GODDARD SPACE FLIGHT CENTER

RESEARCH & ADVANCED TECHNOLOGICAL DEVELOPMENT ACTIVITIES

QUARTERLY PROGRESS REPORT (ART/SRT)

MARCH 1966

ADMINISTRATION AND TECHNICAL SERVICES

GODDARD SPACE FLIGHT CENTER

FOR OFFICIAL USE ONLY

QUARTERLY PROGRESS REPORT (ART/SRT)

March 31, 1966

C O N T E N T S

ADMINISTRATION AND TECHNICAL SERVICES DIRECTORATE

EXPERIMENTAL FABRICATION AND ENGINEERING DIVISION

PROGRESS REPORT R&D QUARTERLY

For Period January 1 **to** March 31, **19**66

Originator (Organization) Experimental Fabrication and Engineering Division **(Signature)** M. Levinsohn

SUBJECT: Vacuum UV Coatings, Microcircuitry Welding, Metal Polishing Study, Absolute Spectral Response System, Parabolic Reflectors, Soldering to Electrodeposited Metals

Remarks:

VACUUM UV COATINGS, Job Order No. 284Y09-19 (NASA Code 124-09-05-16)

The procedure, reported in the last quarter, for depositing uniform vacuum ultraviolet reflecting coatings on large surfaces was applied to the task of recoating the 39-inch diameter primary mirror in the Vacuum Optical Bench facility.

In order to monitor the recoating process, glass slides were mounted in the aperture and around the periphery of the mirror, corresponding to radial distances of 2 inches and 21 inches, respectively. At a distance of 2 inches from the center, the average reflectance at Lyman alpha was 81 percent, whereas at 21 inches the average reflectance was 74 percent.

This range of 7 percent was unexpected since previous data indicated that a range of 4 percent could be attained. In previous runs, however, using a slide-holding fixture duplicating the size and shape of the mirror, samples had been located at distances of 4 to 18 inches from the center. Therefore, it was surmised that the reflectance distribution deviated from a straight line beyond these limits.

In order to demonstrate this, the mirror-simulating fixture was modified to include slides at distances of 2 and 21 inches and another test run was made. The data from this run indicated that the distribution curve more closely approximated a parabola than a straight line, with a maximum at a distance of about 7 inches from the center.

Incomplete removal of contamination from the surface of the mirror necessitated stripping the coating and applying a new one. When this was done, the average reflectances of the monitoring slides at 2 inches and 21 inches were 80 percent and 72 percent respectively. Based on this data and the assumption that the shape of the reflectance distribution curve was the same as for the test run, it was estimated that the reflectance on the surface of the mirror, which includes the area from 3 1/2 to 19 inches from the center, varied from 75 to 80 percent at Lyman alpha with a mean of 78 percent over the entire surface. The greatest deviation from a straight line occurred, therefore, beyond the outside edge of the mirror.

PROGRESS REPORT R&D QUARTERLY

Period January 1 to March 31, 1966

MICROCIRCUITRY WELDING, Job Order No. 284Y25-06 (NASA Code 125-25-04-02)

In the last quarterly report, the initial phase of a program to measure embedment nondestructively was described. In this phase, a preliminary model of a device for measuring the distance that the electrode tip moves during the welding cycle was installed on a pincer welding head (Figure 1). The dial indicator is attached to the fixed portion of the head, and the indicator actuating arm rotates about the same axis as does the electrode tip. The dial indicator reading can be made to correspond to the electrode movement by locating the indicator such that its spindle contacts the arm at the same distance from the center of rotation as the welding tip.

The welder actuating mechanism has two positions, an initial one for applying the necessary force and a final position for discharging the capacitors in the welder supply for the required electrical energy. As this device is presently used, the welding force is applied before the indicator is set to zero, and the force is maintained after welding until the movement is read.

In a future model, it is planned to measure the electrode movement automatically.

Tests have been conducted with this device by cross-wire welding .020-inch diameter Alloy 180 (widely used as a nonmagnetic interconnect) to a number of lead wires (.020-inch nickel; .020-inch gold plated Dumet; .018-inch gold plated Kovar; .025-inch Alloy 42; .020-inch Alloy 180) commonly found on components used in the fabrication of cordwood welded modules. Twelve samples were welded at each of seven energy settings using 5 pounds force for each of the above material combinations. Dial indicator readings and pull strength were measured on each weld. The data are being evaluated to determine if electrode movement measurements can be used for predicting weld strength and consistency and for monitoring production welding.

