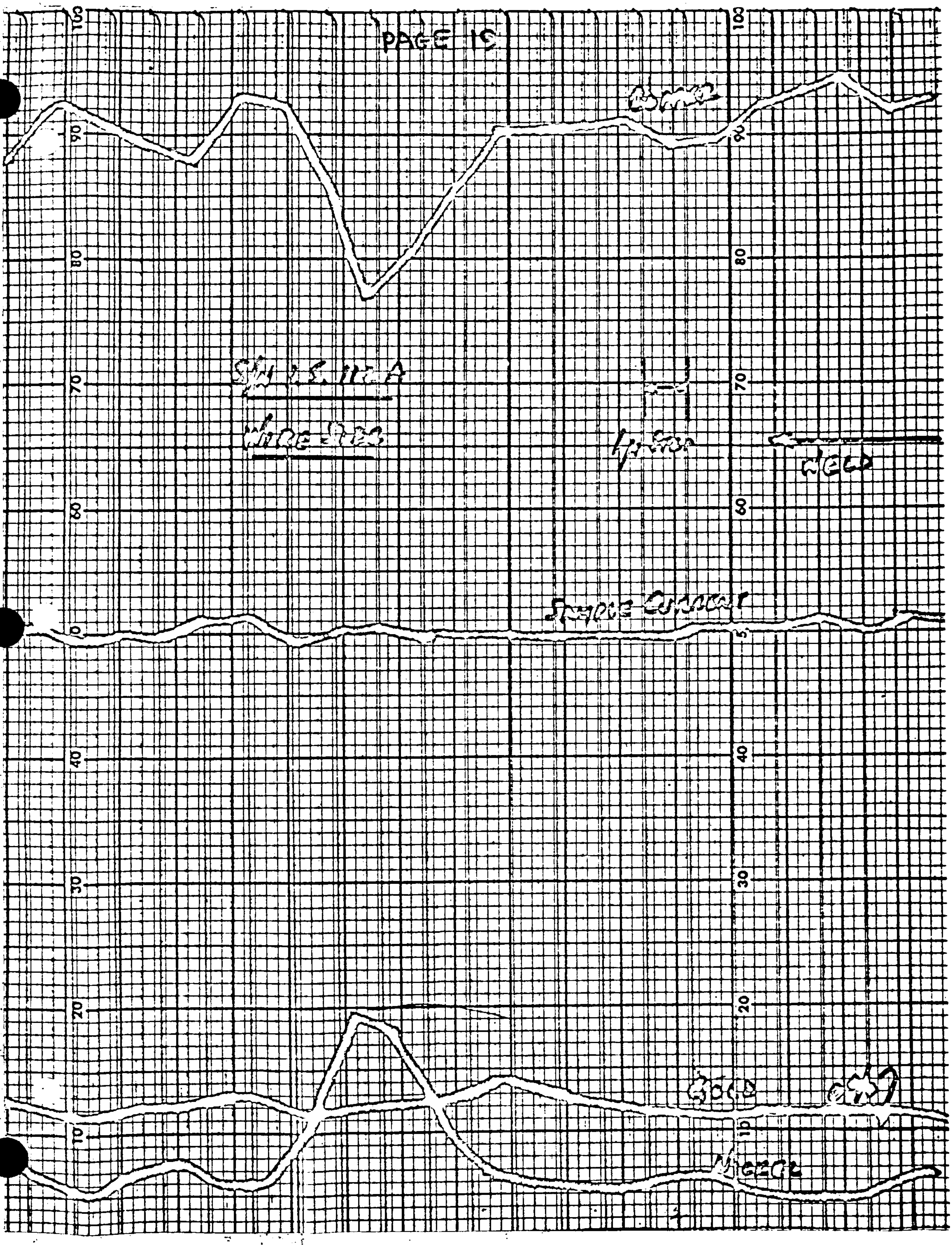
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Wire Size
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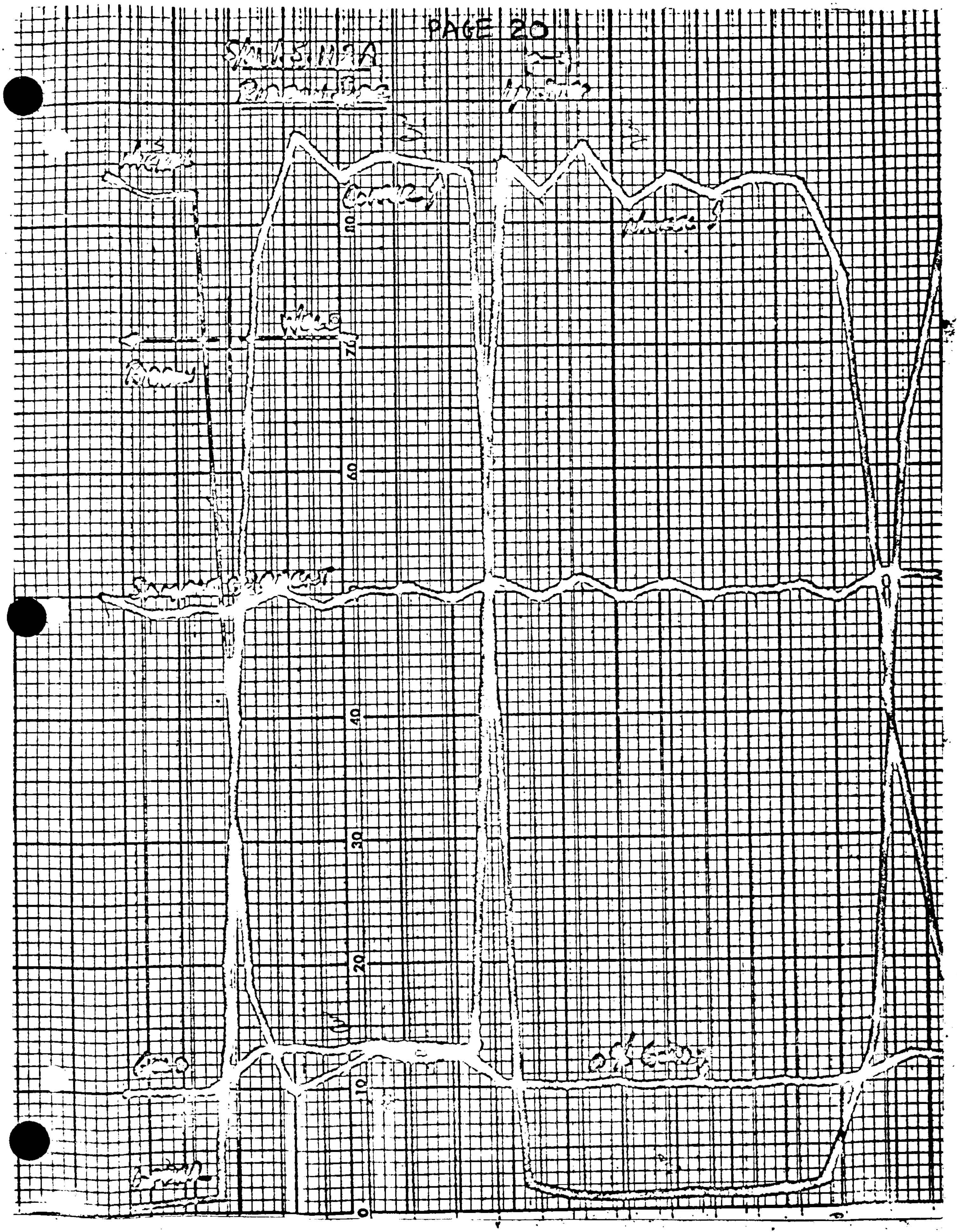
Single Conductor
Good
Megger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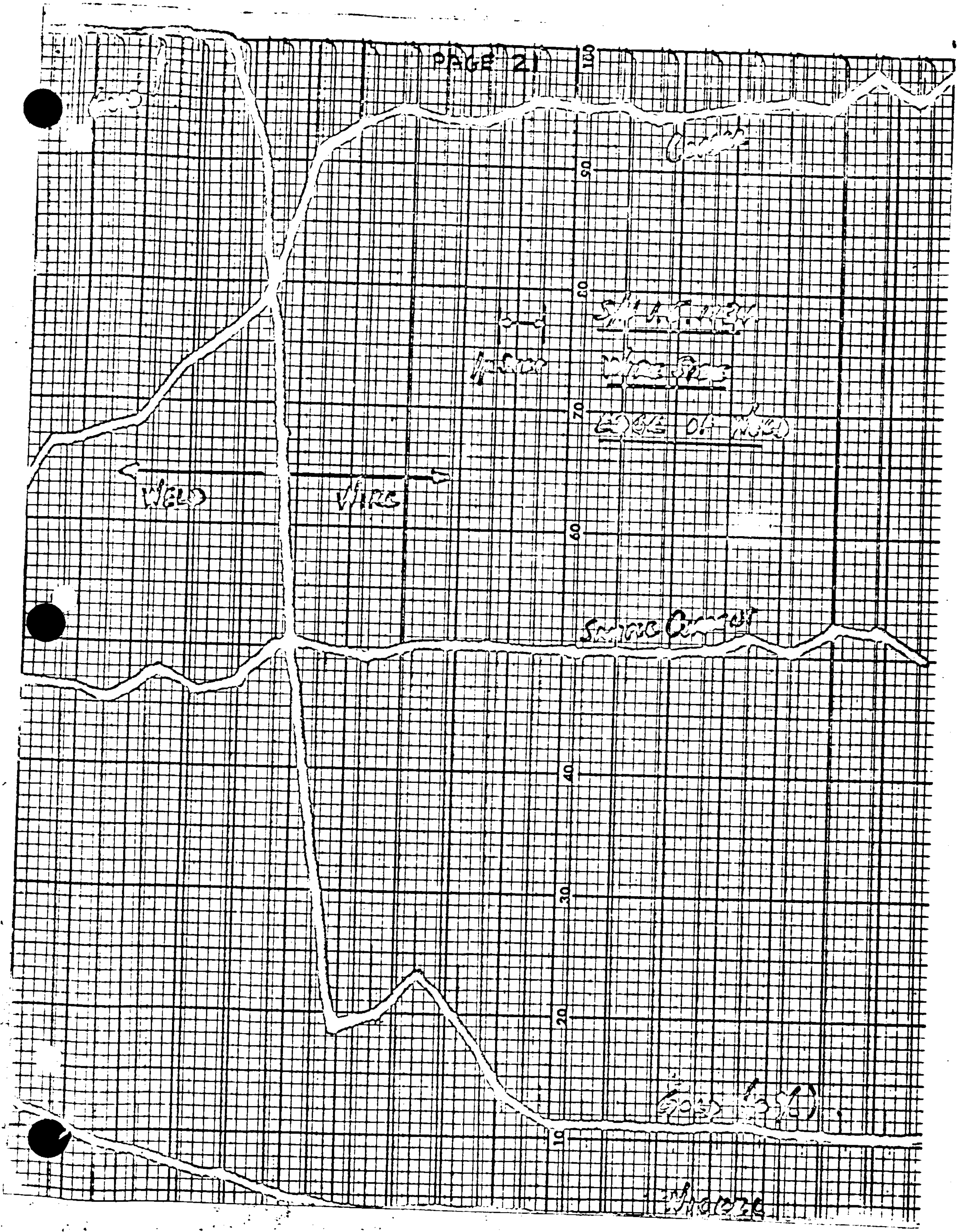

