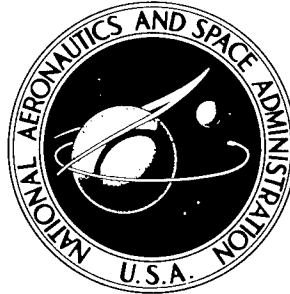


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WELDED ELECTRONIC MODULE FABRICATION

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SUMMARY

A pilot facility for the fabrication of welded electronic modules has been developed at the Goddard Space Flight Center for the purposes of: (1) providing a quick-reaction group in the research and development phases of module fabrication, and (2) determining in detail the requirements in terms of facilities and trained personnel to insure the production of high quality welded modules. The experience gained in the successful application of the welding technique to modules in Ariel I (the International Ionosphere Satellite, 1962 01) and Explorer XVIII (the Interplanetary Monitoring Platform, 1963 46A) has provided a firm base for the utilization of this concept in future spacecraft programs.

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INTRODUCTION

This report presents a general discussion of the activities of the Goddard Space Flight Center in the area of welded electronic module fabrication during the past 2 years. The experience acquired during progress of the work on the International Ionosphere Satellite, Ariel I (1962 01) and the Interplanetary Monitoring Platform, Explorer XVIII (1963 46A) forms the basis of the report.

The welding technique offers great advantages over other methods of module fabrication. Since interconnection wire can be welded to component leads immediately adjacent to the component body, greater packing densities are achieved. Since the strength of the weld joint closely approaches the yield strength of the wire itself, mechanical integrity of the module is enhanced. Welded interconnections are not limited to connections on one or two surfaces. Therefore, layout design is simplified and packing density increased by the addition of layers of interconnections as required. The successful operation of the encoders in Ariel I has effectively demonstrated the value of the welding technique in module fabrication. These encoders comprised approximately 2000 components and were about 90 percent welded. A study of the effects of random and single frequency sinusoidal vibration on a test unit encoder for the Explorer XVIII program has been completed. This unit, shown in Figure 1, contains approximately 1300 components and 8000 welded interconnections. It was found to be unaffected, electrically and mechanically, after

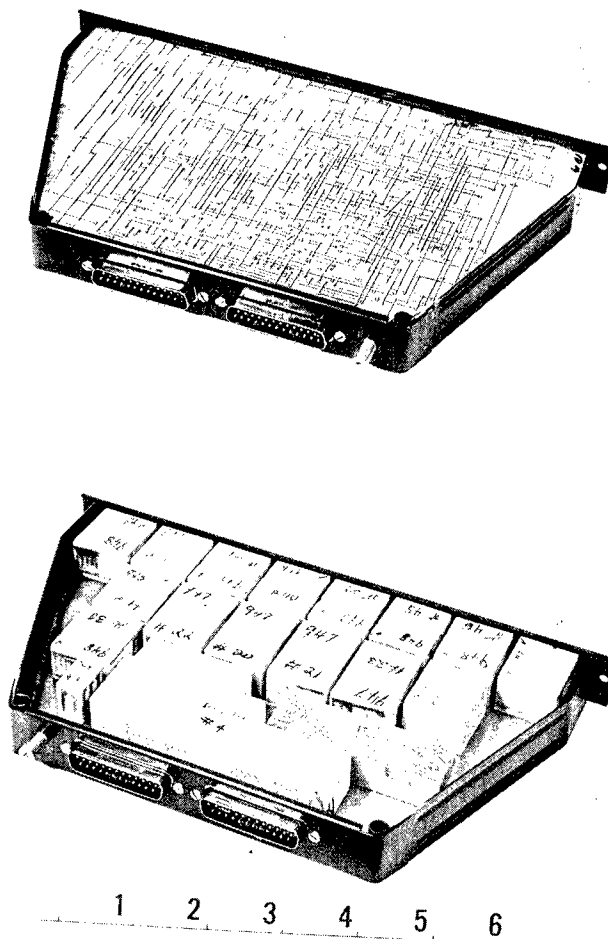


Figure 1—Typical welded electronic package.

satellites, a nonmagnetic weldable metal, such as Alloy 180, should be used for component leads and interconnecting wires in these applications. Standard stable-base photographic film is adequate for the matrix film.