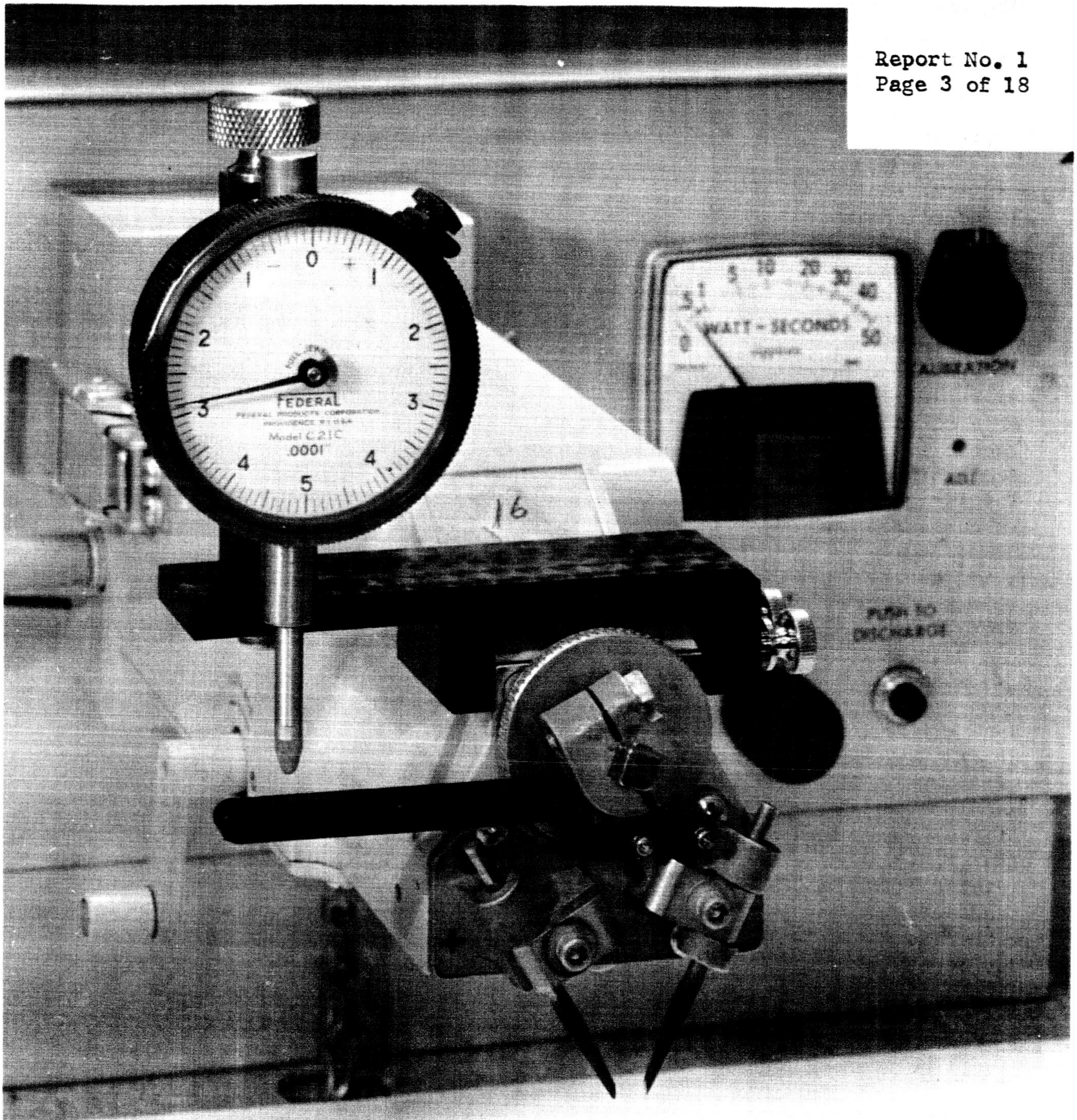

Figure 1—Electrode movement measuring device installed on welding equipment.

PROGRESS REPORT R&D QUARTERLY

Period January 1 to March 31, 1966

METAL POLISHING STUDY, Job Order No. 336Y03-13 (NASA Code 129-03-14-13)

The contract, awarded to the Isomet Corporation, for the optimization and standardization of a polishing procedure for 304L stainless steel has been completed. Although a final procedure was documented and demonstrated by Isomet, a final report has not been received for evaluation. A discussion of the results of this program would be premature at this time and, therefore, will be deferred until the next quarter.

A broad program to determine the suitability of candidate metals for use as reflective optical elements is on contract to the American Optical Company. This program is divided into three major parts: (1) production of optical surfaces, (2) testing and stability of the polished samples as affected by time, temperature and stress, and (3) determination of the reflectance of the surfaces. The first phase of this program has been completed, and the stability testing is currently in progress.

The developments during this quarter are discussed by material type.

Nickel

The nickel test samples were prepared for grinding, as was the sample for the polishing experimentation. Rough grinding, fine grinding and polishing were done with the pieces blocked "five a round one" on a "pick-up" block. Such a block is prepared by placing a quarter-inch-thick layer of hard pitch (75175 Pitch, Universal Shellac and Supply Company, Brooklyn, New York) on the back of each piece. The pieces are then placed face down on an optical flat with five pieces symmetrically arranged around a central piece. A heated 12-inch-diameter, flat tool is then placed on the pitch and is allowed to melt into the pitch. After cooling, all six pieces are held coplanar and, because of the cold flow tendencies of the pitch, the pieces are held without strain. These blocks were worked as a single piece would be, using the polishing techniques perfected during the polishing experimentation. The figure and surface quality of all pieces was satisfactory. The figure of three of these samples has been recorded photographically and the samples stored for time-stability testing.