PAGE 21
Wire Stop
EDGE OF WOOD
WELD
WIRE
Surface Contact
Good
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80
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30
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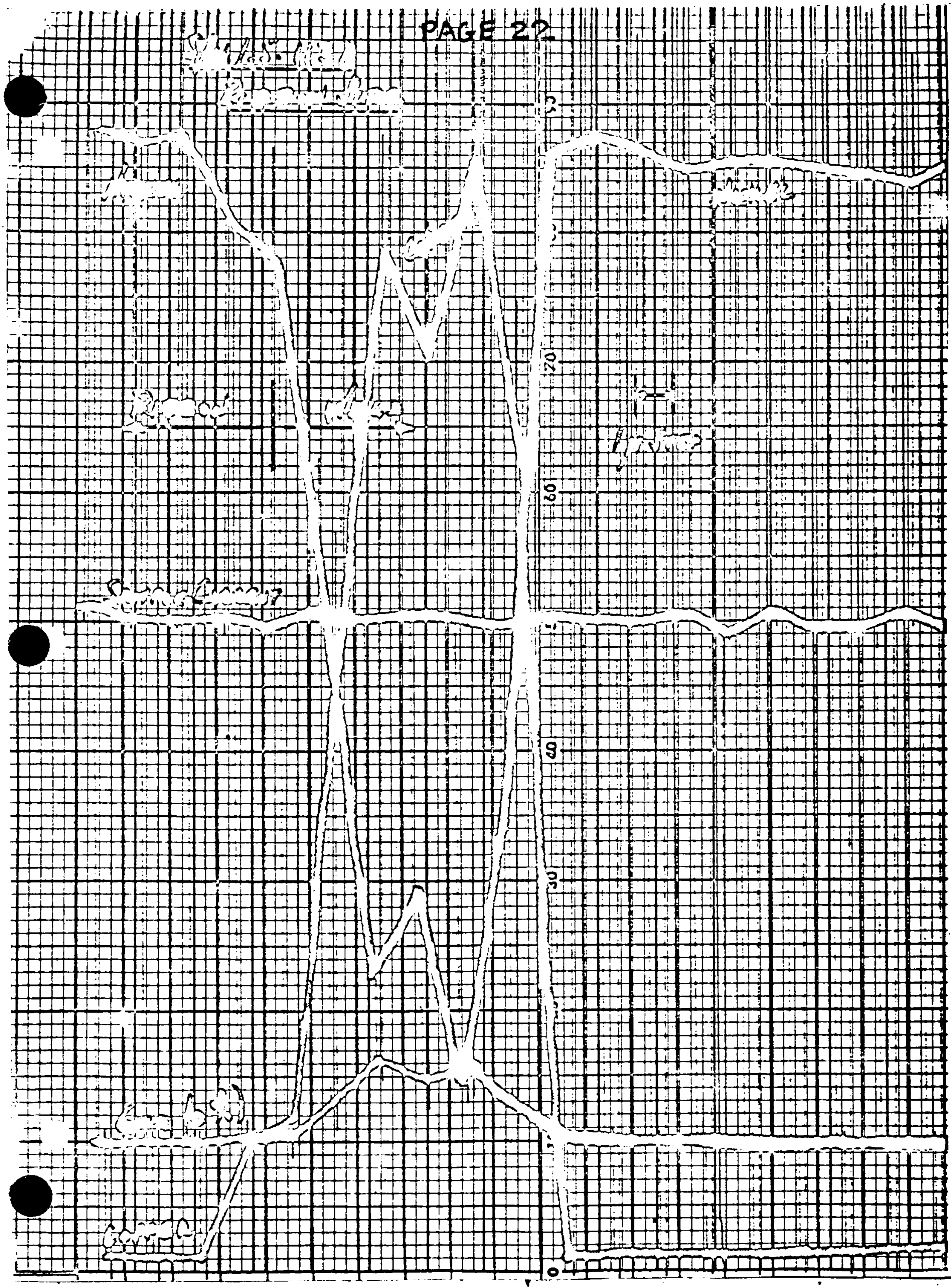
10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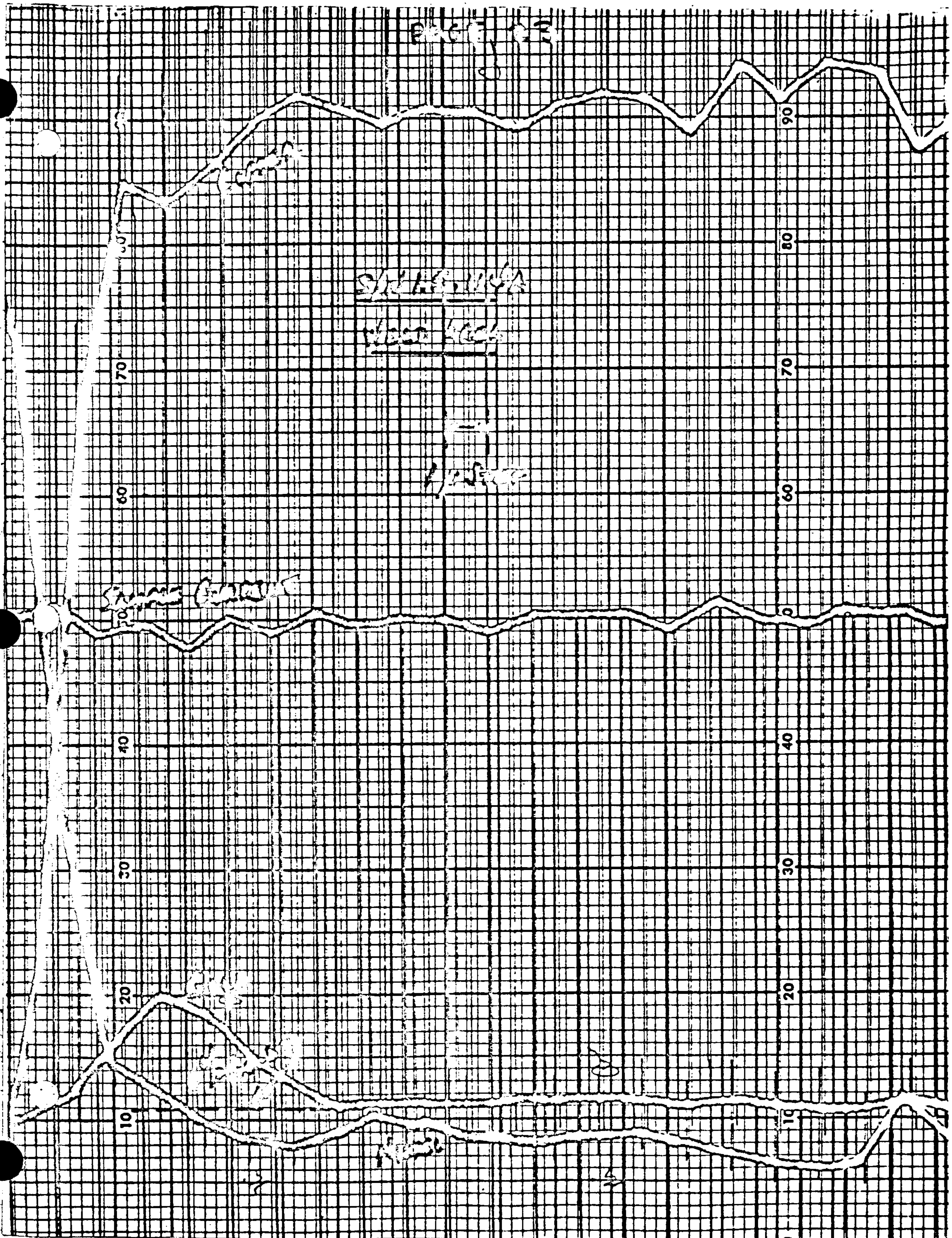
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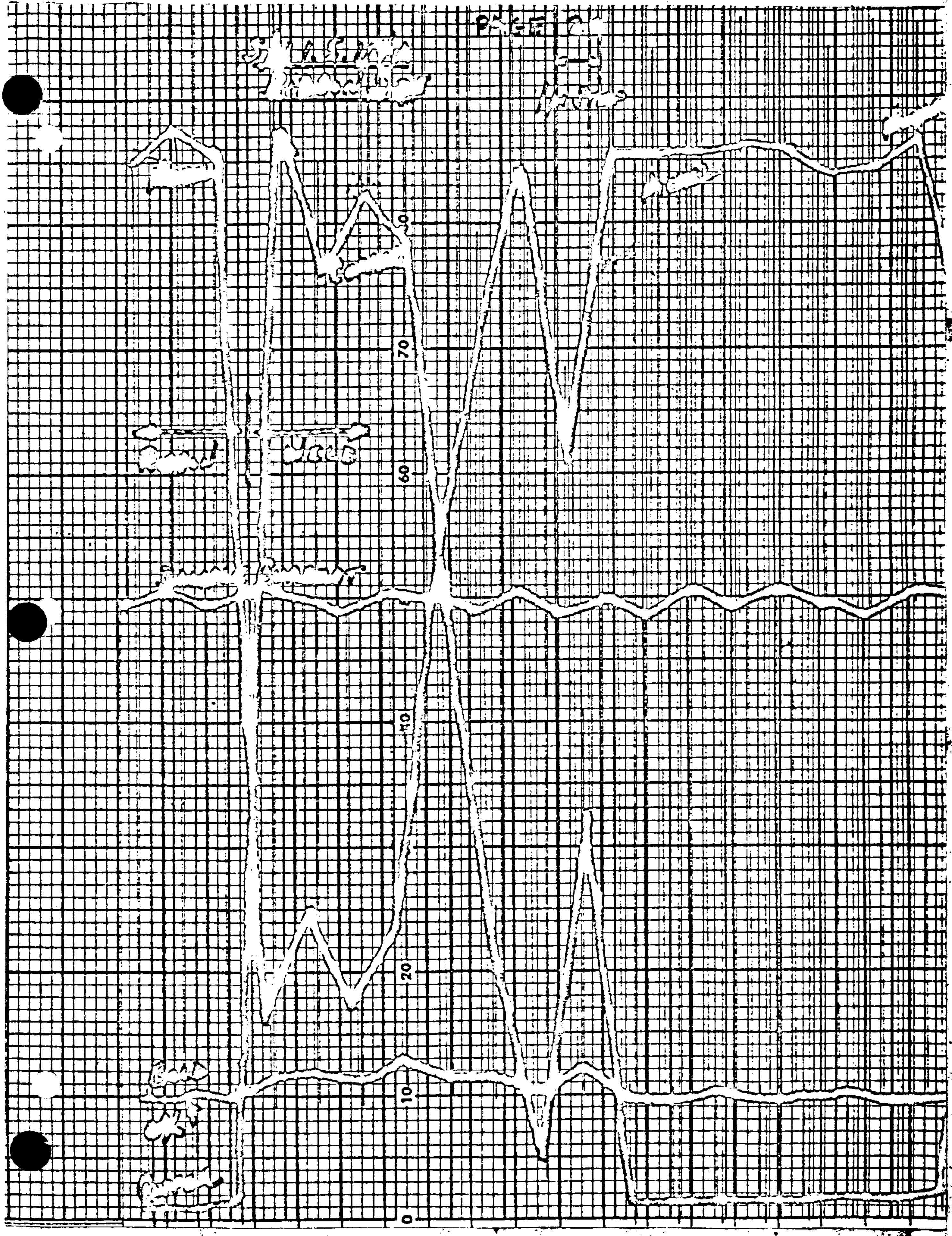
PAGE 2
70
60
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REPORT NO. P65-117

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, sponsored by the National Aeronautics and Space Administration under Contract NAS7-100.

FINAL REPORT - PART III
(Contract No. 951069)

DETERMINATION OF THE EFFECTS OF THERMAL BAKE-OUT, HEAT STERILIZATION, AND ETHYLENE OXIDE DECONTAMINATION ON THE SOLDERABILITY OF COMPONENT LEADS

Prepared for:
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

9 OCTOBER 1965

AEROSPACE GROUP
HUGHES
HUGHES AIRCRAFT COMPANY
CULVER CITY, CALIFORNIA

FINAL REPORT - PART III

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by

F. Z. Keister, Hughes Project Engineer

9 October 1965

For

Jet Propulsion Laboratory
California Institute of Technology
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Approved: E. F. Smith

E. F. Smith, Manager
Materials Technology Department

Materials Technology Department

AEROSPACE GROUP

Hughes Aircraft Company · Culver City, California

ABSTRACT

The purpose of this investigation was to determine the effects of thermal bake-out, heat sterilization, and ethylene oxide decontamination on the solderability of component leads.

This program involved the preparation and testing of 320 specimens, of which 64 were metallographically examined and 256 were solderability tested. The specimens for this program included nine different solid and stranded wire conductor materials, two types of connector cups, and two types of bifurcated terminals. Specimens were solderability tested (by dipping in a solder pot) and examined metallographically before and after three treatments: 1) thermal bake-out; 2) heat sterilization; and 3) ethylene oxide decontamination. Photomicrographs at 1000X magnification were taken of all specimen types before and after treatment. All solderability test results were analyzed statistically.

Based on the test results, it was concluded that thermal bake-out, heat sterilization, and ethylene oxide decontamination had very little effect on the solderability or metallurgical integrity of the specimens tested. Although a few specimen types did exhibit certain effects due to either thermal bake-out or heat sterilization, these effects were minimal and could be attributed to either unrelated causes or to factors which could be corrected in production usage.

CONTENTS

ILLUSTRATIONS

TABLES

1. PURPOSE AND SCOPE

1.1 PURPOSE

The purpose of this investigation was to determine the effects of thermal bake-out, heat sterilization, and ethylene oxide decontamination on the solderability of component leads. The primary purpose of this contract (refer to Parts I and II) was to determine the effects of a thermal sterilization process on the mechanical and electrical properties of soldered and welded joints.

This work was done for the Jet Propulsion Laboratory under Contract No. 951069 (subcontract under NASA Contract NAS 7-100). Mr. A. G. Fitak was the JPL Project Engineer on this program. During the final stages of this program, Mr. R. F. Holtze became the new JPL Project Engineer on this program, since Mr. Fitak was transferred to other duties.

This final report has been divided into three separate parts. Part I covers the thermal sterilization effects on solder and weld joints. Part II contains the weld schedule isoforce diagrams, raw data sheets, photomicrographs, and electron probe microanalysis charts for the solder and weld joints under Part I. Part III, which is this part, covers the solderability studies and is complete in itself with all its own data sheets and photomicrographs included under the same cover.

1.2 SCOPE

Part III of this final report is a determination of the effects of thermal bake-out, heat sterilization, and ethylene oxide decontamination on the solderability of component leads. This portion of the program involved preparing and testing 320 specimens of which 64 were metallographically examined and 256 were solderability tested. The specimens for this program included 9 different conductor materials, 2 types of connector cups, and 2 types of bifurcated terminals. Specimens were solderability tested (by dipping in a solder pot) and examined before and after three treatments: 1) thermal bake-out; 2) heat sterilization; and 3) ethylene oxide decontamination. Thirty-six photomicrographs were taken (32 of them at 1000 x magnification) of typical specimens before and after treatment. The test results were analyzed statistically. Photographs were taken of typical specimens of each type after being solder dipped and before and after thermal bake-out, heat sterilization, and ETO decontamination. Photographs were also taken of each type of test equipment used.

2. MATERIALS AND EQUIPMENT

2.1 MATERIALS FOR SOLDERABILITY SPECIMENS

The materials used in this program for the solderability specimens are listed in Table I. These materials (i.e., conductors, terminals, and connector cups) are identical to those used in Part I of this program, except for two new materials - items 12 and 13. Both of these conductors had a nickel underplating beneath the outer gold plating. Metallographic and spectrographic examination of these two new materials showed them to be as ordered with the thickness of the nickel strike being 80-92 microinches and the thickness of the gold plating being 100-112 microinches.

2.2 MATERIALS FOR FLUXING AND SOLDER DIPPING SPECIMENS

2.2.1 Alpha No. 611 activated rosin flux per MIL-F-14256C, Type A. This flux was used for fluxing all gold plated and solder coated solid wire conductors, connector cups, and bifurcated terminals.

2.2.2 Alpha No. 100 unactivated rosin flux per MIL-F-14256C, Type W. This flux was used for fluxing stranded conductors.

2.2.3 Alpha No. 90 stainless steel flux. This flux was used for fluxing bare nickel solid wire conductors.

2.2.4 Kester bar solder per QQ-S-571d, Type Sn 63-B-S. This solder (63% tin, 37% lead) was used in the dip solder pot.

2.2.5 1, 1, 1 - Trichloroethane per Federal Specification O-T-620. This solvent was used to remove flux residues from all specimens fluxed with Alpha No. 100 and Alpha No. 611 flux. Water was used to remove residues of Alpha No. 90 flux.

Table I. List of materials.

1. Stranded conductor, #24 AWG, 19/36, per MIL-W-16870, Type E, silver plated, Teflon insulated.
2. Cinch connector cup per JPL 20045/200-E.
3. Bendix connector cup per JPL ZPH-2245-0300-B, JPL DS317, and MIL-C-26482C.
4. Bifurcated terminal, solder coated, per JPL DS167-7.
5. Bifurcated terminal, gold plated, per JPL DS99-7.
6. Conductor, copper, OFHC, 0.020" diam., gold plated per MIL-G-45204, Type I, Class 1.
7. Conductor, copper, OFHC, 0.020" diam., tin-lead coated, tin 10-70%, 0.0001" average min. thickness -0.001" average maximum thickness per Revision A to MIL-STD-1276. Preferred tin-lead alloy to be 63-37 or 60-40.
8. Conductor, Dumet, 0.020" diam., per MIL-STD-1276, Type D, gold plated per MIL-G-45204, Type I, Class 1.
9. Conductor, Kovar, 0.018" diam., per MIL-STD-1276, Type K, gold plated per MIL-G-45204, Type I, Class 1.
10. Conductor, Nickel, 0.025" diam., per MIL-STD-1276, Type N-2, gold plated per MIL-G-45204, Type I, Class 1.
11. Conductor, Nickel, bare, 0.025" diam., per MIL-N-46026.
12. Conductor, Dumet, 0.020" diam., per MIL-STD-1276, Type D, gold plated per MIL-G-45204, Type I, Class 1, having a nickel strike (50-100 microinches) under the gold plating.
13. Conductor, copper, OFHC, 0.020" diam., gold plated per MIL-G-45204, Type I, Class 1, having a nickel strike (50-100 microinches) under the gold plating.

2.3 MATERIALS FOR PREPARING METALLOGRAPHIC MOUNTS

2.3.1 Precision Scientific "Precisionite" mounting powder for all hot mounts.

2.3.2 Fulton Metallurgical "Quickmount" mounting powder for all cold mounts.

2.4 EQUIPMENT

2.4.1 Dee Melting Pot, Model 13. Used for solder dipping tests.

2.4.2 Leitz Wetzlar (German) binocular microscope, Serial No. 505106 with an American Optical Illuminator, Model 11144. Used for visual examination of solder dipped specimens at 30x magnification.

2.4.3 National Appliance Co. Vacuum Oven, Model 58402, Serial No. B59. Used for bake-out of all specimens at 200°C in a nitrogen atmosphere and also used for dry heat sterilization of all specimens.

2.4.4 Hughes Aircraft Company specially-designed antechamber and apparatus for exposure of specimens to ethylene oxide decontamination.

2.4.5 Zeiss Inverted Metallurgical Microscope, Model No. B-5000 and Reichert Metallograph, Model MeF. Used for examining metallographic mounts at 500x to 1000x magnifications and also used for taking photomicrographs since the Reichert Metallograph is equipped with a built-in camera. Photomicrographs were taken with Kodak Super Panchro Press film.

2.4.6 Buehler Model 67-1509 Vibromet Polisher and Buehler Model 1330AB Mounting Press. Used for preparing metallographic specimens.

