PROCEEDINGS

MICRO-MODULE INDUSTRY CONFERENCE

A Series of Papers Presented at the First Micro-Module Industry Conference, Philadelphia, Pennsylvania, September 12-13, 1962.

Sponsored By

U.S. Army Electronics Materiel Agency

Philadelphia, Pa

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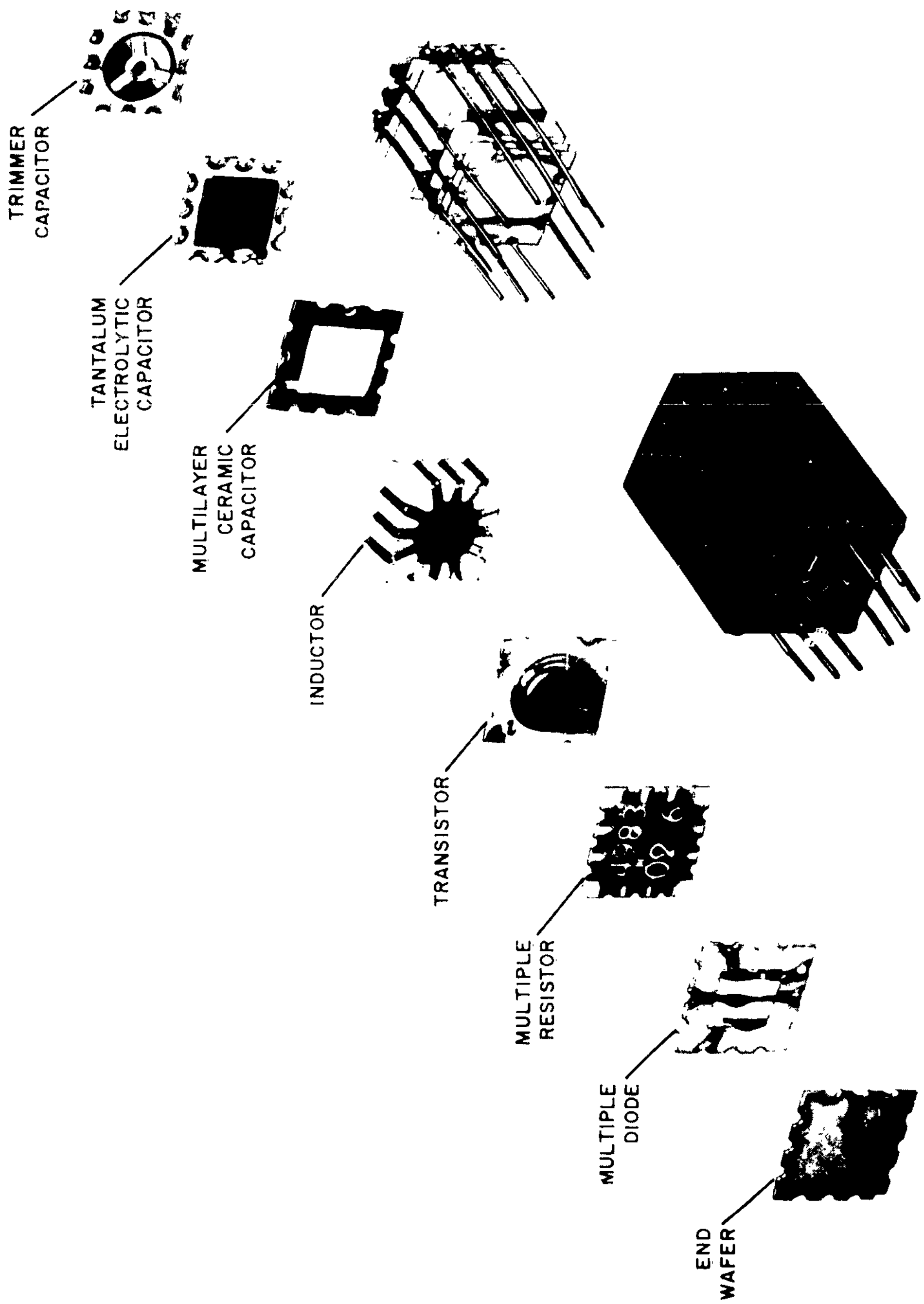
TRIMMER CAPACITOR
TANTALUM ELECTROLYTIC CAPACITOR
MULTILAYER CERAMIC CAPACITOR
INDUCTOR
TRANSISTOR
MULTIPLE RESISTOR
MULTIPLE DIODE
END WAFER

PARTICIPATING ORGANIZATION AND SPEAKERS

UNITED STATES ARMY ELECTRONIC RESEARCH AND DEVELOPMENT AGENCY

Mr. Sherman Bassler - Chief of the Micro-Assemblies Area

Mr. Daniel Elders - Project Engineer, Micromodule Program

Mr. Weldon Lane - Project Leader of the Material Processing Team

UNITED STATES ARMY ELECTRONICS MATERIEL AGENCY

Mr. Arthur B. Gittelman - Project Manager, Micromodule Program

Mr. Leo Kapust - Deputy for Industrial Mobilization

Mr. Theodore Kyne - Chief of Production Development Division

Mr. John Shwop - Assistant Deputy for Industrial Mobilization

Col. D. O. Toft - Deputy Commanding Officer

UNITED STATES ARMY ELECTRONICS MATERIEL SUPPORT AGENCY

Miss Sarah Rosen - Project Engineer

AEROVOX

Mr. J. D. Cronin - Micromodule Capacitor, Project Leader

This vendor is a supplier of precision multilayer ceramic capacitors under the PEM Phase of the Program.