Beryllium

The beryllium test samples were prepared for grinding, as was the sample for the polishing experimentation. These pieces were blocked like the nickel samples and ground and polished, using the techniques perfected during the polishing experimentation. A "clean" surface could not be obtained on the block, and the pieces had to be "de-blocked" and finished individually. This poor surface resulted from the difficulty of getting "good contact" between the block and the polishing lap. The figure and surface quality of all pieces was satisfactory. The figure of three samples has been recorded photographically, and the samples stored for time-stability testing.

Haynes 25

The Haynes 25 samples were fabricated using the techniques perfected during the polishing experimentation and "pick-up" blocks. No difficulties were encountered. The figure and surface quality of all pieces was satisfactory. The figure of three pieces has been recorded photographically, and the samples stored for time-stability testing.

Lurium 5

The techniques reported in the last quarterly report for the aluminum 2024 and 6061 were used on the Lurium 5 without success. The polishing experimentation with this material has been discontinued, and no further work is planned.

Aluminum 2024 and 6061

The polishing experimentation with these materials, as reported in the last quarterly report, was continued without success. The polishing experimentation with these materials has been discontinued and no further work is planned.

The contractor has concluded that the Lurium 5, the Aluminum 2024 and the Aluminum 6061 cannot, at this time, be optically polished and figured to better than $\lambda/2$. Techniques which produce either a clean surface or a good figure have been found, but no technique which produces both has been found.

PROGRESS REPORT R&D QUARTERLY

Period January 1 to March 31, 1966

ABSOLUTE SPECTRAL RESPONSE SYSTEM, Job Order No. 633Y09-06

Initial testing of the High Intensity Light Source Optical System revealed two deficiencies: (1) insufficient energy was received from the tungsten lamp source, and (2) excessive heat was developed at the entrance slit jaws of the scanning monochromator.

The first of these occurred because the paraboloidal reflector collimated light from only a small segment of the tungsten extended filament along the desired optical path. Separate extra axial points on the source were reflected as parallel bundles in off-axis directions. To re-direct this energy, a parabolic cylindrical mirror of f:number 1/3.9 was nested within the paraboloidal collector. Micrometer screw positioning aligned the cylindrical mirror such that the focal line is coincident with the filament coil tips. The emergent beam from the dual mirrors was fourteen times more intense along the desired optical path than that from the paraboloidal reflector alone, and sufficient uniform illumination energy was obtained at the entrance slit jaws of the monochromator to satisfy measurement requirements.

The overheating at the entrance slit jaws was attributed to imaging of the light source. If not reduced, this heating creates thermal drift currents which upset the reference energy levels being measured by the thermopiles in the detector units. This problem was curbed by redesign of the slit jaws to incorporate miniature water passages through which water is circulated at a rate of 0.8 quarts per minute.

All components of the High Intensity Light Source have been fabricated and are now in final assembly.

PROGRESS REPORT R&D QUARTERLY

Period January 1 to March 31, 1966

PARABOLIC REFLECTORS, Job Order No. 322U01-02

As discussed in previous quarterly reports, an experimental explosive forming program, the objective of which is development of expedient techniques for fabrication of metal optical elements, is being performed under a contract with the Martin Company, Baltimore.

No explosive forming was performed during this reporting period since this work is done out of doors and has been delayed by winter weather.

A new die, of type 440C Stainless Steel, has been machined and heat treated by Martin. This die which is being optically polished at Goddard, will be used in future testing for evaluation of the 440C as an explosive forming die material.

SOLDERING TO ELECTRODEPOSITED METALS, Job Order No. 284U54-02

Introduction

A considerable amount of effort has been expended in investigations of the solderability of various electroplatings. Of particular interest, especially in the field of electronic circuitry, is electroplated gold. Gold is frequently plated onto printed wiring boards for several reasons, namely, the ability to preserve solderable surfaces during storage due to its nonoxidizing qualities, its low resistivity which makes it an excellent electrical contact material and its resistance to attack by all of the commonly used etchants.

Considerable controversy has arisen as to the suitability of gold as a base for soldering. Excellent results have been achieved by some, whereas others consider the resultant joints to be highly unreliable.

J. D. Keller (Reference 1) is among those reporting poor results when soldering to gold plated copper circuit boards. Results of pull tests on bare copper and gold plated boards are shown in Table I.

Table I
Pull Test Results for Unplated and Gold Plated Printed Circuit Boards

	Separation Force (Pounds)		
	Maximum	Minimum	Average
Bare Copper	5.9	3.2	4.2
Gold Plated Copper	3.0	0.5	1.8

During the tests, the solder consistently lifted off the gold plated surfaces, whereas on the bare copper pads the wire pulled through the solder, the latter remaining with the copper.

These tests were conducted by the Army Ballistic Missile Agency (ABMA) for the NASA Quality Division at Huntsville and probably formed the basis for the requirement stated in MSFC-PROC-158B (Reference 2) that gold plating shall be removed from areas requiring soldered connections unless the solderability of the gold is such that the minimum pull required to separate the wires from the circuit shall not be less than four (4) pounds, when determined as indicated in the document.