3. TEST PROCEDURES

3.1 GENERAL TEST INFORMATION

Figure 1 outlines the test program plan for the seven (7) wire types (i.e., A, B, C, D, E, F, G) listed in (ii) of the Statement of Work. The Statement of Work is included as Table II. Twenty (20) specimens of each of these seven (7) wire types were prepared. Eight (8) each were solderability tested before and after bake-out and two (2) each were metallographically examined before and after bake-out. Thus a total number of 140 specimens were required, of which 28 were metallographically examined and 112 were solderability tested.

Figure 2 outlines the test program plan for the six (6) specimen types (i.e., A, B, C, D, E, F) listed in (iii) and (iv) of the Statement of Work (Table II). Thirty (30) specimens each of types A, B, C, D, E, and F were prepared. Eight (8) each were solderability tested before sterilization and two (2) each were metallographically examined before sterilization. Eight (8) each were solderability tested after ethylene oxide decontamination and two (2) each were metallographically examined after ethylene oxide decontamination. Eight (8) each were solderability tested after heat sterilization and two (2) each were metallographically examined after heat sterilization. Thus a total number of 180 specimens were required of which 36 were metallographically examined and 144 were solderability tested.

In summation the total program involved 320 specimens of which 64 were metallographically examined and 256 were solderability tested.

3.2 BAKE-OUT TEST PROCEDURES

In accordance with the Test Program Plan (Figure 1) and the Statement of Work (Table II), bake-out tests of all (ii) specimens (i.e., A, B, C, D, E, F, G) were done in a vacuum oven and consisted of exposure to 200°C for a period of 168 hours in an inert nitrogen atmosphere. Figure 10 in Part I of this final report shows a photograph of the vacuum oven used for bake-out tests.

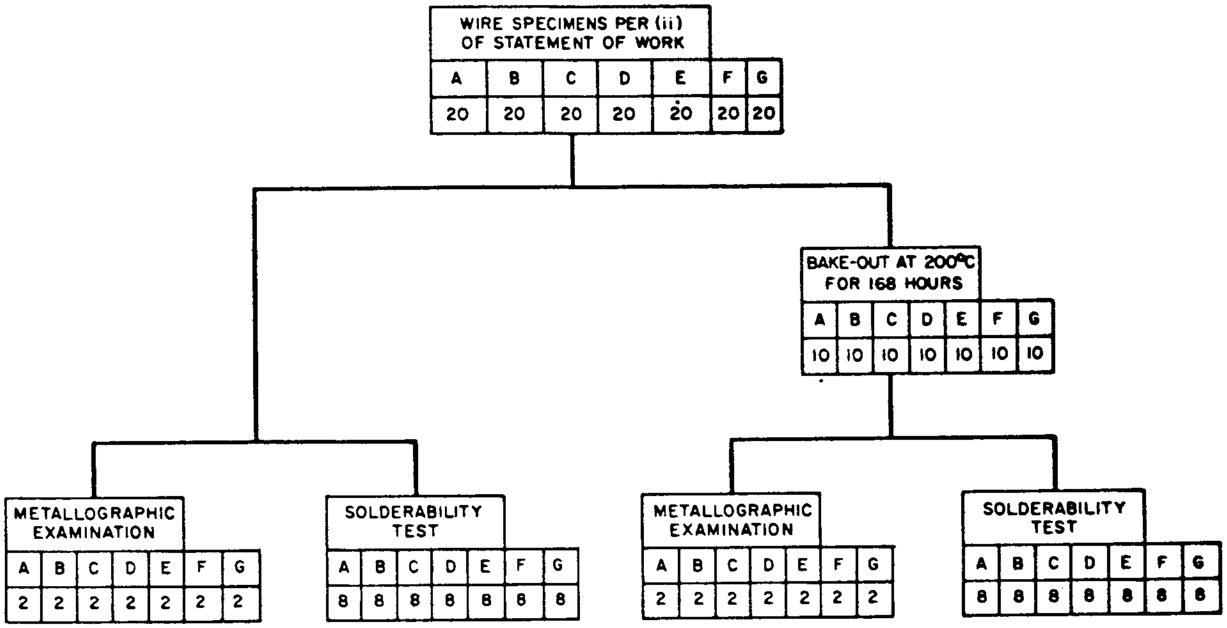

Figure 1. Test program plan per (ii) wire specimens.

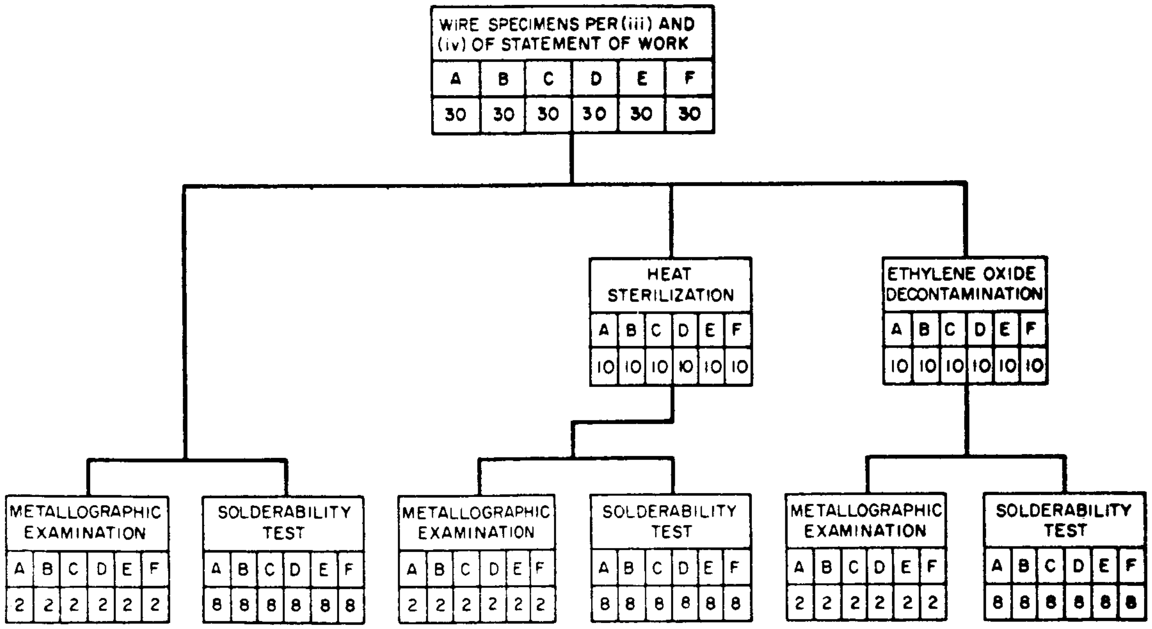

Figure 2. Test program plan per (iii) and (iv) specimens.

Table II. Statement of work for solderability test program.

(i) The following tests shall be performed:

(ii) Metallographic Examination and Solderability before and after exposure, of the following listed materials, to 200°C for a period of 168 hours in inert atmosphere:

- (A) Copper, Gold Plated
- (B) Dumet, Gold Plated
- (C) Kovar, Gold Plated
- (D) Nickel, Gold Plated
- (E) Nickel Bare
- (F) Dumet, Nickel undercoat, Gold Plated
- (G) Copper, Nickel undercoat, Gold Plated

(iii) Metallographic Examination and Solderability before and after exposure, of the following listed materials, to heat sterilization in accordance with JPL Specification No. XSO-30275-TST-A, 24 May 1965:

- (A) Stranded Conductor
- (B) Brass, Copper Plated, Gold Plated, Connector Cups (Cinch)
- (C) Brass, Copper Plated, Silver Plated, Gold Plated, Connector Cups (Bendix)
- (D) Copper wire, Solder coated
- (E) Bifurcated terminals, Solder coated
- (F) Bifurcated terminals, Gold Plated

(iv) Metallographic Examination and Solderability before and after exposure, of the following listed materials and components, to the ethylene oxide decontamination treatment as specified in JPL Specification GMO-50198-ETS-A, dated 3 September 1964:

- (A) Stranded Conductor
- (B) Brass, Copper Plated, Gold Plated, Connector Cups (Cinch)
- (C) Brass, Copper Plated, Silver Plated, Gold Plated, Connector Cups (Bendix)
- (D) Copper wire, Solder coated
- (E) Bifurcated terminals, Solder coated
- (F) Bifurcated terminals, Gold Plated

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3.3 DRY HEAT STERILIZATION TEST PROCEDURES

In accordance with the Test Program Plan (Figure 2) and the Statement of Work (Table II), heat sterilization of all (iii) specimens (i.e., A, B, C, D, E, F) was done in accordance with JPL Specification XSO-30275-TST-A "Compatibility Test for Planetary Dry Heat Sterilization Requirements." Heat sterilization consists of three 36 hour cycles at 145°C in a dry nitrogen environment. Dry heat sterilization testing is described completely in Section 4.2 in Part I of this final report. Figures 10 and 11 in Part I of this final report show views of the vacuum oven used for dry heat sterilization testing. In the photograph in Figure 11 can be seen certain of the solderability test specimens in Petri dishes within the vacuum oven on the lower shelf.

3.4 ETHYLENE OXIDE DECONTAMINATION TEST PROCEDURES

In accordance with the Test Program Plan (Figure 2) and the Statement of Work (Table II), ethylene oxide decontamination of all (iv) specimens (i.e., A, B, C, D, E, F) was done in accordance with JPL Specification GMO-50198-ETS-A "Compatibility Tests for Ethylene Oxide Decontamination Requirements" dated 3 September 1964. Exposure is accomplished by subjecting specimens to 12% ethylene oxide - 88% Freon 12 gas mixture by weight at 35% relative humidity and 24°C for 24 hours, followed by a similar exposure at 40°C if specimens show no deterioration of properties. The concentration of the ethylene oxide in the decontamination chamber is 500 ±50 milligrams of ethylene oxide per liter of gaseous atmosphere. The gas composition and relative humidity were determined by gas chromatographic analysis. The test chamber is subjected to a vacuum to remove sterilant gas atmosphere within 30 minutes after the exposure period ends. Only specimens of good quality were selected for testing and all necessary steps were taken to assure maximum cleanliness of the samples prior to testing.

Figure 3 is a photograph of the special antechamber used for ethylene oxide decontamination. This antechamber is capable of being evacuated or pressurized.

Figure 4 is a close-up photograph showing specimens A, B, C, D, E, and F in Petri dishes ready for ethylene oxide decontamination.

3.5 SOLDERABILITY TEST PROCEDURES

In accordance with the Test Program Plan (Figures 1 and 2) and the Statement of Work (Table II), all specimens were solderability tested per MIL-STD-202C, Method 208A "Solderability" dated 12 September 1963. Essentially this test method consists of dipping a fluxed wire or other applicable specimen in a pot of molten solder. The dipped specimen is then cleaned and visually examined for solder coverage. Operator manual dipping was used, as opposed to machine dipping, in order to simulate more closely actual production conditions. One operator performed all dipping tests on all specimens. This was a deviation from MIL-STD-202C which calls out mechanical dipping. The temperature of the molten solder was maintained at $450^{\circ} \pm 10^{\circ}$F. The composition of the solder was 63% tin - 37% lead. This was a deviation from MIL-STD-202C which calls out 60-40 solder. The fluxes used (see Paragraphs 2.2.1, 2.2.2, and 2.2.3 under the Materials section) for the solder dipping tests were mutually agreed upon between JPL and Hughes.

Following is a step-by-step procedure:

Step 1. Dip specimen in appropriate flux for 2-5 seconds.

Step 2. Skim dross from top of molten solder and dip specimen in solder to a depth approximately one-half the specimen length. The immersion and emersion rates were approximately 1-2 inches per second and the dwell time in the solder bath was 5 ±1/2 seconds for all specimens.

Step 3. Allow the specimen to cool in air and then remove flux residues by immersion in the applicable solvent followed by gentle wiping with a clean cloth.

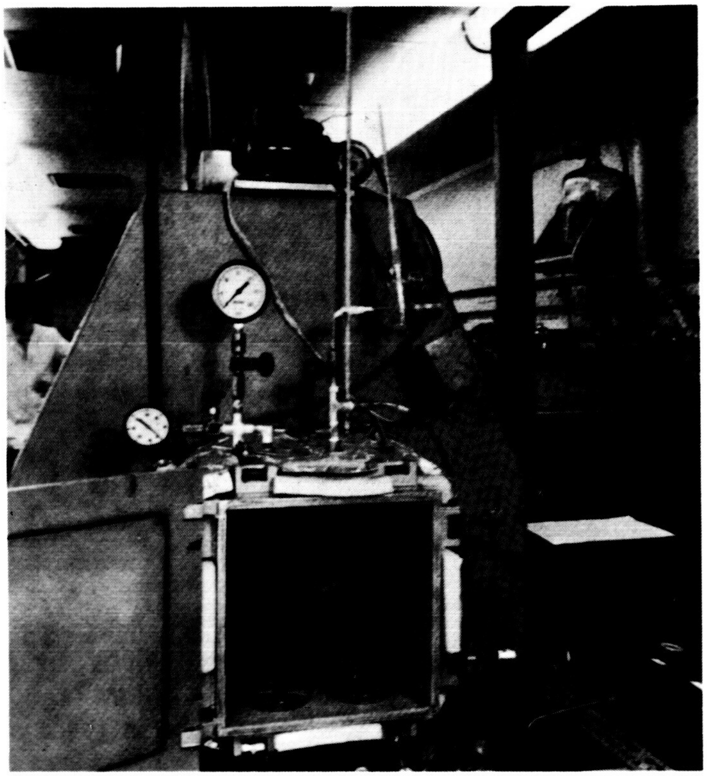

Figure 3. Ethylene oxide decontamination antechamber. (R105390)

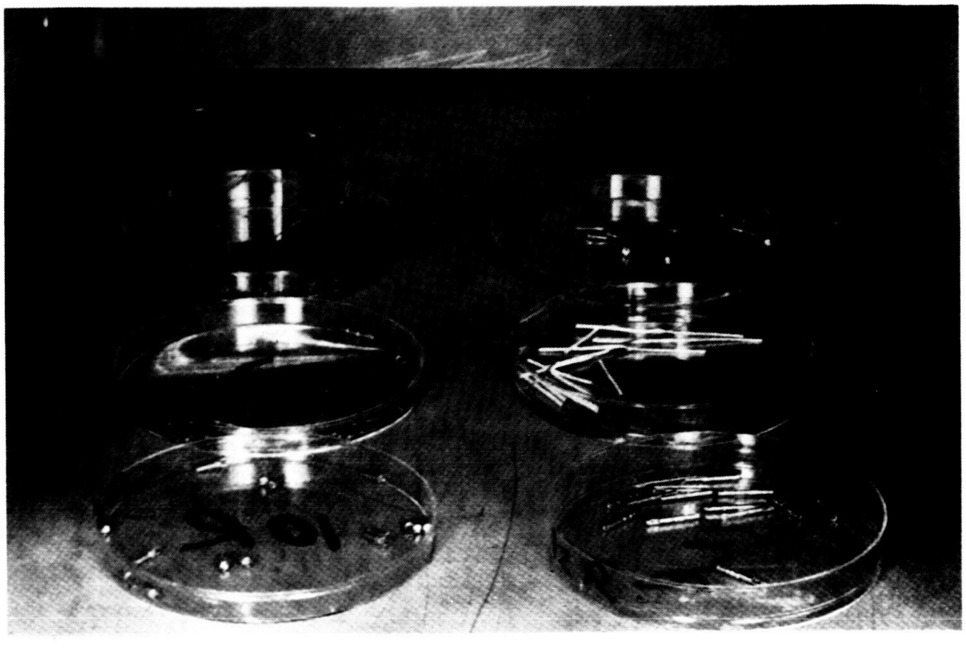

Figure 4. Specimen (iv) types A, B, C, D, E, and F in ethylene oxide decontamination antechamber. (R105260)

Step 4. Examine the specimen under 30x magnification to determine:

- (a) That the specimen is 95-percent covered by a continuous new solder coating
- (b) That pinholes or voids are not concentrated in one area and do not exceed 5-percent of the total area.