The shop equipment necessary for a welded module fabrication facility consists of welding machines, microscopes, punch presses, a pull tester, and assorted hand tools. This equipment is shown in Figure 3. The welding machines comprise two major components, a weld head and a power supply. The weld head is a two-electrode device which passes current through the workpiece to make the weld. The power supply is basically a dc supply employing a large capacitor at its output which is discharged through the primary of a step-down transformer. The secondary of the transformer is a low voltage, high current winding connected to the two electrodes. The microscopes are of the adjustable focus, variable power, binocular type and are used in observing the welding process and inspecting the welds for quality control purposes. The pneumatically operated pull tester is also an essential quality control tool. A close correlation has been established between external appearance of the welds and the pull-test results.

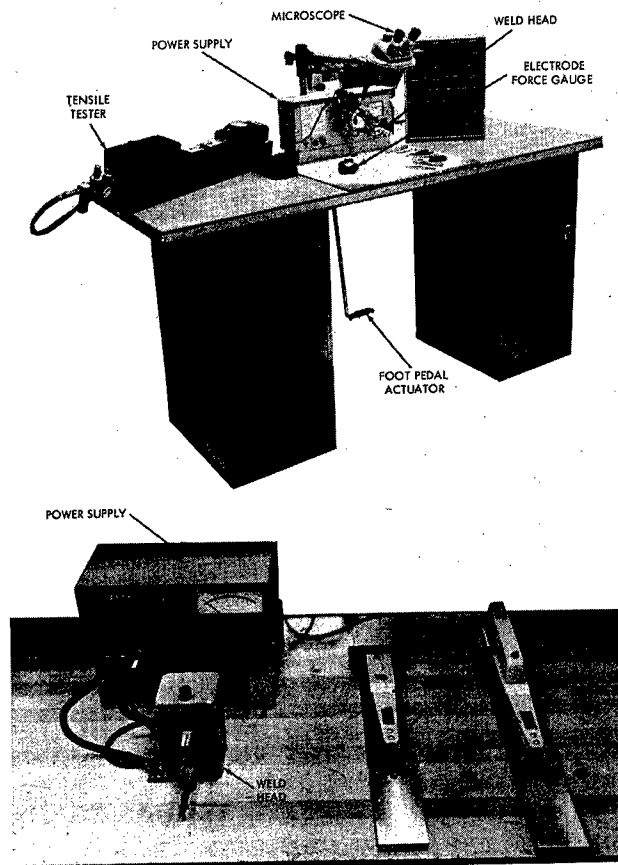


Figure 3—Shop equipment.

ENVIRONMENTAL CONDITIONS

It has been effectively shown that welded electronic modules can be successfully fabricated under ordinary laboratory conditions. Therefore, although the industrial practice of providing special workrooms and regulations for welding operations should be encouraged, it is not mandatory to maintain "white room" conditions.

WELD SCHEDULES

Weld schedules specify the equipment to be used, the material and configuration of the electrodes, the electrode pressure to be applied, and the weld energy in watt-seconds for each combination of materials to be welded. A typical schedule is shown in Figure 4. It might be expected that strict adherence to the schedule would enable the welder to produce consistently acceptable welds. It has been found, however, that because of minor daily variations in the performance of