At the time this present work was begun, the standard procedure at GSFC was to erase the gold from areas to be soldered, as called for in the aforementioned MSFC document and its offshoot, NASA Quality Publication NPC 200-4. However, no work had been done to determine whether or not the gold plating process being used was able to meet the minimum pull strength requirement. It was decided, therefore, to evaluate this particular process, which uses an acid type bath that deposits a gold-cobalt alloy having a purity of 99.9 percent gold.

This evaluation was deemed necessary since the procedure of erasing the gold from areas to be soldered is both time consuming and wasteful of a valuable material. In addition, there is a possibility that the copper substrate may be damaged in the process. A method of selective electroplating has been developed (Reference 3) whereby only the conductive paths between terminals are gold plated while the pads themselves are plated with another metal. The disadvantages of this method are its additional processing steps as well as the problem of selecting a more suitable plating than gold.

Procedure

Test boards, as shown in Figure I, with both unplated copper and gold-plated copper pads were prepared in accordance with MSFC-PROC-158B, using rosin-cored 60:40 tin-lead solder to attach the wires. The connections were pull tested in a direction perpendicular to the plane of the board at a rate of 0.5 inches per minute.

Based on a report by Braun (Reference 4) of an improved solder containing indium for making connections to gold wires or gold plated components, gold-plated test boards were also prepared using this solder to connect the wires to the plating, both with and without the use of rosin-alcohol flux.

The composition of the solder is as follows:

	Weight Percent
Lead	29.0
Tin	53.0
Indium	17.5
Zinc	0.5

In anticipation of results that would confirm the unsuitability of gold for soldered connections, which would necessitate a substitute plating for the circuit or at least the terminal pads, several other electrodeposited platings with reputations for good solderability were also investigated. A listing of these with the flux and solder used appears in Table II.

Table II
Electrodeposited Coatings
Investigated for Solderability

Top Layer	Intermediate Layer	Solder	Flux
Gold	-	60:40*	Rosin-Alcohol
"	-	Indium**	None
"	-	"	Rosin-Alcohol
White Gold	-	60:40	" "
Tin-Nickel	-	"	" "
Gold	Tin-Nickel	"	" "
"	" "	Indium	None
"	" "	"	Rosin-Alcohol
Solder Plate*	-	60:40	" "
Immersion Tin	-	"	" "

* 60 percent tin, 40 percent lead.
** 29.0 percent lead, 53.0 percent tin, 17.5 percent indium, 0.5 percent zinc.

Initially no attempt was made to control the thickness of the gold plating. However, since the work of Foster (Reference 5) indicates that the strength of a soldered joint on gold plating depends on the amount of gold dissolved in the solder, further pull tests were made on various thicknesses of gold plating. The plating thickness was measured by the beta-ray back scatter technique and varied from approximately 50 to over 200 microinches. An attempt was made to cover the same thickness range with the white gold plating but the bath was new and operating conditions were not clearly established. As a result, the plating on one board varied from zero to 13 microinches, as determined by sectioning, while the other two had approximately 20 microinches of plating over the copper. The gold flash

Aside from the gold plating, the material that showed the greatest promise as a coating for printed wiring boards, as far as solderability is concerned, was the white gold, which is a gold-nickel alloy containing 75-85 percent gold. Pull tests on the boards with about 20 microinches of the plating gave an average strength only 0.2 pounds below that of the unplated copper and a somewhat narrower range of strengths. This plating may present a problem, however, if non-magnetic properties are required.

Since one of the properties required of electroplating on printed circuits is protection of the circuit against corrosion, all of the platings tested for solderability were submitted to an accelerated corrosion test designed to check susceptibility to sulfides (Reference 7). All of the platings except the immersion tin exhibited excellent resistance to sulfide corrosion. The immersion tin, which after 5 minutes plating time has a thickness of about 35-40 microinches, apparently was full of pinholes through which the solution attacked the copper. In contrast, a 20 microinches coating of white gold afforded ample protection against this type of corrosion.

Future Work

The gold plating process presently being used appears to meet the requirements of MSFC-PROC-158B, if applied at the proper thickness. Additional tests will be run to confirm this data and pinpoint the thickness giving maximum strength. This should justify elimination of the gold removal step prior to soldering.

The white gold plating process will be investigated further to determine the maximum strength obtainable, as a possible alternative to yellow gold plating where hard-wearing surfaces are required.

Tests will also be made to determine how aging and temperature cycling before and after soldering affects the connections on these platings.

over the tin-nickel plating was estimated to be 10 microinches thick, which is more than sufficient to substantially improve the solderability of the tin-nickel deposit, according to Castillero (Reference 6).

Results

The results of the pull strength tests may be seen in Figure II. The strengths obtained on the bare copper were comparable to those reported by the ABMA except that the minimum values obtained were about one pound less. Gold plated boards exhibited considerable variation in joint strength with plating thickness, the maximum strength occurring at about 115 microinches. Most important is the fact that the minimum joint strength at this thickness was four pounds and the solder did not peel off the board. The wetting action of the solder appeared to be equally as good on the gold plating as on the copper, as shown in Figure III.

The expected improvement in the solderability of gold with the use of the indium-bearing solder did not materialize. The wetting characteristics of this solder were very poor, both with and without rosin-alcohol flux, as evidenced in Figure IV. When no flux was used, the solder pulled off the board with the wire in all cases. Use of the flux improved the adhesion of the solder to the gold somewhat, but some of the joints failed prior to actual testing, as a result of handling.