Figure 5 is a photograph showing the equipment used in the solderability tests.

All results of the specimen examinations were recorded on Raw Data Sheets in terms of percentage coverage of the specimen by a continuous new solder coating. All examinations of the before and after bake-out specimens were done by one operator and all examinations of the before and after heat sterilization and ETO decontamination specimens were done by one operator.

3.6 METALLOGRAPHIC EXAMINATION TEST PROCEDURES

In accordance with the Test Program Plan (Figures 1 and 2) and with the Statement of Work (Table II), two each of all specimens before and after bake-out, before and after heat sterilization, and before and after ethylene oxide decontamination (ETO) were metallographically examined. A total of 64 specimens were mounted and examined. Specimens A, B, C, D, E, F, and G per Figure 1 were all hot mounted in Precisionite. Specimens A, B, C, D, E, and F per Figure 2 were all cold mounted in Quickmount.

Thirty-two photomicrographs at 1000x magnification of typical specimens before and after bake-out, heat sterilization, and ETO decontamination were taken. In addition, four photomicrographs at 50x magnification were taken of a typical connector cup, typical bifurcated terminal, typical solid wire conductor, and typical stranded conductor specimen in the mounted condition.

All mounted specimens were examined in both the polished and etched conditions at magnifications from 500x to 1000x. Specimens were examined primarily for grain boundary diffusion of the plating

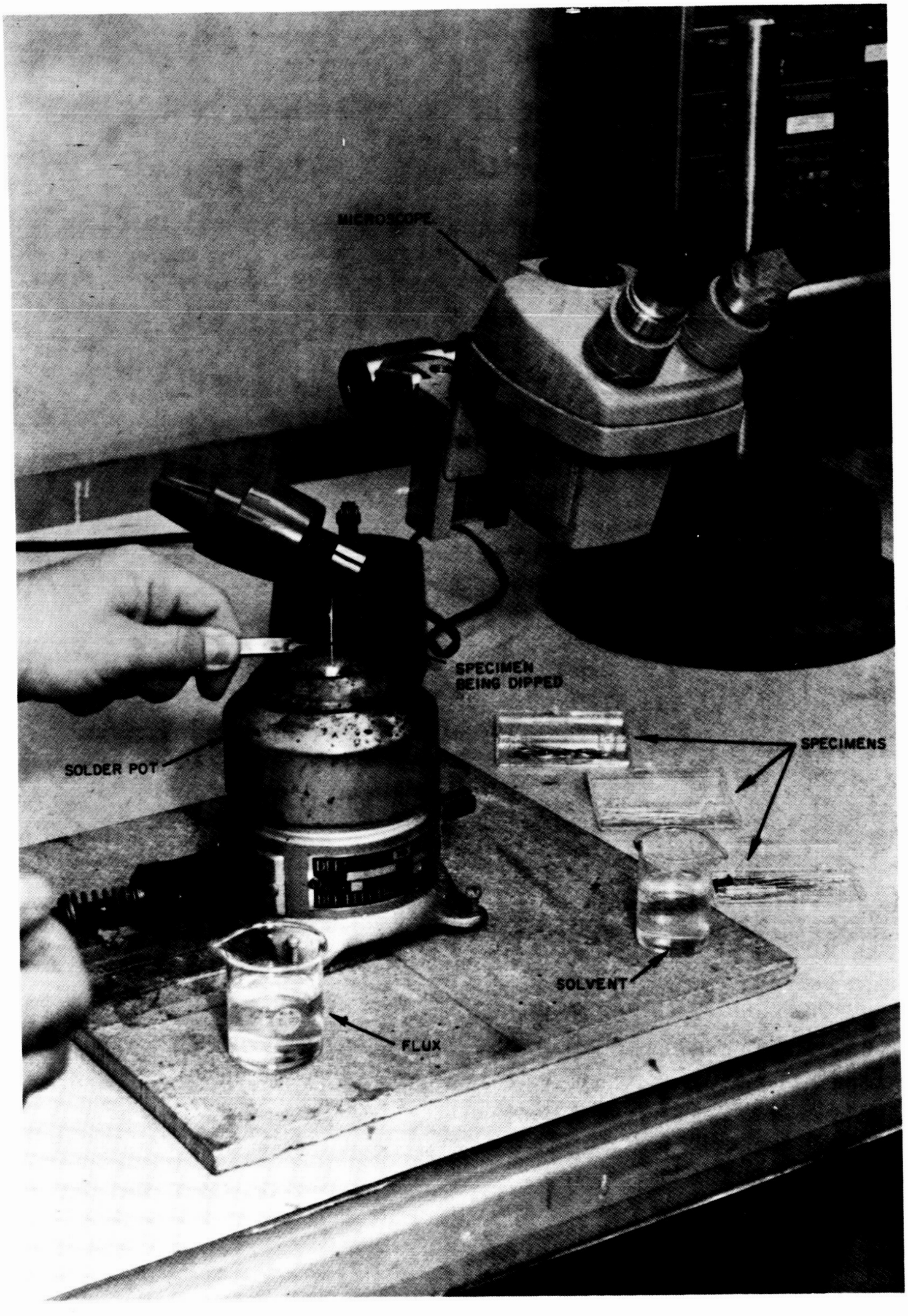

Figure 5. Solderability test equipment (R105893).

alloy in the parent metal as well as any interdiffusion of the surface plating. By comparing treated and untreated specimens at high magnification, any degrading effects of the thermal and/or sterilization treatments on the electroplated or solder coated surfaces of the specimens should be revealed.

Metallographic mounts of all specimens were prepared by multiple mounting so that the "before" and "after" specimens could be compared side-by-side without the necessity of switching mounts. Figure 6 illustrates the various multiple mounting methods employed. Figure 6A shows the mounting method used for specimens A, B, C, D, E, F, and G which were all solid wire conductors untreated and baked-out. Figure 6B shows the mounting method used for specimens A, B, C, D, E, and F which were conductors, connector cups, and bifurcated terminals untreated, heat sterilized, and ETO decontaminated. Specimens A and D were in one mount, B and C in another mount, and E and F in the third mount since these pairs were similar types of specimens.

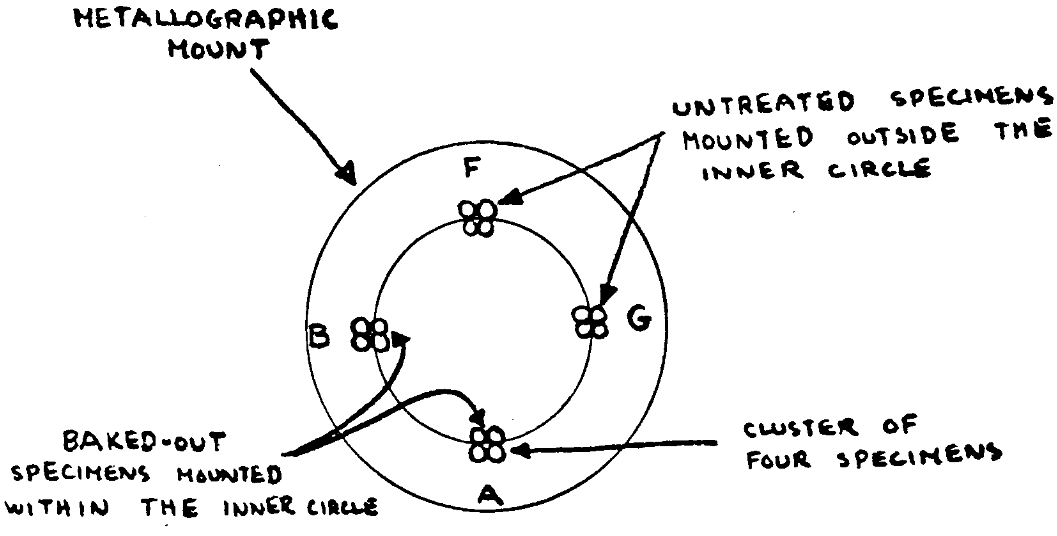

Figure 6A. Mounting configuration for specimen types A, B, F, and G before and after bake-out.

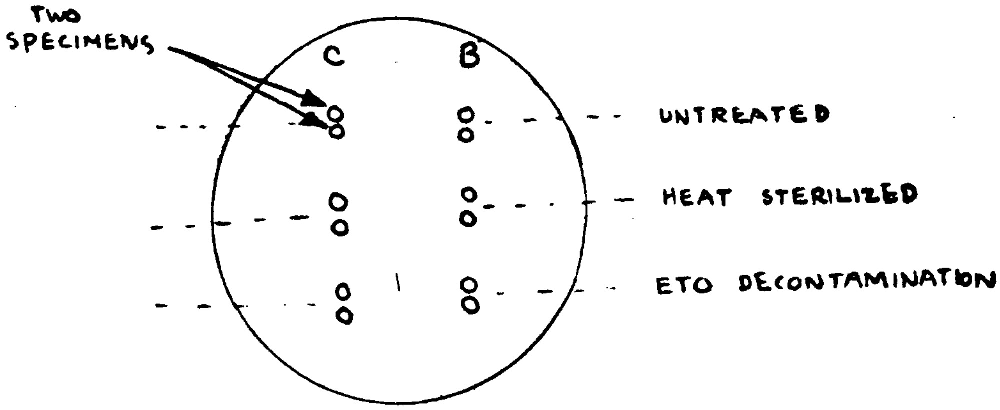

Figure 6B. Mounting configuration for specimen types C and B before and after heat sterilization and ETO decontamination.

Figure 6. Mounting configurations for treated and untreated specimens.

4. RESULTS

4.1 SOLDERABILITY TEST RESULTS

Figure 7 is a photograph showing a typical example of each type of specimen before bake-out (on the left) and after bake-out (on the right). These specimens in Figure 7 have all been solder dipped. The solder dipped ends of the wires are towards the center of the photograph.

Table III is the Raw Data Sheet giving the test results for the solderability tests on the specimens before and after bake-out at 200°C for 168 hours in nitrogen.

Table IV presents the results of a statistical analysis of the data shown in Table III. The statistical analysis was done using the binomial distribution with an arc sine transformation of the percentage data. The gold plated Kovar C (ii) specimens showed a slight effect due to bake-out; however they still pass the requirements of MIL-STD-202C. The 95% confidence interval of the mean was 96.0% - 99.9%, the lower limit of which is greater than the 95% minimum solder coverage. The gold plated Dumet specimens F (ii) with the nickel undercoat failed to pass the solderability requirements of MIL-STD-202C after bake-out. In this case the 95% confidence interval of the mean was 92.3% - 97.4%. In other words we are 95% confident that the mean falls within this range. This same wire type, before bake-out, showed 100% solder coverage for all eight specimens examined.

Figure 8 is a photograph showing a typical example of each type of specimen as follows:

a) Not solder dipped
b) Solder dipped - untreated
c) Solder dipped - after heat sterilization
d) Solder dipped - after ethylene oxide decontamination.

The solder dipped portions of the connector cups and bifurcated terminals point towards the right, while the solder dipped portions of the conductors point towards the center.

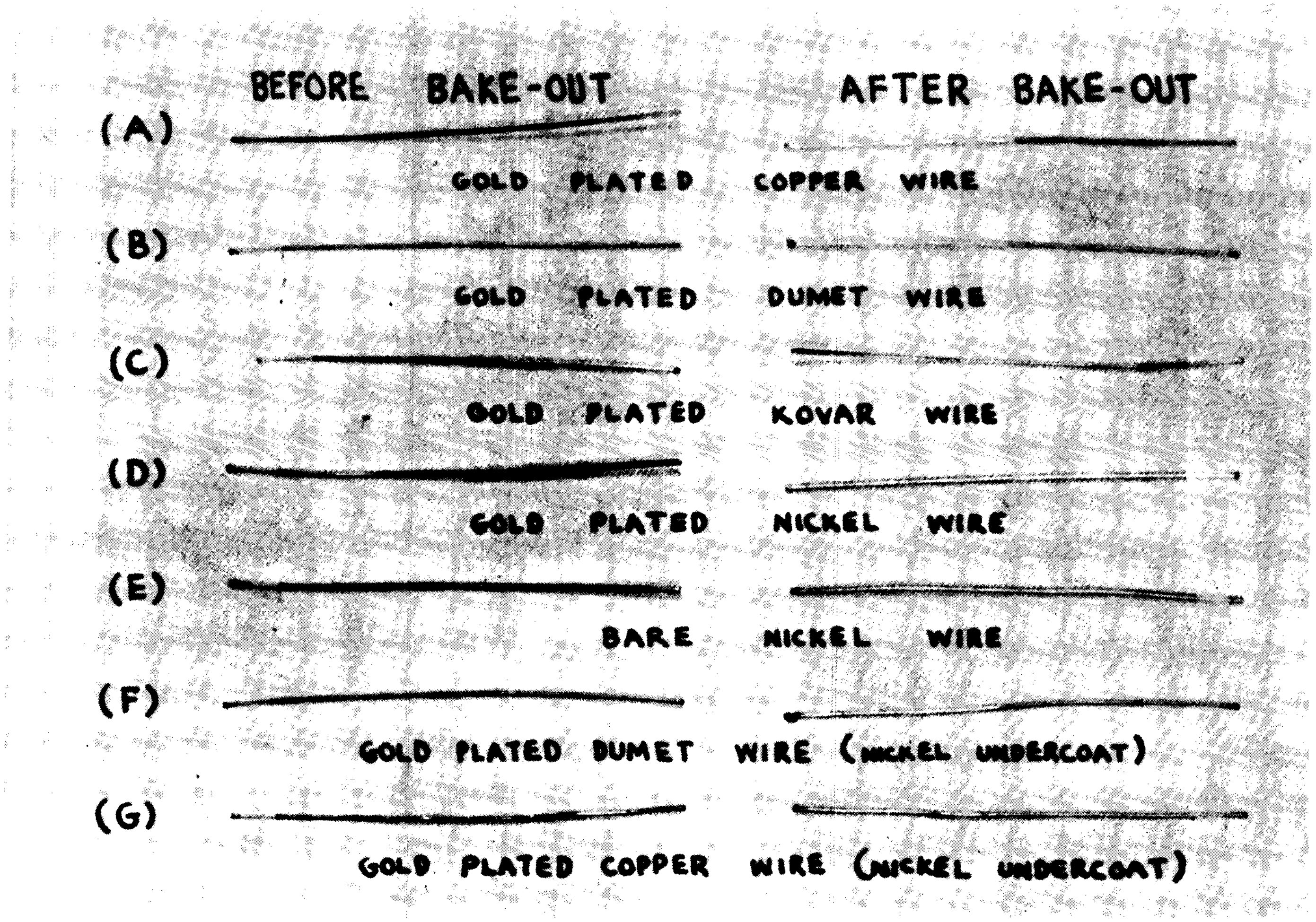

Figure 7. Solderability test specimens which have been solder dipped before and after bake-out. (R105894)

ANALYSIS SOLDERABILITY
PREPARED BY D. Teter 7-9-65
CHECKED BY F. Kuster
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Table III. Solderability test results for specimens before and after bake-out.

1) Numbers in columns refer to percentage coverage of lead with new solder.

2) 63/37 solder @ 450°F in Dee Melting Pot, Model 13. 5 second dip

3) 2 second flux dip Alpha 611 for all except E(ii) which was Alpha 90.