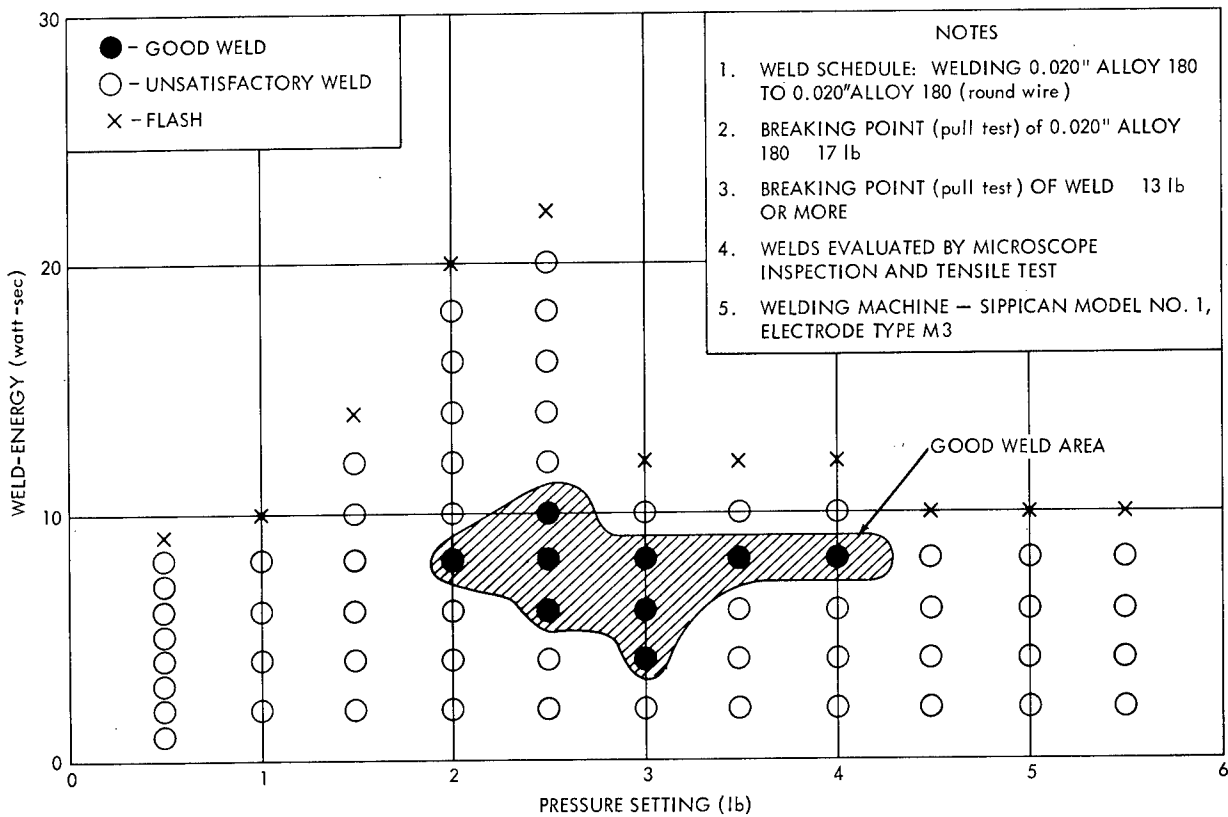


Figure 4—Typical weld schedule.

machines, coupled with the effect of the basic differences between operators, a standard weld schedule does not insure consistently acceptable welds. Therefore, the pressure and energy settings specified in weld schedules should be considered as rough estimates, defining the range in which acceptable welds can be produced. Figure 5 shows this range.

Visual inspection is the most valuable quality control tool. Metallographic analyses and pull tests may be used to determine the quality of welds in establishing the basic schedule. An analysis requires the examination of photomicrographs of the cross-section of welds, by a metallographer, to determine whether the crystalline structure of the joint is satisfactory. Since neither the external appearance nor the pull strength of a weld can be closely correlated with the

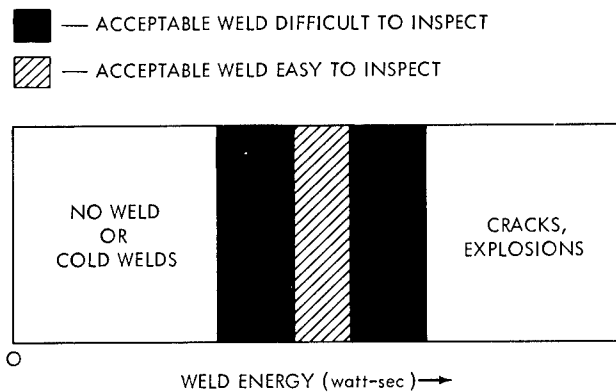


Figure 5—Range of acceptable welds.