The only other platings, the use of which resulted in average joint strengths higher than that of the bare copper, were tin-nickel and immersion tin. In the case of the tin-nickel, the wettability was only fair as seen in Figure V, and the minimum joint strength was less than four pounds. The contact angle of the solder on the board exceeded 60 degrees. As a result of this "balling-up," there was a considerable amount of solder above the wire and the joint strengths were undoubtedly a combination of shear strength of the solder and bond strength of the solder to the wire. The wide variation in joint strength was probably due to varying amounts of solder above the wire.

The flash of gold on the tin-nickel plating improved the wetting action of the solder considerably, greatly reducing the variation in strength. However, the average strength was less than that on the bare copper.

The solder wet the immersion tin plating well and gave the highest joint strengths of any of the platings tested. There is some evidence, however, that the plating bath attacks the bond of the copper to the board, which is the probable cause of the wide range of pull strengths obtained. In the case of the board immersed for 3 minutes in the plating bath, 20 percent of the joints failed as a result of the copper cladding being pulled off the board, whereas 85 percent of the joints failed in this manner on the board which had been immersed for 5 minutes.

PROGRESS REPORT R&D QUARTERLY

Period January 1 to March 31, 1966

REFERENCES

1. Keller, J. D., "Printed Wiring Surface Preparation Methods—Elimination of Gold Plating as a Surface Preparation for Printed Circuits and Development of a Contamination—Free Surface," in: Papers on Soldering (1962), ASTM Special Technical Publication No. 319, American Society for Testing and Materials, Jan. 1963, pp. 3-12.

2. "Soldering of Electrical Connections (High Reliability), Procedure for," George C. Marshall Space Flight Center (MSFC) Procedure MSFC-PROC-158B, Feb. 15, 1963, pp. 28-31.

3. Whitfield, C. E., Sr., and Herzig, H., "Selective Electroplating of Etched Circuits," NASA Technical Memorandum X-1168, Nov. 1965.

4. Braun, J. D., "An Improved Soft Solder for Use With Gold Wire," Transactions of the American Society for Metals, Vol. 57, 1964, pp. 568-571.

5. Foster, F. G., "Embrittlement of Solder by Gold from Plated Surfaces," in: Papers on Soldering (1962), ASTM Special Technical Publication No. 319, American Society for Testing and Materials, Jan. 1963, pp. 13-19.

6. Castillero, A. W., "Gold Plating to Improve Solderability on Tin-Nickel," Metal Finishing, Feb. 1964, p. 61.

7. Rubin, J. C., "Review of the Problem of the Formation of Insulating Films on Gold Plated Contact Surfaces," Parts and Components Evaluation Report (PACER) 201-001, Goddard Space Flight Center, March 30, 1965.