	EXAMINATION AT 30 X MAGNIFICATION							
	SPECIMEN NUMBER	BEFORE BAKE-OUT	AFTER BAKE-OUT		SPECIMEN NUMBER	BEFORE BAKE-OUT	AFTER BAKE-OUT	
Gold plated copper	A(ii) - 1	~100%	~100%		D(ii) - 5	~100%	~100%	Gold plated nickel
	2	"	"		6	"	"	
	3	"	"		7	"	"	
	4	"	"		8	"	"	
	5	"	"					
	6	"	"		E(ii) - 1	~100%	99%	Bare nickel
	7	"	"		2	99%	"	
	8	"	"		3	~100%	~100%	
					4	"	"	
Gold plated Dumet	B(ii) - 1	~100%	99%		5	"	"	
	2	"	~100%		6	"	"	
	3	"	"		7	"	"	
	4	"	"		8	"	"	
	5	"	"					
	6	"	"		F(ii) - 1	~100%	90%	Gold plated Dumet nickel undercoat
	7	"	"		2	"	95%	
	8	"	"		3	"	95%	
					4	"	94%	
Gold plated Kovar	C(ii) - 1	~100%	~100%		5	"	93%	
	2	"	"		6	"	98%	
	3	"	96%		7	"	99%	
	4	"	98%		8	"	94%	
	5	"	~100%					
	6	"	98%		G(ii) - 1	~100%	99%	Gold plated copper nickel undercoat
	7	"	95%		2	"	~100%	
	8	"	96%		3	"	"	
					4	"	96%	
Gold plated nickel	D(ii) - 1	~100%	~100%		5	"	~100%	
	2	"	99%		6	"	"	
	3	99%	~100%		7	"	"	
	4	~100%	"		8	"	"	

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Table IV. Bake-out effects on solderability.

Type of Lead		Effect
A (ii)	Gold plated Copper	None
B (ii)	Gold plated Dumet	None
C (ii)	Gold plated Kovar	Slight, passes*
D (ii)	Gold plated Nickel	None
E (ii)	Bare Nickel	None
F (ii)	Gold plated Dumet (Nickel undercoat)	Fails*
G (ii)	Gold plated Copper (Nickel undercoat)	None

*Refers to the solderability specification which requires minimum of 95% coverage.

Tables V and VI are Raw Data Sheets giving the test results for the solderability tests on the specimens outlined in (iii) and (iv) of the Statement of Work (Table II) and shown in Figure 8. Note that specimens A and C were especially good with 100% solder coverage throughout.

Table VII presents the results of a statistical analysis of the data shown in Tables V and VI. In only one case (solder coated bifurcated terminal) was there any significant decrease in solderability. The significance level was 0.001 indicating that there is only 1 chance in 1000 that the analysis is wrong. With this same specimen, the effect of ETO decontamination was not significant.

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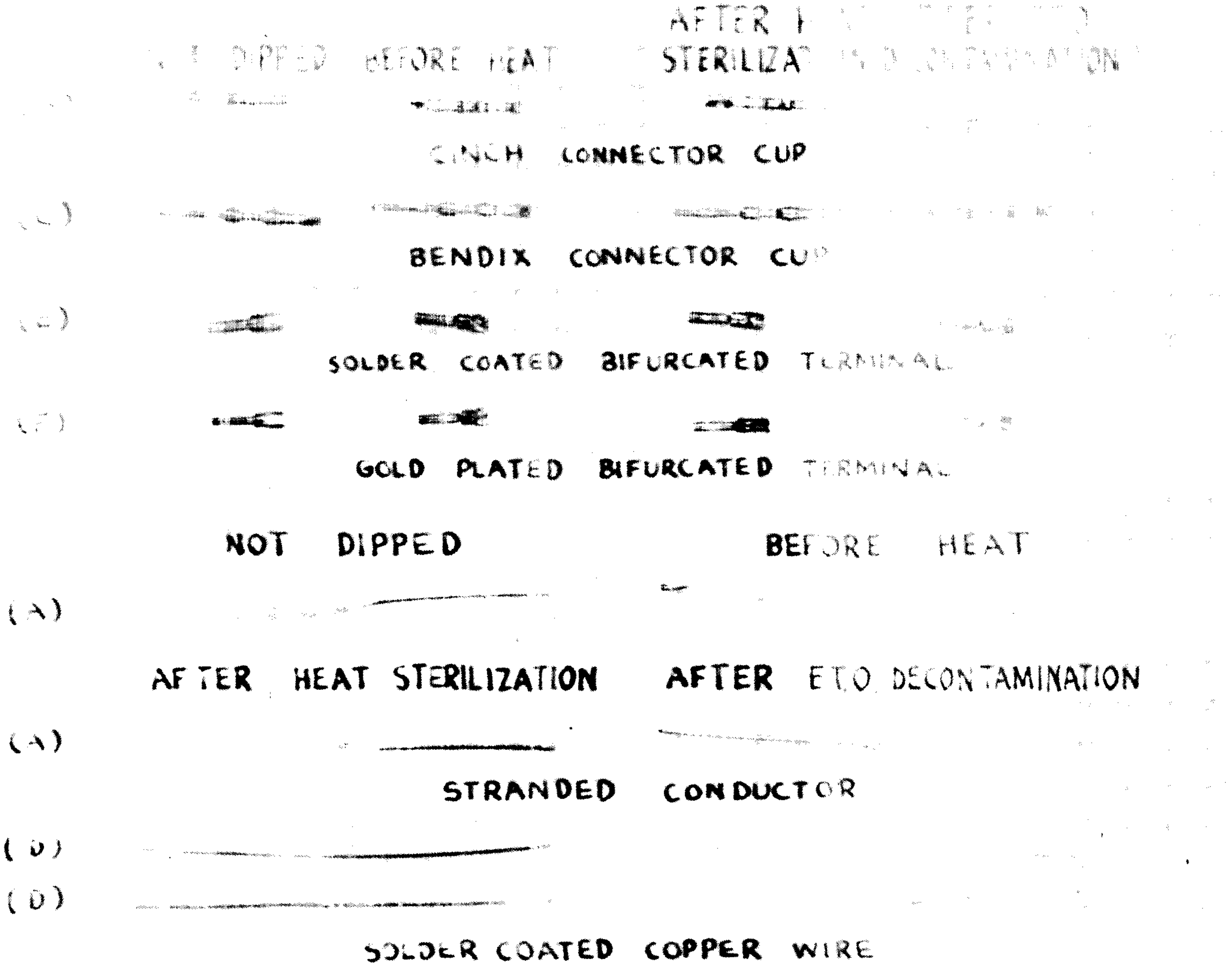

Figure 8. Solderability test specimens which have been solder dipped before and after heat sterilization and ethylene oxide decontamination. (R105895)

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ANALYSIS SOLDERABILITY

PREPARED BY F. Keister Aug. 17, 1965

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Table V. Solderability test results before and after heat sterilization and ETO decontamination.

Hand dip in solder pot of 63/37 solder @ 450°F for 5 sec. Specimens first fluxed by a 5 sec. dip in appropriate flux. Flux removal with trichloroethane. Inspect per MIL-STD-202C, Method 208A. Dipping done by D. Teter.

	EXAMINATION	AT 30X MAGNIFICATION				
SPECIMEN NUMBER	NO TREATMENT	AFTER HEAT STERILIZATION	AFTER ETO DECONTAMINATION			
A(iii)-1	~100%	~100%	~100%	Stranded conductor		
2	"	"	"			
3	"	"	"			
4	"	"	"			
5	"	"	"			
6	"	"	"			
7	"	"	"			
8	"	"	"			
B(iii)-1	98%	~100%	~100%	Gold plated CINCH connector cup		
2	~100%	98%	"			
3	"	97%	"			
4	"	~100%	"			
5	"	"	"			
6	"	"	"			
7	"	95%	"			
8	"	~100%	"			
C(iii)-1	~100%	~100%	~100%	Gold plated BENDIX connector cup		
2	"	"	"			
3	"	"	"			
4	"	"	"			
5	"	"	"			
6	"	"	"			
7	"	"	"			
8	"	"	"			

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Table VI. Solderability test results before and after heat sterilization and ETO decontamination

	EXAMINATION AT 30X MAGNIFICATION					
SPECIMEN NUMBER	NO TREATMENT	AFTER HEAT STERILIZATION	AFTER ETO DECONTAMINATION			
D(iii) -1	~100%	~100%	~100%	Solder coated copper wire		
2	"	"	98%			
3	"	95%	~100%			
4	98%	~100%	"			
5	~100%	"	"			
6	"	"	"			
7	98%	98%	"			
8	~100%	~100%	95%			
E(iii) -1	~100%	60%	95%	Solder coated bifurcated terminal		
2	"	90%	92%			
3	98%	65%	95%			
4	98%	80%	97%			
5	97%	90%	97%			
6	96%	95%	98%			
7	98%	70%	98%			
8	97%	85%	95%			
F(iii) -1	~100%	~100%	~100%	Gold plated bifurcated terminal		
2	"	"	"			
3	99%	"	"			
4	~100%	"	98%			
5	"	"	97%			
6	"	"	~100%			
7	97%	"	99%			
8	~100%	"	~100%			

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Table VII. Effects of thermal sterilization and ethylene oxide decontamination on the solderability of connector cups, bifurcated terminals, stranded wire, and solid wire.

Part	Effect of Thermal Sterilization	Effect of Ethylene Oxide Decontamination
A. Stranded conductor	None	None
B. Gold plated Cinch cup	None	None
C. Gold plated Bendix cup	None	None
D. Solder coated copper wire	None	None
E. Solder coated bifurcated terminal	Significant drop	None
F. Gold plated bifurcated terminal	None	None

4.2 METALLOGRAPHIC EXAMINATION TEST RESULTS

4.2.1 General

Figure 9 and Figure 10 are photomicrographs at 50X magnification showing a typical metallographically mounted specimen of:

Figure 9 (top) - Solid conductor
Figure 9 (bottom) - Stranded conductor
Figure 10 (top) - Connector cup
Figure 10 (bottom) - Bifurcated terminal

These photomicrographs at low magnification (50X) were included to give a reader an idea of the mounting configuration used for each type of solderability specimen. The photomicrographs which follow (Figures 11 through 23) are all at much higher magnification (1000X) and show only a very small area of the mounted specimen.

4.2.2 Before and After Thermal Bake-Out

Figures 11 through 17 are photomicrographs at 1000X magnification of Specimens A, B, C, D, E, F, and G as outlined in Figure 1 and Table II. Each figure contains two photomicrographs. The top photomicrograph is of that particular specimen before thermal bake-out. The bottom photomicrograph is of a similar type specimen which has been thermally baked-out at 200°C for 168 hours in a nitrogen atmosphere. The different etchants used were selected to bring out the metallographic structure of that particular type of wire and electroplating. All of the specimens in Figures 11 through 17 are solid wire conductors.

Although Specimen F(ii), as shown in Figure 16, failed the solderability test per MIL-STD-202C, Method 208A (refer to Table IV), there was no evidence of any grain boundary diffusion of the nickel plating into the outer copper sheath or of any interdiffusion of the gold and nickel electroplated layers. <u>None</u> of the specimens which were metallographically mounted showed any signs of degradation which could be

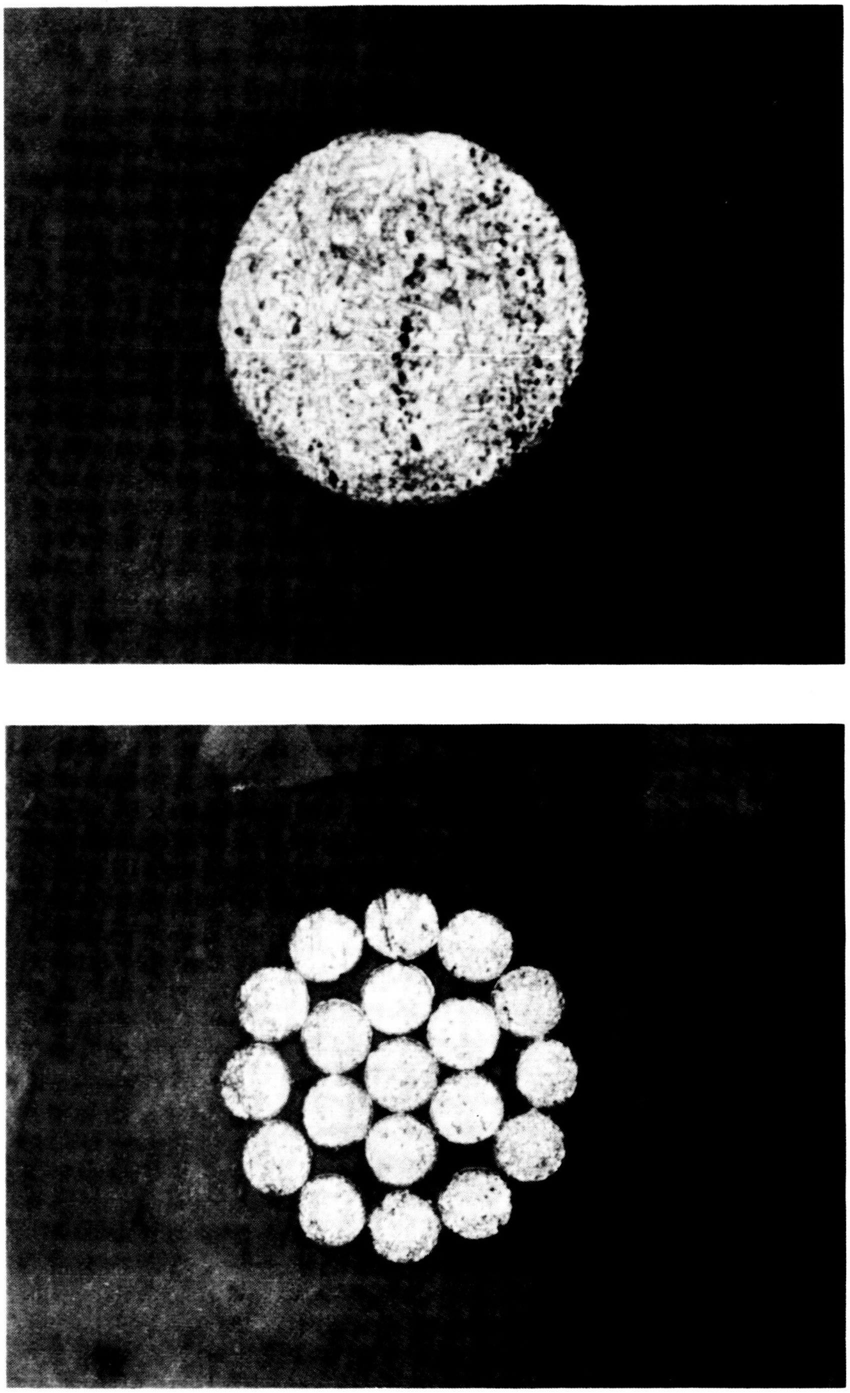


Figure 9. Photomicrographs of a typical solid conductor (top picture) and a typical stranded conductor (bottom picture) as metallographically mounted. Magnification at 50X. Potassium dichromate etchant. The solid conductor (Neg. 02407) is a solder coated copper wire and the stranded conductor (Neg. 02409) consists of 19 strands of 36 AWG silver plated copper wire.