results of metallographic analysis, and since welds cannot be sectioned during flight package fabrication, metallographic analysis, although of academic interest, is of little practical value in the workshop. The results of pull tests, flexure tests, etc. may be very closely correlated with external appearance of the welds. For example, the color, deformation, and bead configuration (where applicable) have been found to have a definite relationship to the strength of the weld. Visual criteria have been successfully employed in training personnel to produce acceptable welds.

ASSEMBLY AND INSPECTION

The assembly operation proceeds from the photographic reduction of circuit layouts to the installation of the final layers of the module. The major stages of assembly are illustrated on the following pages: Typical matrix films are shown in Figures 6 and 7. Matrix wires are welded into place (Figure 8); note the parallel arrangement of the wires on each side of the film. Figure 9 shows an operator welding a component lead to the matrix. Transistors are installed in the matrix (Figure 10). Submodules similar to the one depicted in Figure 11 are fabricated and assembled to the matrix (Figure 12). When the bottom layers (Figure 13) are welded into place the module is ready for potting. Figure 14 shows a completely assembled module.

Operators and inspectors should examine welds microscopically, using established visual criteria to determine the quality of welds. One important criterion for inspection is consistency. It is important that all welds in any given package be consistent in appearance.

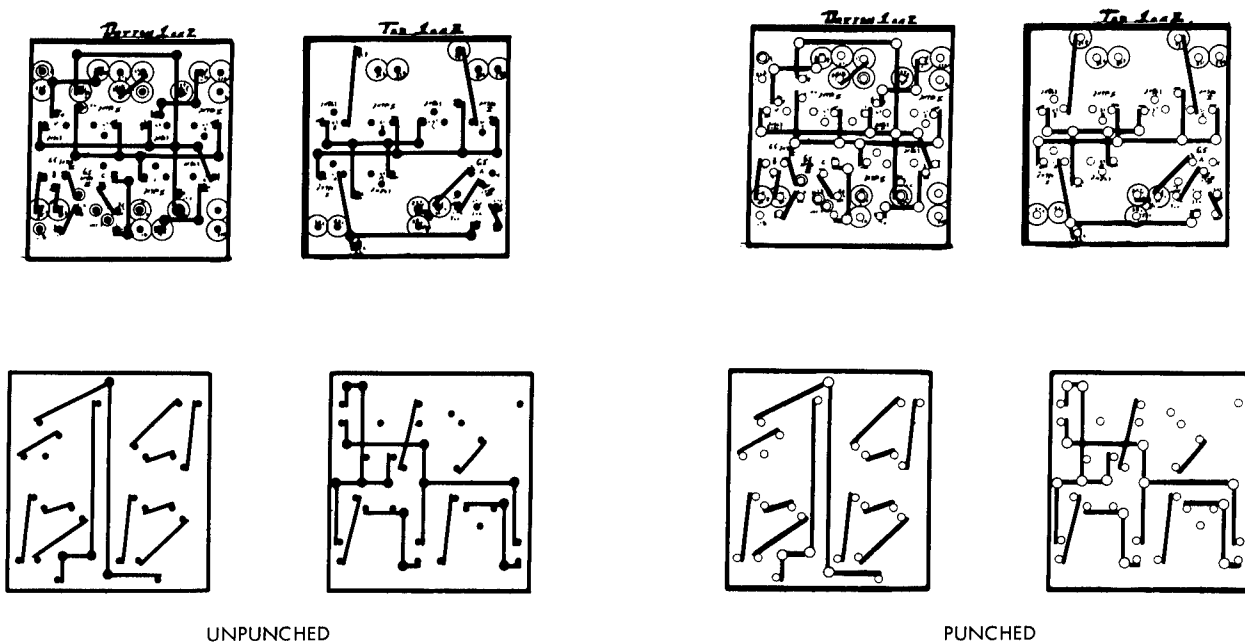


Figure 6—Matrix films for a module.