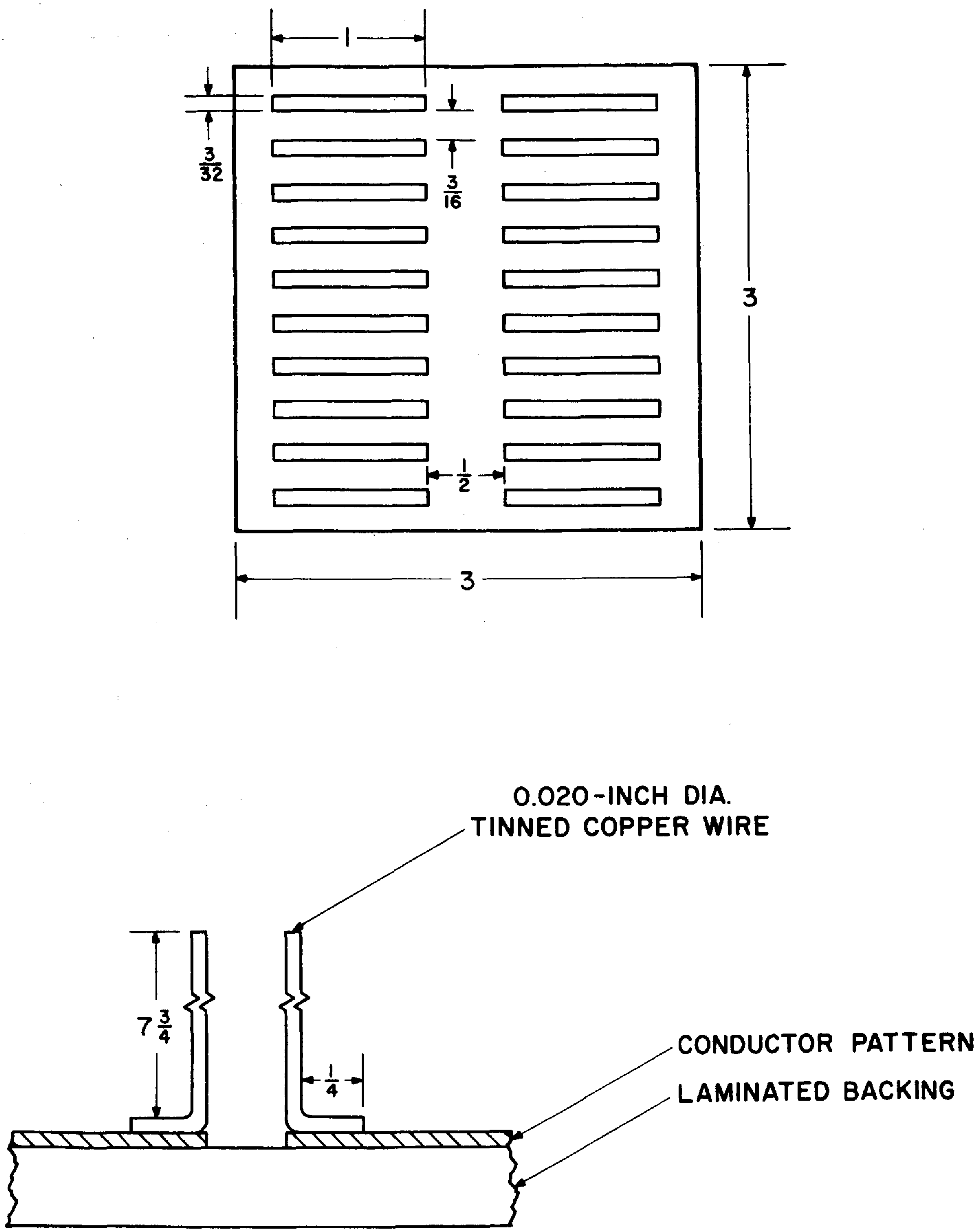

FIGURE I - PULL TEST SAMPLE BOARD

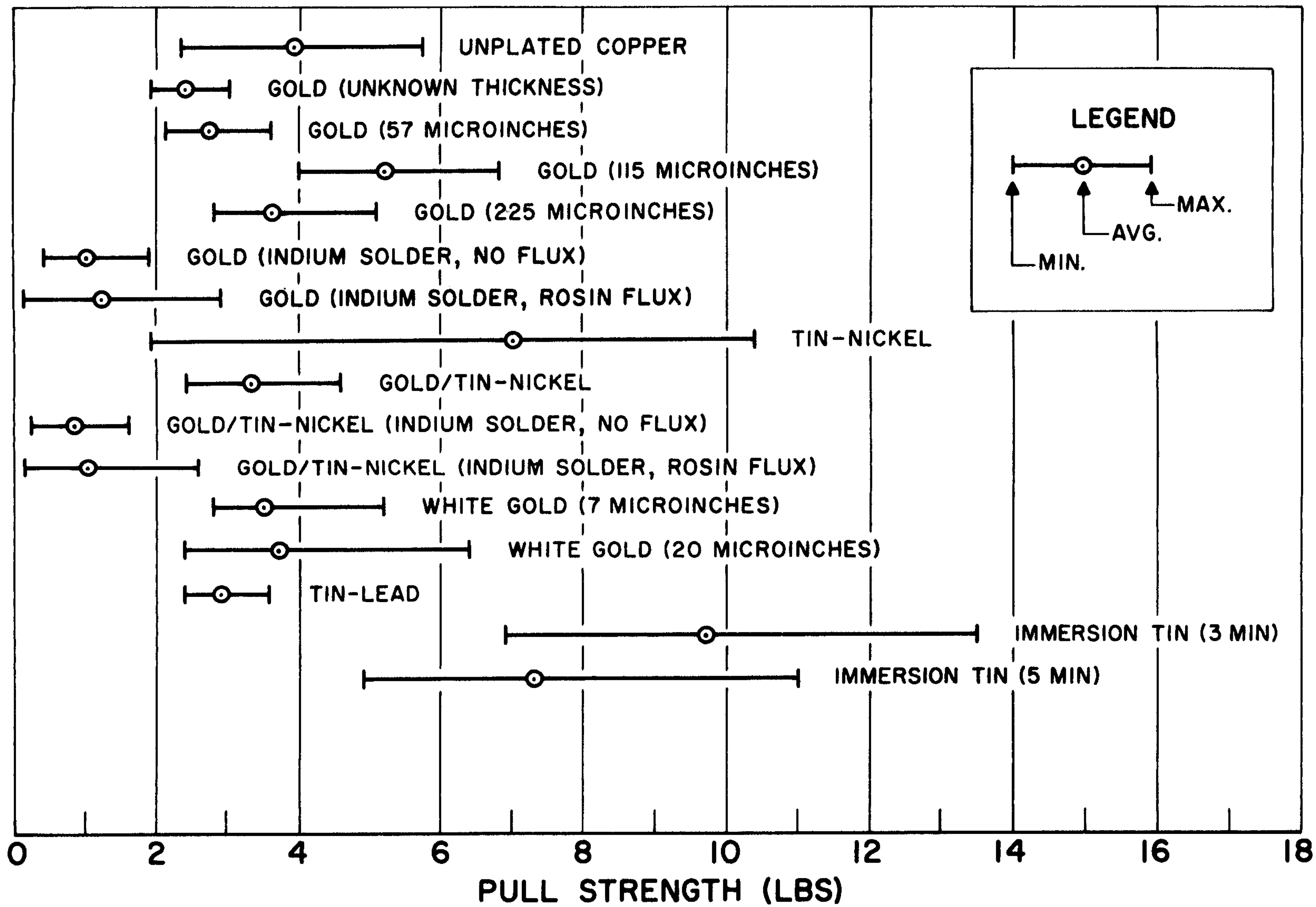

FIGURE II - PULL STRENGTH OF SOLDERED JOINTS ON ELECTRODEPOSITED METALS