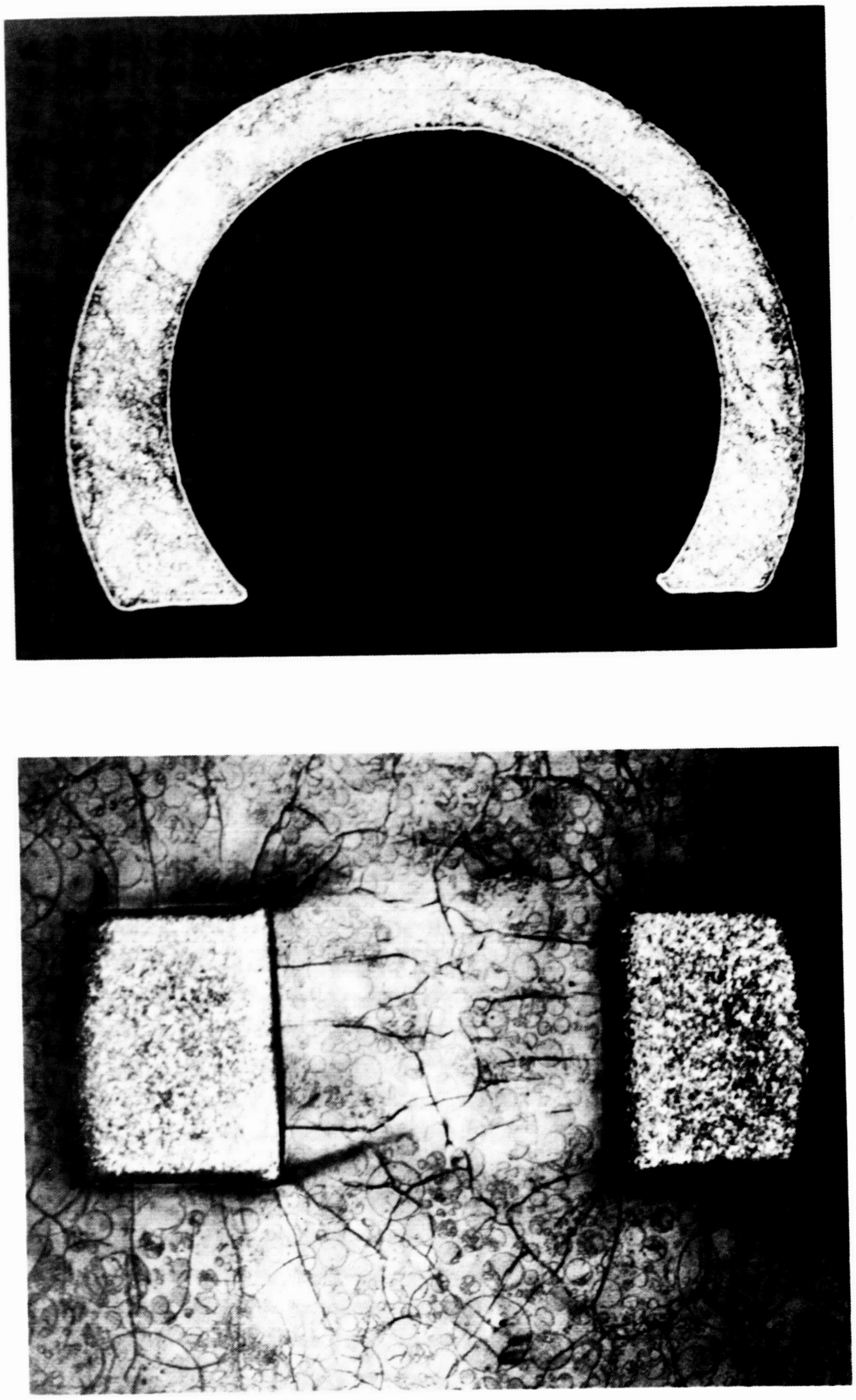
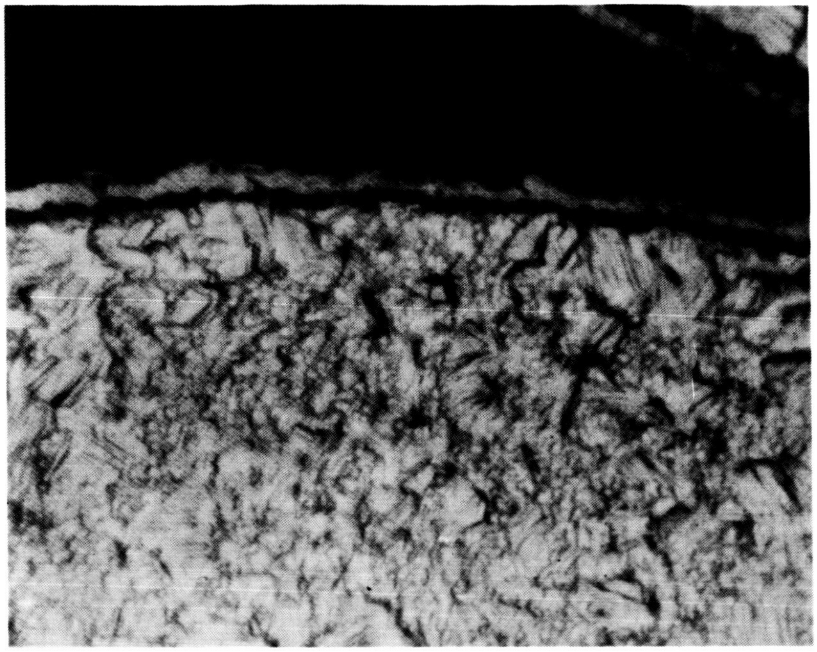
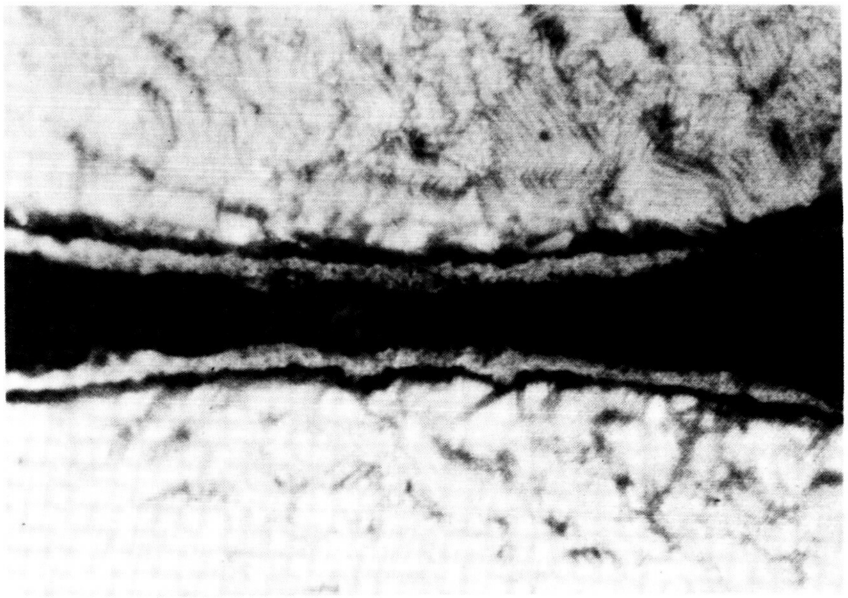


Figure 10. Photomicrographs of a typical connector cup (top **picture**) and typical bifurcated terminal (bottom picture) **as metallo**graphically mounted. Magnification at 50X. **Potassium** dichromate etchant. Connector cup (Neg. 02406) **is the** Bendix type and the bifurcated terminal (Neg. 02408) **is the** gold plated type.

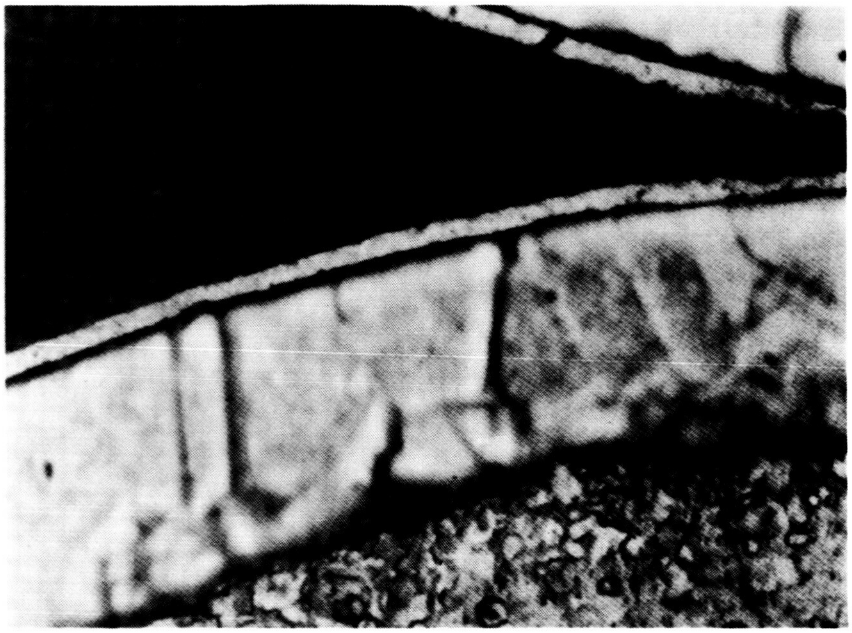


Before
Bake-Out
(Neg. 02392)



After
Bake-Out
(Neg. 02393)

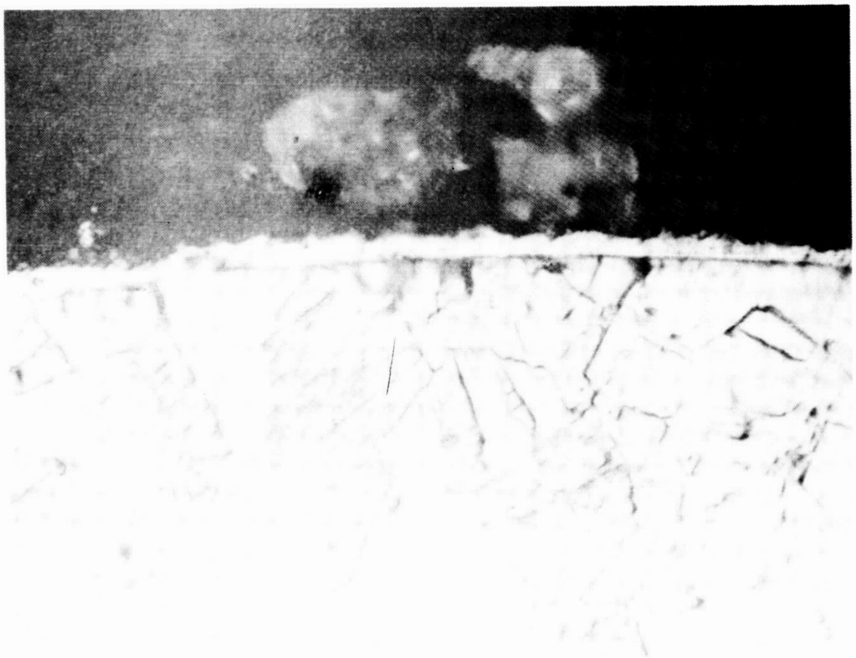
Figure 11. Photomicrographs at 1000X of Specimen A(ii) (gold plated copper wire) before and after thermal bake-out. Potassium dichromate etchant.



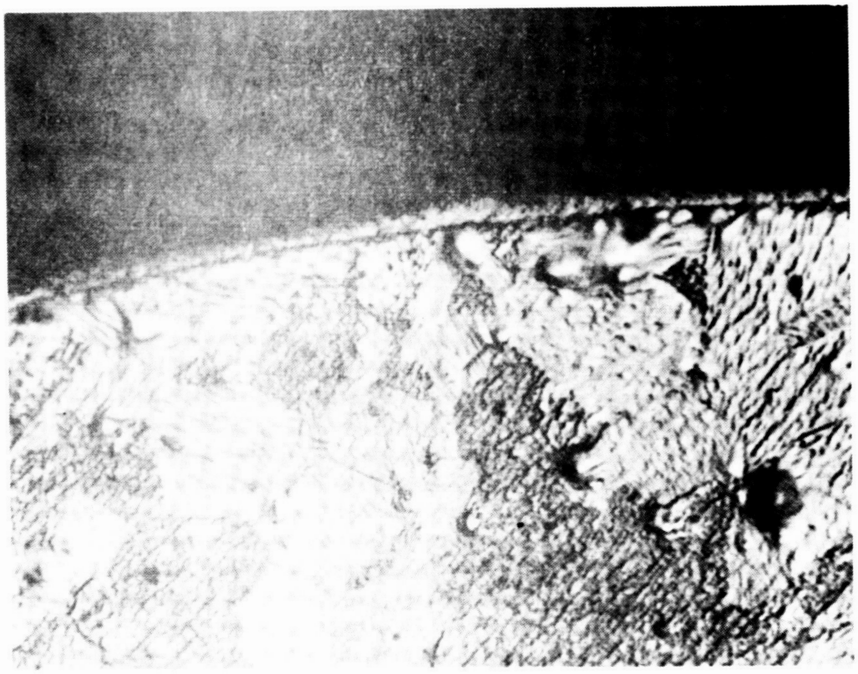
Before
Bake-Out
(Neg. 02394)

After
Bake-Out
(Neg. 02395)

Figure 12. Photomicrographs at 1000X of Specimen B(ii) (gold plated Dumet wire) before and after thermal bake-out. Acetic-nitric etchant.

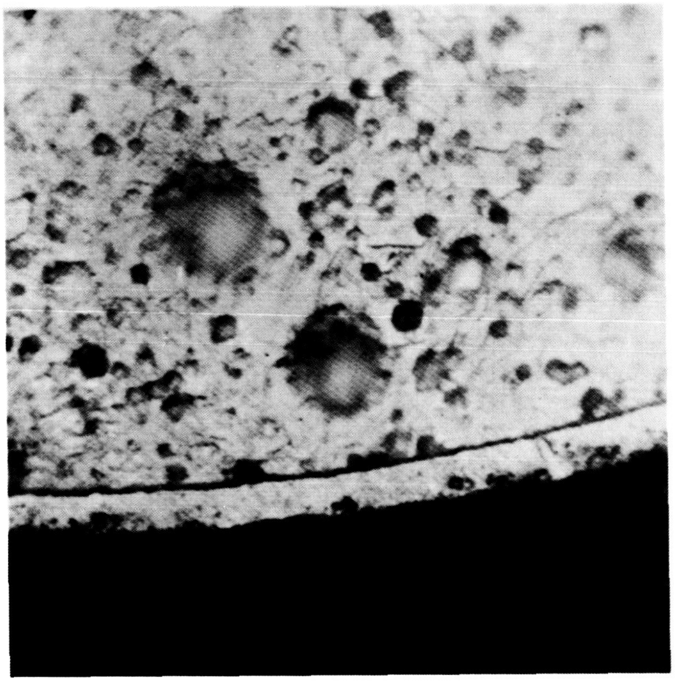


Bake-Out
(Neg. 02396)

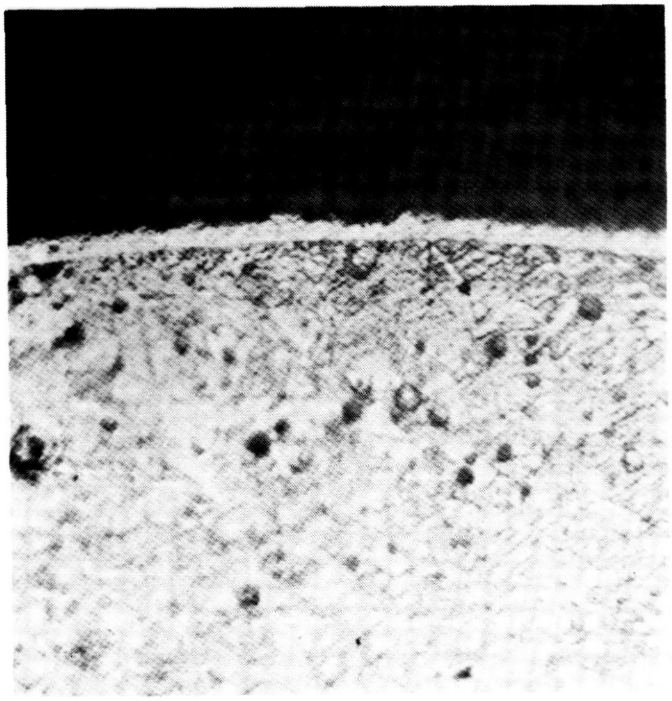


After
Bake-Out
(Neg. 02397)

Figure 13. Photomicrographs at 1000X of Specimen C(ii) (gold plated Kovar wire) before and after thermal bake-out. Carapella etchant.