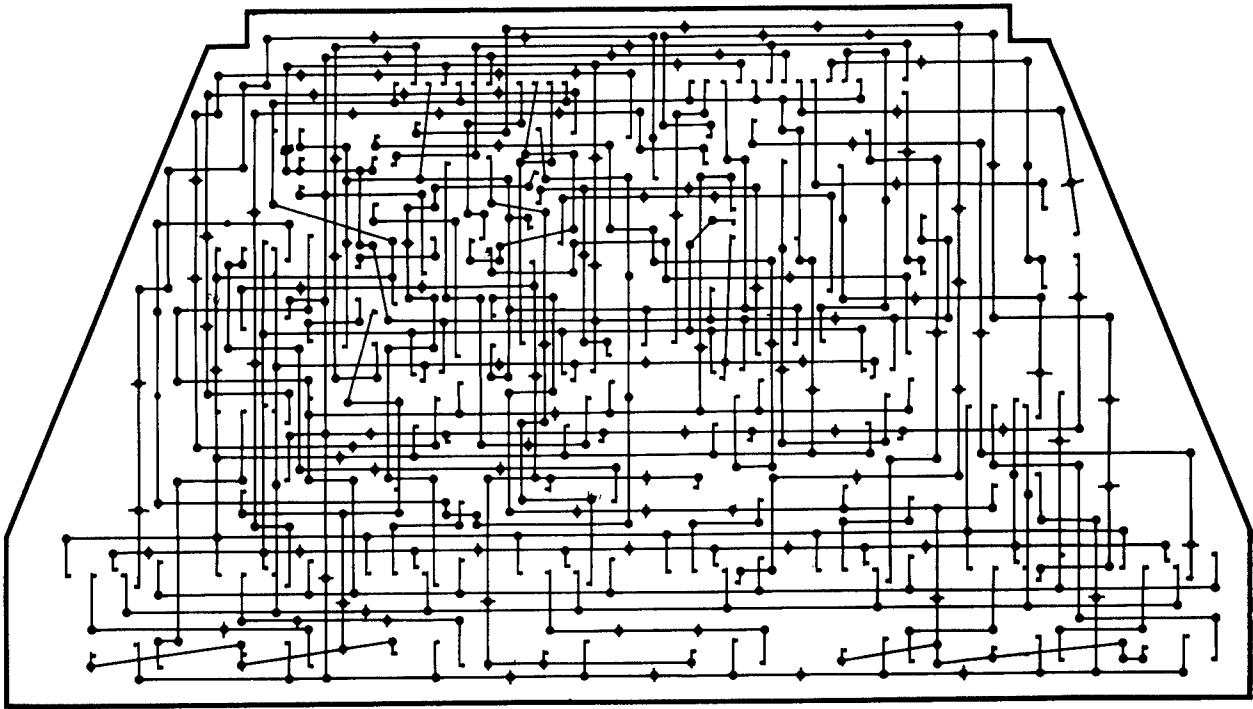


Figure 7—Unpunched matrix film of a package interconnection layer.

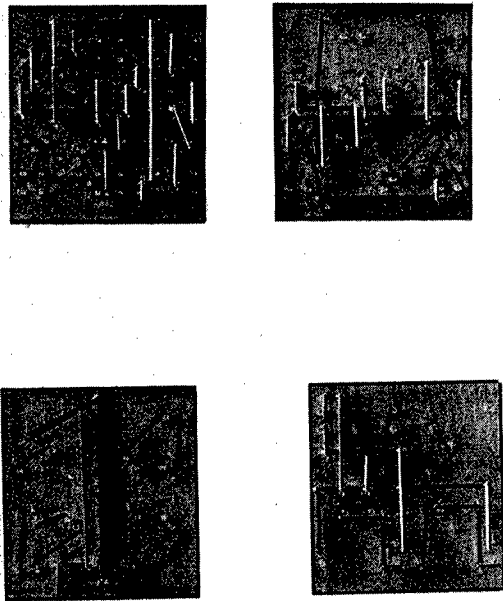


Figure 8—A welded matrix.