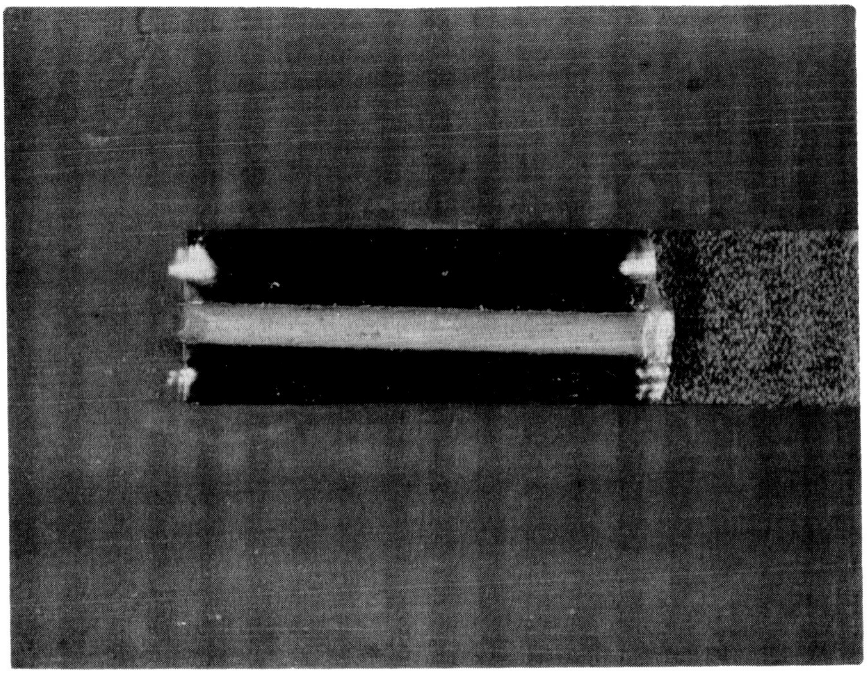

Figure IIIa — Solder joint on unplated copper after pull test (10X).

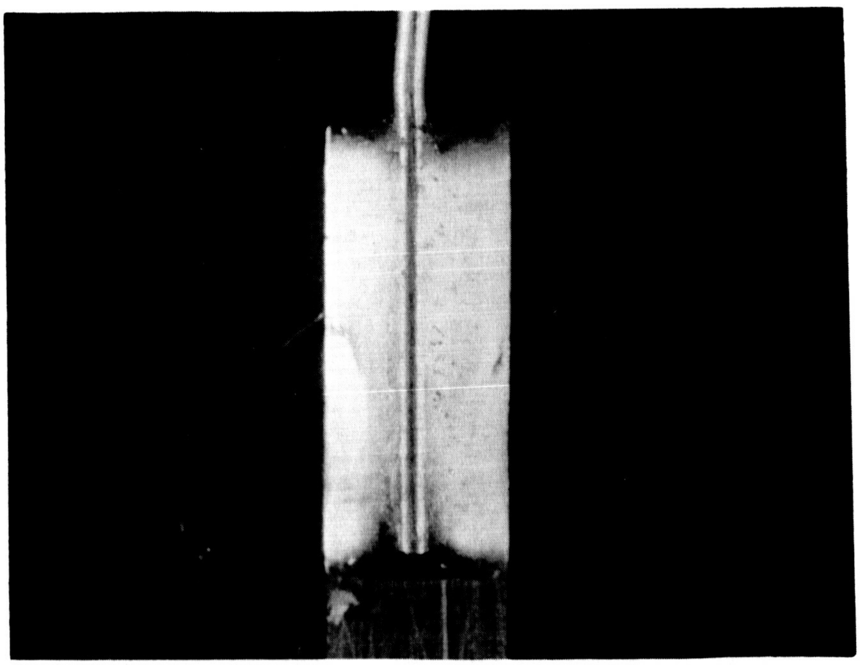

Figure IIIb — Solder joint on gold plated board (10X).