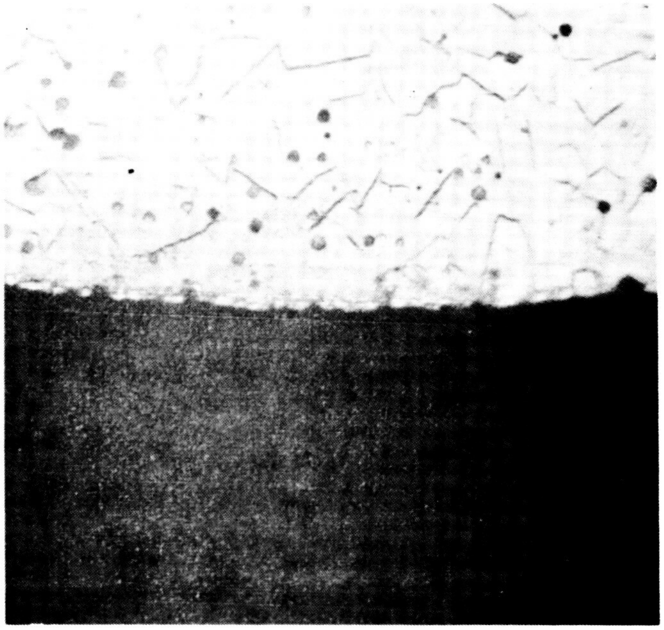


Before
Bake-Out
(Neg. 02398)

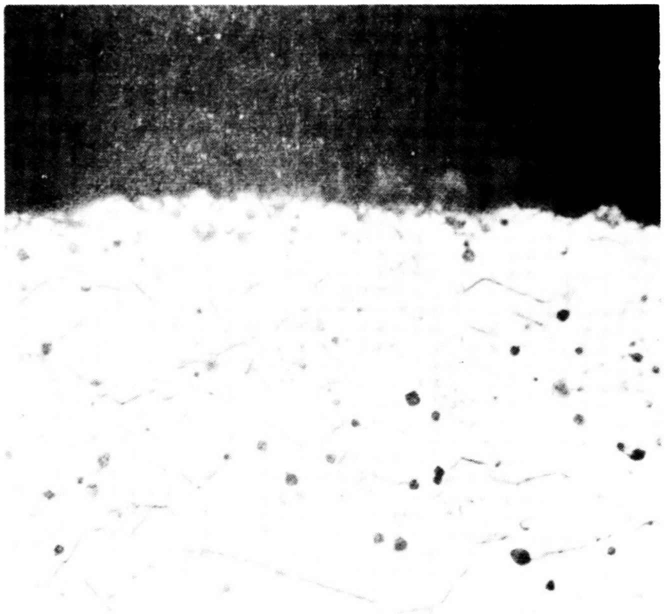


After
Bake-Out
(Neg. 02399)

Figure 14. Photomicrographs at 1000X of Specimen D(ii) (gold plated nickel wire) before and after thermal bake-out. Acetic-nitric etchant.



Before Bake-Out (Neg. 02400)



After Bake-Out (Neg. 02401)

Figure 15. Photomicrographs at 1000X of Specimen E(ii) (bare nickel wire) before and after thermal bake-out. Acetic-nitric etchant.

Before
Bake-Out
(Neg. 02402)

After
Bake-Out
(Neg. 02403)

Figure 16. Photomicrographs at 1000X of Specimen F(ii) (gold plated Dumet with nickel undercoat) before and after thermal bake-out. Acetic-nitric etchant.


Before Bake-Out (Neg. 02404)

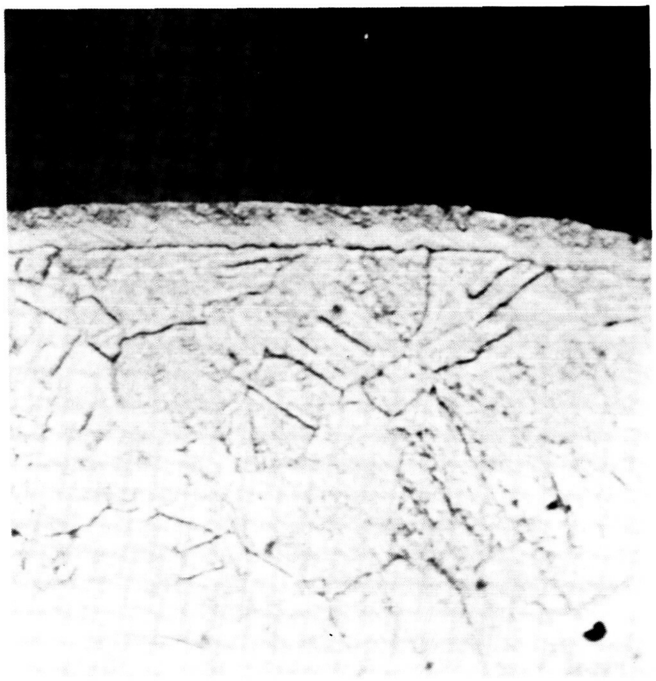
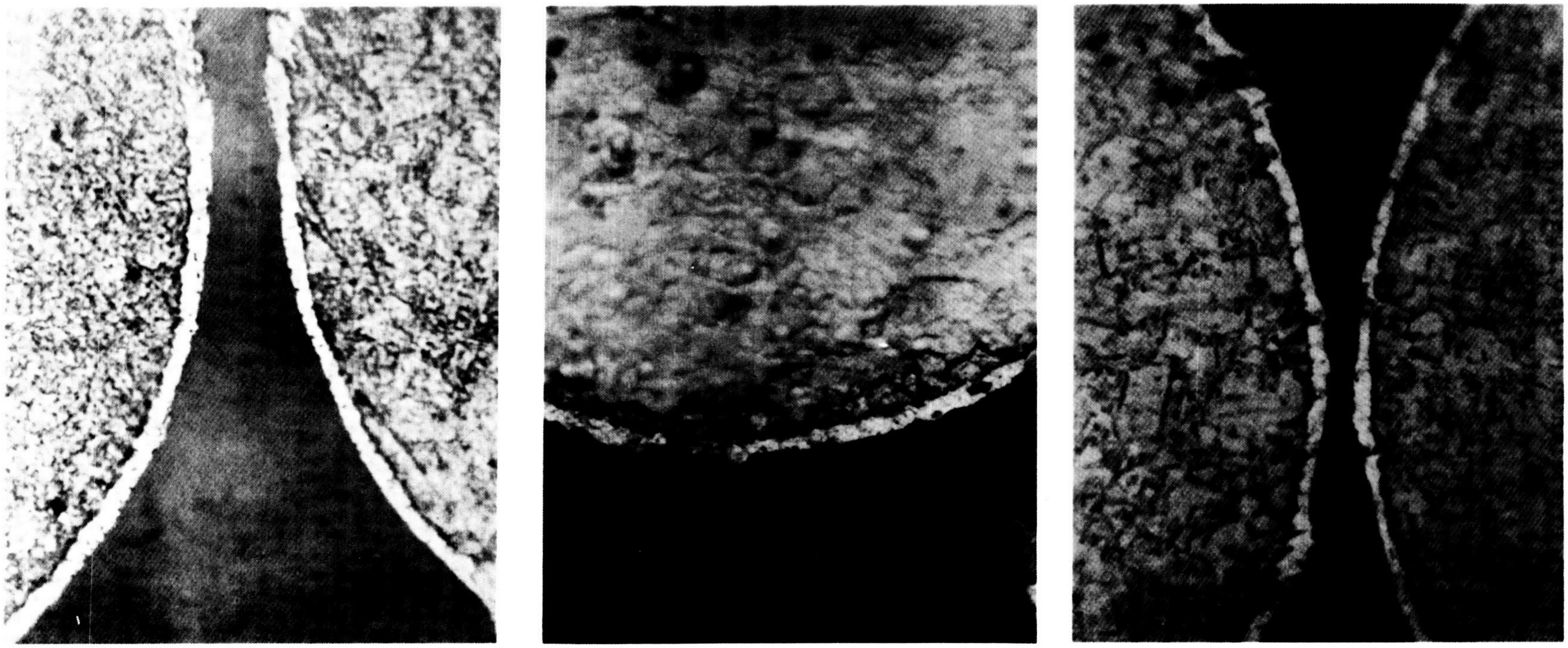

After Bake-Out (Neg. 02405)

Figure 17. Photomicrographs at 1000X of Specimen G(ii) (gold plated copper wire with nickel undercoat) before and after thermal bake-out. Potassium dichromate etchant.

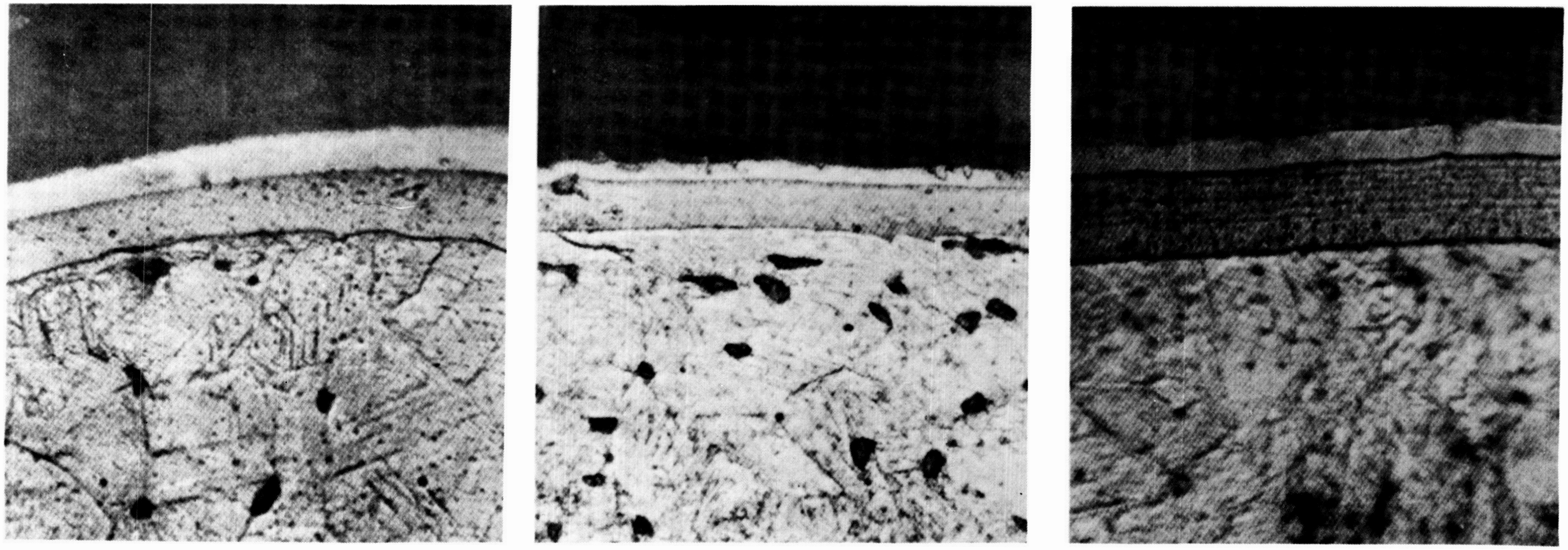


No Treatment
(Neg. 02366)

After Heat Sterilization
(Neg. 02372)

After ETO Decontamination
(Neg. 02378)

Figure 18. Photomicrographs at 1000X of Specimen A(iii-iv) (stranded conductor) before and after heat sterilization and ETO decontamination. Potassium dichromate etchant. Photomicrographs show only one or two of the silver plated copper strands.

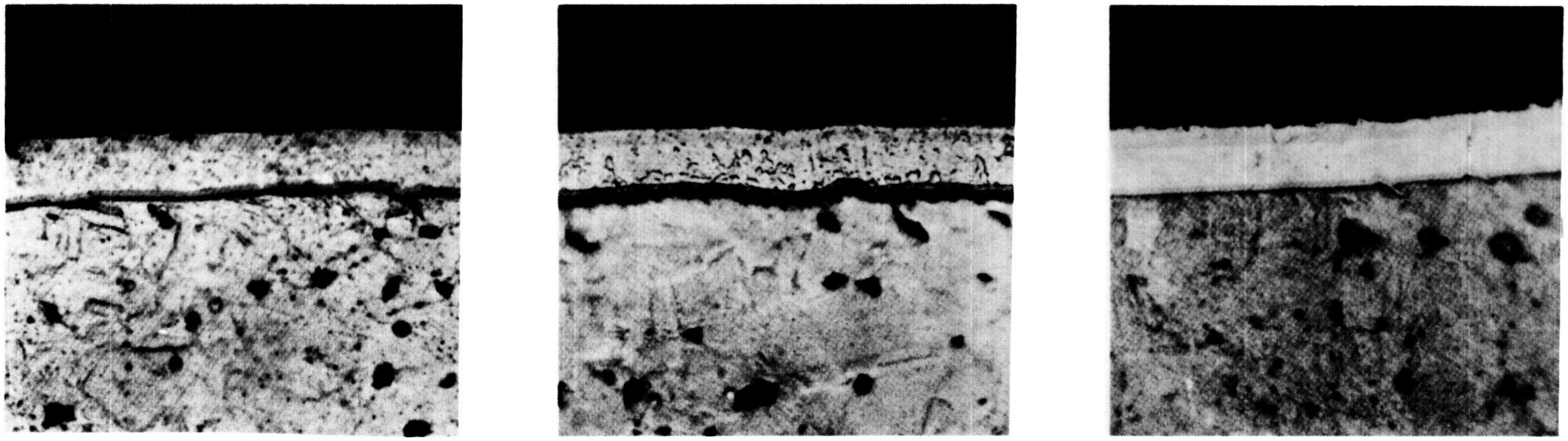


No Treatment
(Neg. 02367)

After Heat Sterilization
(Neg. 02373)

After ETO Decontamination
(Neg. 02379)

Figure 19. Photomicrographs at 1000X of Specimen B(iii-iv) (brass, copper plated, gold plated Cinch connector cups) before and after heat sterilization and ETO decontamination. Potassium dichromate etchant.