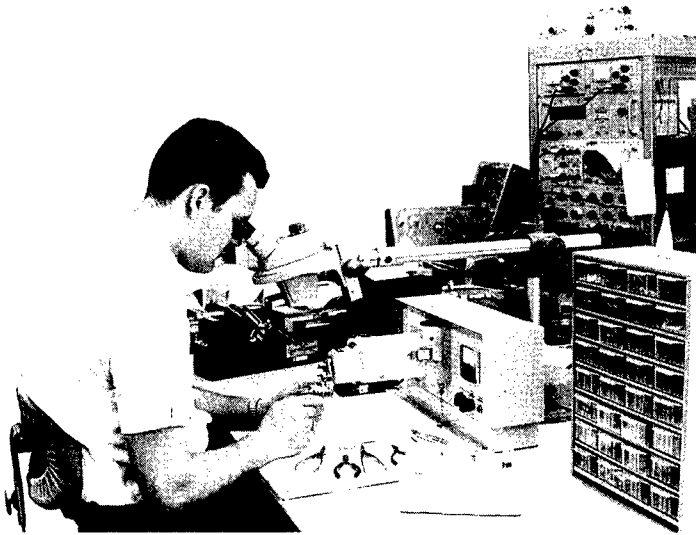


Figure 9—The welding operation.

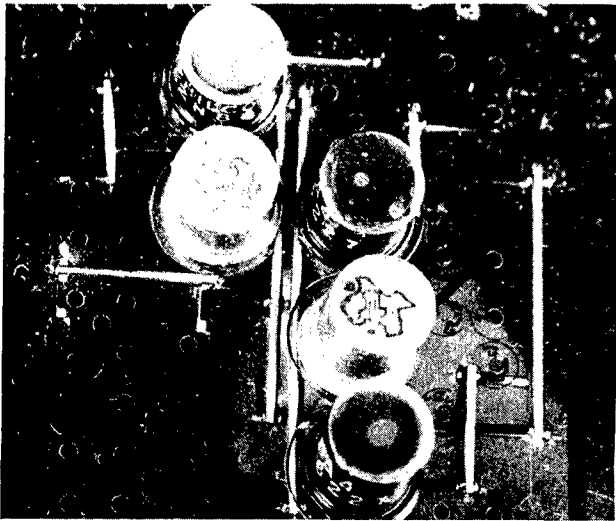


Figure 10—Matrix, transistors installed.

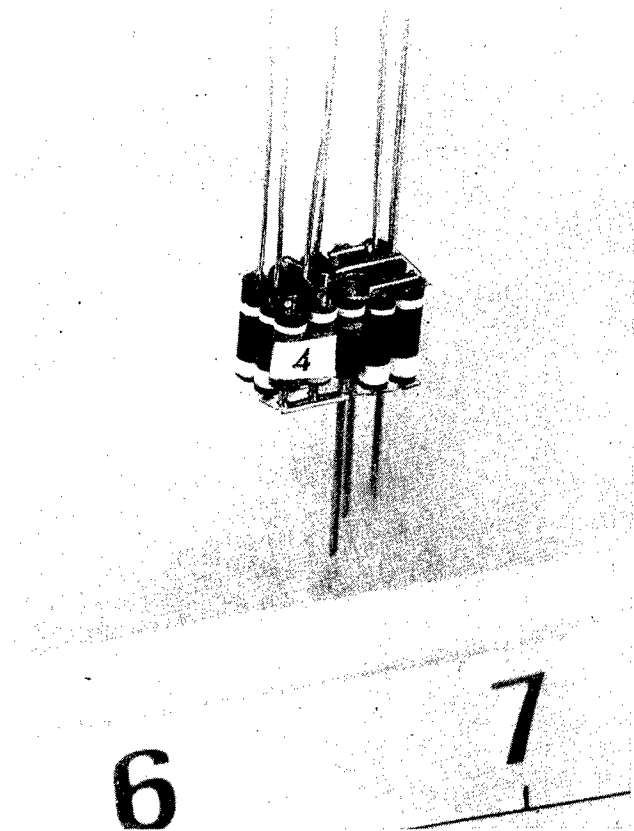


Figure 11—A typical submodule.