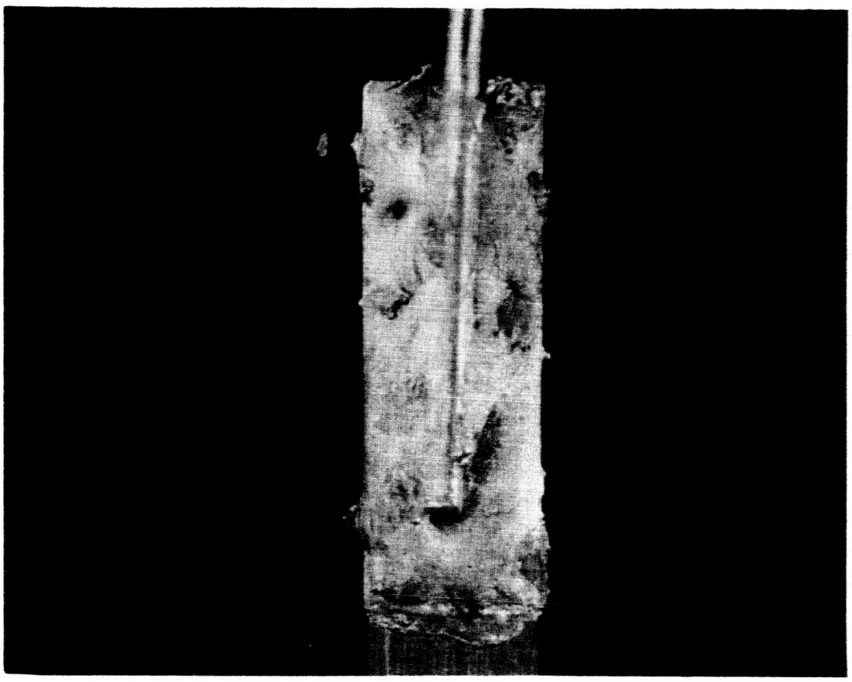

Figure IV — Solder joint on gold plated board using 17.5 percent indium solder (10X).

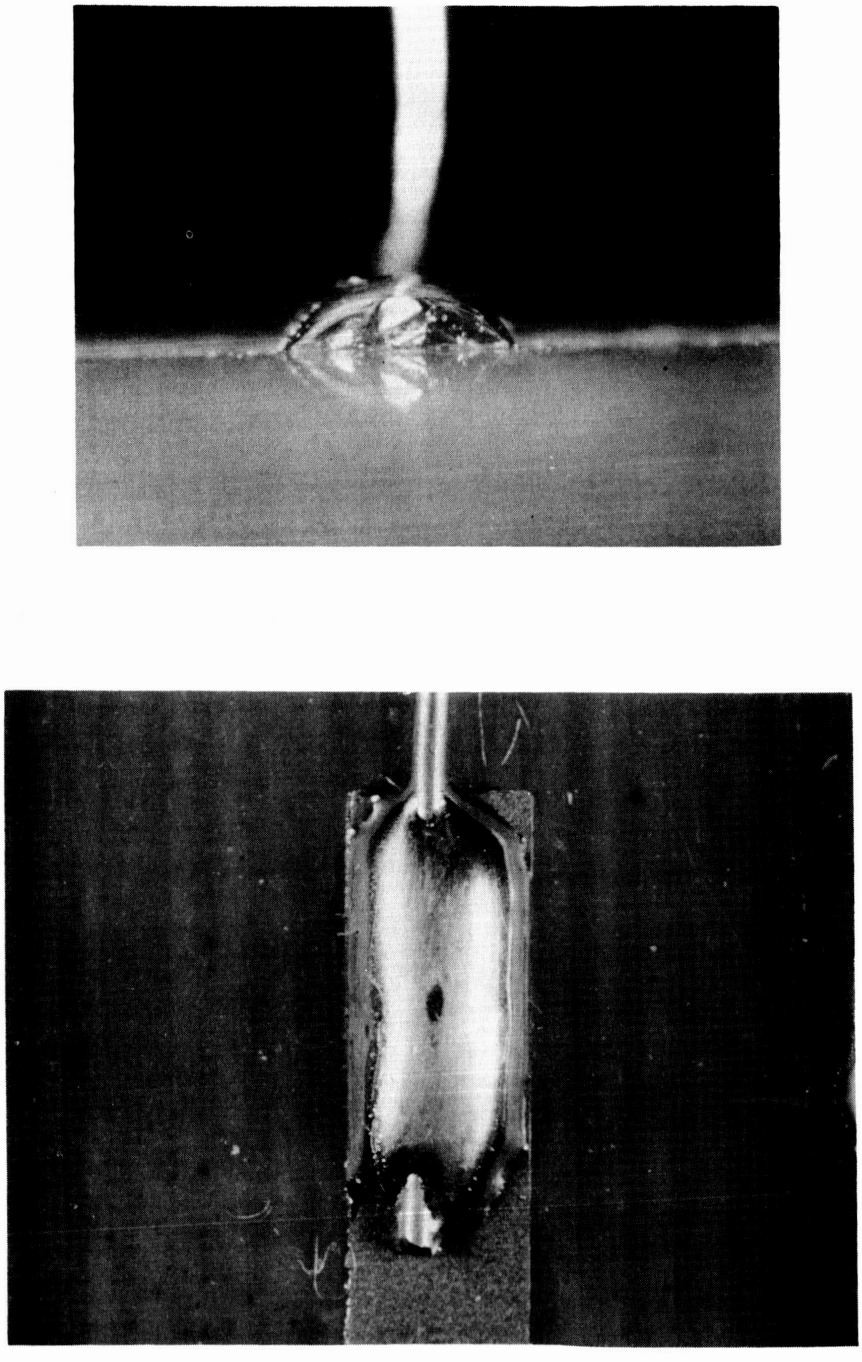

Figure V — Solder joint on tin-nickel plated board (10X).