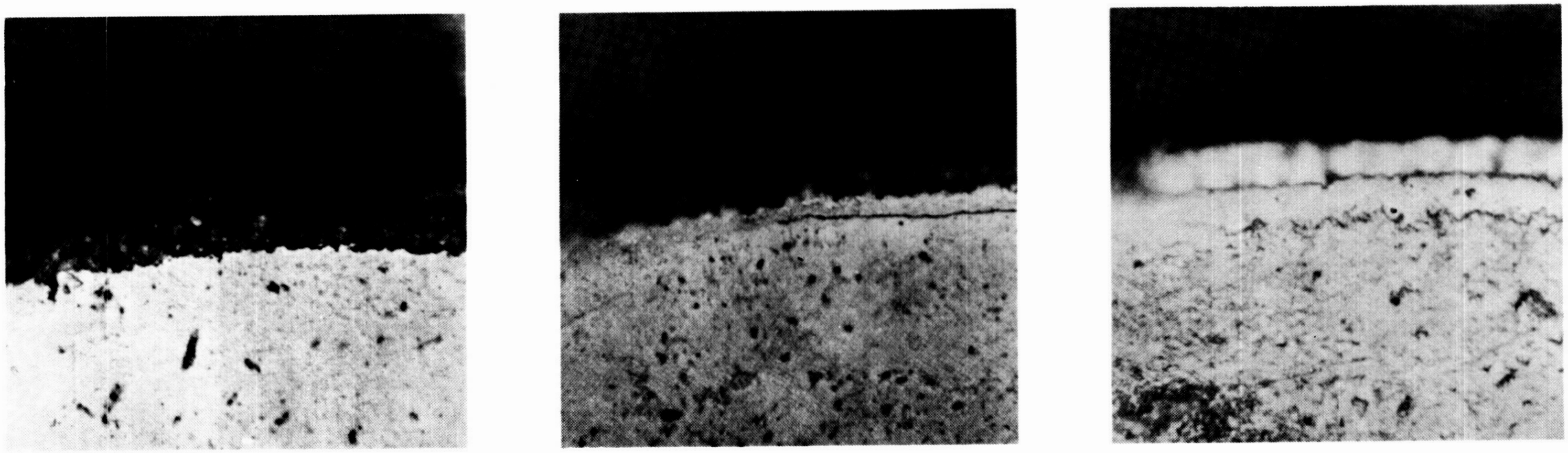


No Treatment
(Neg. 02368)

After Heat Sterilization
(Neg. 02374)

After ETO Decontamination
(Neg. 02380)

Figure 20. Photomicrographs at 1000X of Specimen C(iii-iv) (brass, copper plated, silver plated, gold plated Bendix connector cup) before and after heat sterilization and ETO decontamination. Potassium dichromate etchant.

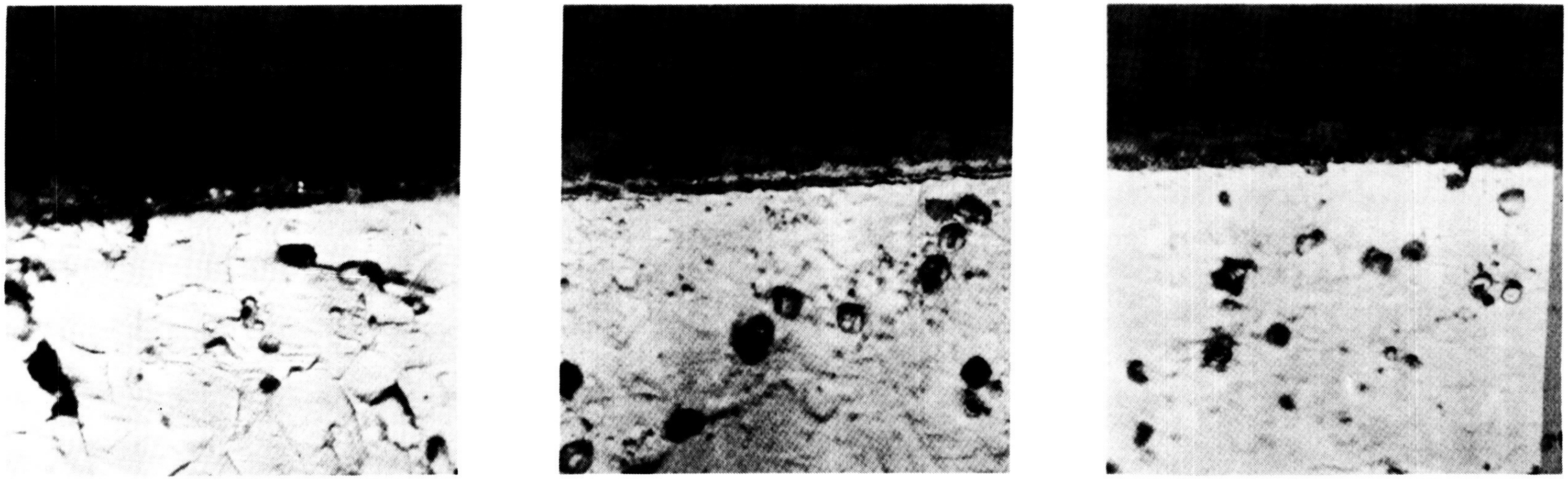


No Treatment
(Neg. 02369)

After Heat Sterilization
(Neg. 02375)

After ETO Decontamination
(Neg. 02381)

Figure 21. Photomicrographs at 1000X of Specimen D(iii-iv) (solder coated copper wire) before and after heat sterilization and ETO decontamination. Potassium dichromate etchant.

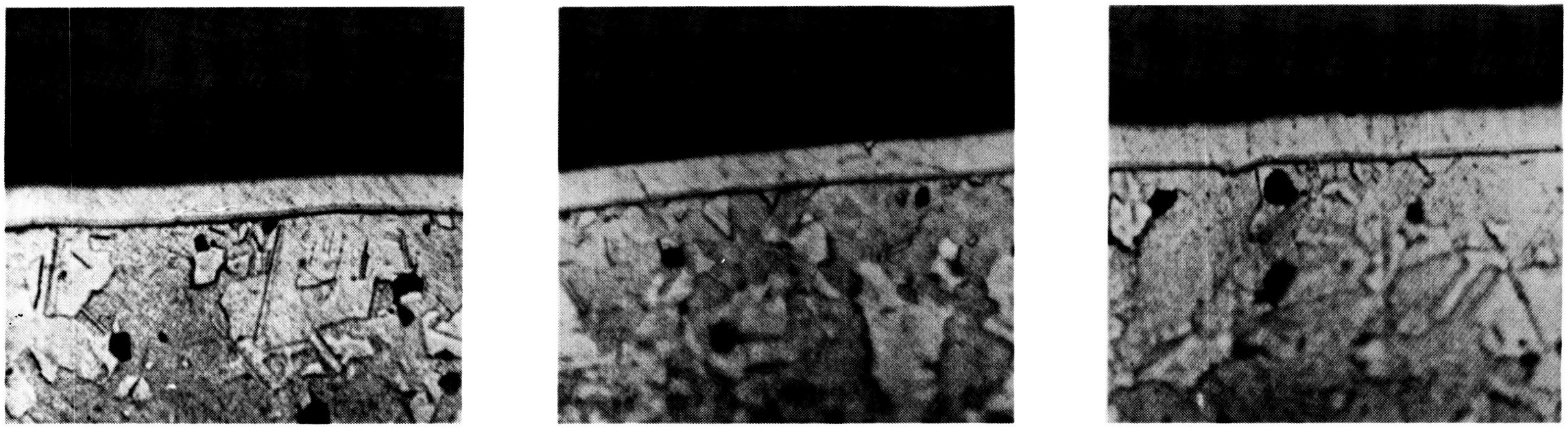


No Treatment
(Neg. 02370)

After Heat Sterilization
(Neg. 02376)

After ETO Decontamination
(Neg. 02382)

Figure 22. Photomicrographs at 1000X of Specimen E(iii-iv) (solder coated bifurcated terminal) before and after heat sterilization and ETO decontamination. Potassium dichromate etchant.



No Treatment
(Neg. 02371)

After Heat Sterilization
(Neg. 02377)

After ETO Decontamination
(Neg. 02383)

Figure 23. Photomicrographs at 1000X of Specimen F(iii-iv) (brass, copper strike, silver plated, gold plated bifurcated terminal) before and after thermal sterilization and ETO decontamination. Potassium dichromate etchant.

attributed to thermal bake-out. The nickel undercoat on Specimens F and G did not appear to enhance the solderability of the gold plated copper or gold plated Dumet wires. Since the effect was not observable metallographically, it is assumed that the nickel underplating formed a type of barrier layer hindering a wetting or alloying reaction between the tin in the solder and the copper basis metal. It has been reported[1] that nickel undercoats will form a duplex intermetallic compound layer with tin which, although assisting initial solderability of freshly plated coatings, can decrease solderability after storage if the thickness of the coating is not adequate. Nickel plating, by itself, is not very solderable (as compared to tin, solder, gold, copper, etc.). If the outer gold electroplate was porous, the nickel underneath would therefore inhibit optimum wetting. By similar reasoning it would then be expected that the gold plated copper wire (with the nickel undercoat) would also experience decreased solderability. However, such was not the case. Further testing of these questionable wire types would be necessary in order to obtain a full understanding of this phenomenon.

4.2.3 Before and After Heat Sterilization and Ethylene Oxide Decontamination

Figures 18 through 23 are photomicrographs at 1000X magnification of Specimens A, B, C, D, E, and F as outlined in Figure 1 and Table II. Each figure contains three photomicrographs of the same type of specimen which has been submitted to three different environments. The specimen in each left-hand photomicrograph has received no treatment. The specimen in each middle photomicrograph has undergone heat sterilization. The specimen in each right-hand photomicrograph has undergone ethylene oxide (ETO) decontamination. All

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[1] Thwaites, C. J. "The Solderability of Some Tin, Tin Alloy and Other Metallic Coatings," *Trans. Inst. Met. Finishing*, vol. 36, 203 (1959).

metallographic mounts were etched in potassium dichromate. The different specimens are as follows:

Figure 18 - Stranded conductors
Figures 19 and 20 - Connector cups
Figure 21 - Copper wire solid conductors
Figures 22 and 23 - Bifurcated terminals.

Only two of the specimens exhibited any apparent metallurgical change as a result of the exposures. Specimens B, C, D, and F showed no evidence of any grain boundary diffusion of the plating layer into the basis metal or any interdiffusion of the surface plating layers. Specimen C (Figure 20) shows a slight change in the metallic copper and silver plated layers, but this phenomenon was not observed on all heat sterilized specimens and did not appear to affect the solderability (refer to Table V). A noticeable change appears on the stranded conductor specimen (Figure 18 - middle picture) which has undergone heat sterilization. Although this might appear to be a grain boundary diffusion of the silver plating, it could also be caused by unequal etching or polishing of the mount and improper focusing. This effect was not as pronounced during examination of the actual mount. This change was not observable on all specimens and did not appear to affect the solderability (see Table V). During the soldering operation, the thin silver electroplate becomes soluble in the tin of the tin/lead solder alloy and may cause silver scavenging from the plated wire strands. For this reason it is common to use a solder alloy containing a small percentage of silver (i.e., 1.5% - 2%) when soft soldering silver plated parts.

Specimen E (solder coated bifurcated terminal) was the other specimen showing what appears to be a marked difference in metallurgical structure after heat sterilization. Note that the middle photomicrograph in Figure 22 shows an intermediate layer between the brass basis metal of the bifurcated terminal and the outer solder coating. Metallographic examination showed this layer to be a thin gold electroplate approximately 0.000016 inch thick. This gold plated layer is not present on the left-hand or right-hand photomicrographs. Further checking revealed that the vendor of the bifurcated terminals apparently shipped a mixed lot of terminals, some of which were solder coated directly over brass and some of which were solder coated over gold plated brass. This is proven by examining Figures 14, 20, and 22 in Attachment 3, Part II, of this final report. The gold plated intermediate layer is also shown in these photomicrographs of actual solder joints, while other photomicrographs of solder joints to solder coated bifurcated terminals do not exhibit the gold electroplate. This mixed lot of terminals could possibly account for some of the poor solderability results of this type of specimen (refer to Tables VI and VII). It should also be kept in mind that the solder coated bifurcated terminals were all coated with a layer of Sealbrite No. 230-10. Overheating of this protective coating during the heat sterilization cycle could possibly inhibit good solderability. The gold plated bifurcated terminals were not coated with Sealbrite, nor were the gold plated connector cups. Connector cups are not ordinarily protectively coated until after tinning.

It must therefore be stated that none of the specimens exhibited significant metallurgical degradation or diffusion characteristics which could definitely be attributed to either heat sterilization or ethylene oxide decontamination. The changes appearing in the photomicrographs could logically be assigned to other unrelated causes. The heat sterilization temperature (145°C) is about 70°F below the melting point of 63/37 tin/lead solder and the nitrogen atmosphere prevents the formation of any metallic oxides which would otherwise form in air. The ETO decontamination exposure had even less effect on the metallurgical structure than the heat sterilization exposure.

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5. CONCLUSIONS

Table VIII presents a summary of the test results concerning the effects of thermal bake-out, heat sterilization, and ethylene oxide decontamination on the solderability of component leads. A more detailed discussion of the results is given in Sections 4. 1 and 4. 2 of this report, including raw data sheets, a statistical analysis of the solderability tests, and thirty-six photomicrographs.

Of the seven different types of solid wire conductors tested before and after thermal bake-out, only the gold plated Kovar wire and the gold plated Dumet wire (with the nickel undercoat) showed any decrease in solderability after thermal bake-out. Of these two wire types, the gold plated Dumet wire (with the nickel undercoat) would be the only one actually failing to meet the 95% minimum solder coverage required by MIL-STD-202C, Method 208A. Metallurgical examination at 1000X magnification of these seven types of solid wire conductors showed <u>no</u> signs of degradation, grain boundary diffusion, or inter-diffusion of the electroplated layers which could be attributed to thermal bake-out.

Of the six types of specimens (i. e., stranded and solid conductors, connector cups, and bifurcated terminals) tested before and after heat sterilization and ETO decontamination, only the solder coated bifurcated terminal exhibited a significant drop in solderability as a result of thermal sterilization. A metallographic examination of the solder coated bifurcated terminals later revealed that certain of the specimens had a thin gold electroplate beneath the outer solder coating while others did not. These terminals also had a protective lacquer overcoating. It is felt that these two factors (not present on any of the other specimen types) could have contributed to some of the poor solderability results. Metallurgical examination of the six types of specimens (A, B, C, D, E, and F) in the lower half of Table VIII revealed that two of the specimen types showed a slight change in metallurgical structure after heat sterilization. However, these slight changes were not evidenced on all

Table VIII. Summary of test results.

Type of Specimen	Effect of Different Exposures					
	Thermal Bake-Out		Heat Sterilization		ETO Decontamination	
	Solderability Test	Metallurgical Examination	Solderability Test	Metallurgical Examination	Solderability Test	Metallurgical Examination
A. Gold plated copper wire	None	None	--	--	--	--
B. Gold plated Dumet wire	None	None	--	--	--	--
C. Gold plated Kovar wire	Slight, passes*	None	--	--	--	--
D. Gold plated nickel wire	None	None	--	--	--	--
E. Bare nickel wire	None	None	--	--	--	--
F. Gold plated Dumet wire with nickel undercoat	Fails*	None	--	--	--	--
G. Gold plated copper wire with nickel undercoat	None	None	--	--	--	--
A. Stranded conductor	—	—	None	Slight**	None	None
B. Brass, copper plated, gold plated connector cup (Cinch)	—	—	None	None	None	None
C. Brass, copper plated, silver plated, gold plated connector cup (Bendix)	—	—	None	Slight**	None	None
D. Solder coated copper wire	—	—	None	None	None	None
E. Solder coated bifurcated terminal	—	—	Significant drop	None	None	None
F. Gold plated bifurcated terminal	—	—	None	None	None	None

*Refers to solderability specification which requires minimum of 95% coverage.

**Structural change questionable; could be caused by other factors; and was not 100% repeatable.

specimens nor could they be attributed definitely to heat sterilization. Metallurgical examination of the ETO decontaminated specimens showed no signs of degradation, grain boundary diffusion, or interdiffusion of the electroplated layers which could be attributed to ETO exposure.

As a whole it can be concluded that thermal bake-out, heat sterilization, and ethylene oxide decontamination had very little effect on the solderability or metallurgical integrity of the specimens tested. Although a few specimen types did show certain effects due to either thermal bake-out or heat sterilization, these effects were minimal and could be attributed to either unrelated causes or to factors which could be corrected in production electronic systems.

ACKNOWLEDGMENTS

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Mr. N. Ferguson	for all metallographic mounts and photomicrographs.
Mr. R. Rydelek	for conducting all thermal bake-out, heat sterilization, and ethylene oxide decontamination tests.