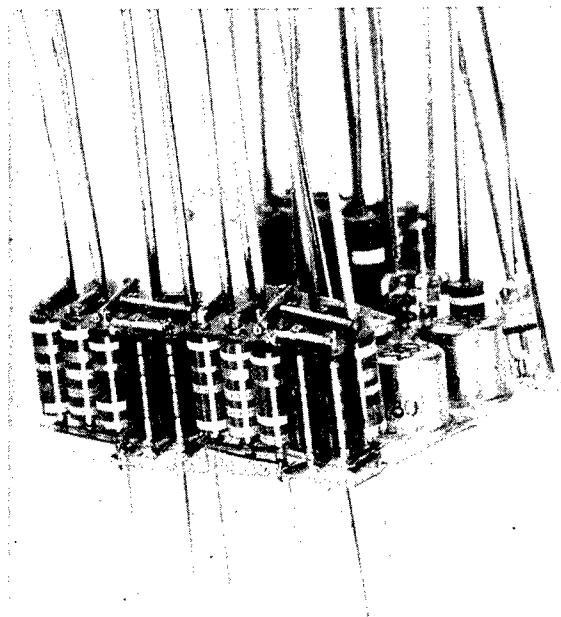


Figure 12—Submodule-transistor assembly.

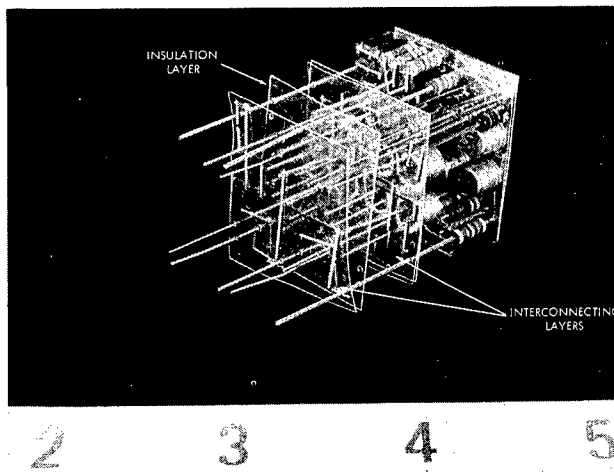


Figure 13—Bottom layers.

REPAIR

Prior to potting, welded modules are completely repairable. Any component that fails can be replaced in a manner that maintains the quality of the unit and assures its acceptability for flight. In most cases potted units can also be repaired. Faulty potted units must be judged on an individual basis in determining the feasibility of accomplishing necessary repairs. The quality of all reworked potted units should be thoroughly evaluated to insure that the repair processes have in no way impaired the reliability of the unit.

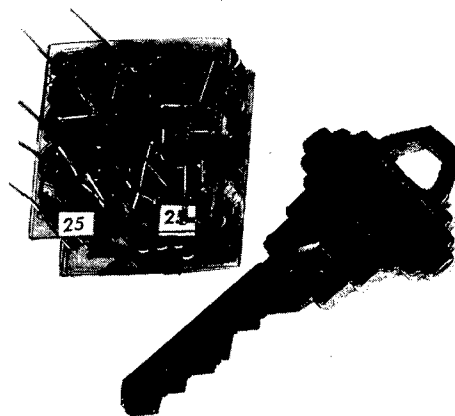


Figure 14—Welded electronic module (ready for potting).

CONCLUDING REMARKS

The research and development phases of the welded electronic module fabrication program have been concluded in most respects. However, all work in this field will be monitored for developments which appear to advance the state of the art. An up-to-date facility and capability in welded electronic module fabrication will be maintained at the Goddard Space Flight Center.

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