COORS

Mr. Dale L. Kuhlke - Micromodule Project Leader

This firm is participating in the program as a supplier of large production quantities of thin ceramic substrates.

PARTICIPATING ORGANIZATION AND SPEAKERS (Continued)

MALLORY

Mr. O.E. Elmore - Manufacturing Engineer, Microcomponents Department

Mr. J.P. Morone, Jr. - Reliability Supervisor - Microcomponents Department

Mr. S.M. Stuhlbarg - Manager, Microcomponents Department

Mallory is one of the companies selected to provide a facility for the production of micromodules under Task 36-4.

MICROELECTRON

Mr. Randy Ragan - Vice-President, Engineering

This firm has been selected to supply resistors under the PEM Phase of the Program.

MITRONICS

Mr. Sandford Cole, Jr. - Director of Research

Mitronics has been a supplier of thin ceramic substrates for the Program. This firm supplies thin substrates to element manufacturers.

MOLECULAR DIELECTRICS

Mr. Jack Liker - Sales Manager

This firm is participating in the program as a supplier of substrates to all element manufacturers. There is no contract with this firm, other than funds provided for the fabrication of tooling necessary to produce glass-bonded mica substrates.

PAKTRON

Mr. Sidney Levine - Manager, Micromodule Department

Paktron was also selected to provide and demonstrate facilities for micromodule production.

PARTICIPATING ORGANIZATION AND SPEAKERS (Continued)

RADIO CORPORATION OF AMERICA

Mr. R.A. Felmly - Manager, Subcontract Control

Mr. J.E. Jensen - Manager, Quality Control

Mr. Paul Nyul - Manager, Micromodule Process Engineering

Mr. W.L. Oates - Product Development Engineer

Mr. B.V. Vonderschmitt - Manager, Micromodule Development Engineering

RCA is the prime contractor for the Signal Corps in the development of the Micromodule Production Program to provide micro-module design, and construction of electronic circuits.

SPRAGUE

Mr. Richard W. Young - Coordinator of Micromodule Program

Sprague is one of two vendors selected to participate in the PEM by supplying electrolytic tantalum capacitors under Task 28-4.

RUTGERS UNIVERSITY

Professor C.J. Phillips - Professor, School of Ceramics

Rutgers University has no direct contract with the Micromodule Program. Professor Phillips was invited to participate because of his extensive knowledge of ceramics.

I

WELCOME ADDRESS

L. A. KAPUST *USAEMA*

I

WELCOME ADDRESS

LEO A. KAPUST
USAEMA

On behalf of the U. S. Army Electronics Materiel Agency, I would like to extend our welcome to all of the representatives of industry and the various Government agencies to this first Micromodule Industry Conference. The many companies who have participated in the program are represented here, as are a number of firms which have done considerable work entirely with their own funds.

Our guests from the other military services may not be as familiar with the program as our participating companies, so permit me to present a very brief review of our present status.

The micromodule project started in April of 1958 with a contract between the Army Signal Corps and RCA, which now totals in obligations slightly over 18 million dollars. We took "state-of-the-art" materials and components and adapted them into the micromodule shape. We knowingly stayed away from new advances and beyond-the-horizon techniques of any kind. We were after a reliable and economical system that could be used in our equipment in a relatively short time. We completed our engineering feasibility work and then began with the construction of digital and communications equipment to demonstrate the advantages of micromodules in both types of applications. At the same time, we initiated production engineering measures to have our component and module sources establish pilot line facilities. Some component pilot runs have already been completed. The remainder will be finished within a few months.

We have a production capability with high reliability. This high reliability has been proven by the accumulation of a very considerable amount of test data. In addition our cost picture is now approaching what we call a reasonable level. In other words, we feel it is now competitive with other military component systems. The Army has already started using micromodules in several military equipments and plans to extend the applications. Military specifications will soon be issued so that the entire industry can standardize on micromodules. When additional equipment manufacturers start using micromodules, the additional production volume will bring prices down even further. We believe that the ultimate cost of micromodules will be more economical than the present systems of building military equipment. You'll hear much more about our plans during the conference.

The Micromodule Program has had the wholehearted backing of the Army. I'm sure the companies which have already invested in the program will find that their confidence in mocromodules was fully justified.

II

STATEMENT OF PURPOSE OF CONFERENCE

A. B. GITTELMAN *USAEMA*

II

STATEMENT OF PURPOSE OF CONFERENCE

A. B. GITTELMAN
USAEMA

As part of the Production Engineering Measure contracts that we place in our Agency, we obtain complete quarterly and final reports on facilities, processes and results, which are distributed to the interested companies and Government agencies. A few months after we started the production engineering phase of the Micromodule Program, it was obvious that the usual methods of technical communications would be totally inadequate. There was so much going on in so many different locations that it was impossible for us to keep up with it all, except in a very superficial way. In my visits to some of the plants, I saw several cases where a company was trying to debug a process that was already running smoothly at another plant. There were other cases where microelement producers were not fully aware of all of the problems confronting the micromodule assembler. Therefore, this conference was originated to provide for a mutual interchange of technical information so that all participants in the micromodule program may have the opportunity to adapt the solutions developed by others to their own problems.

First, we are not asking manufacturers to disclose any proprietary information, but the Government is entitled to all the information on the work it sponsors, and we intend to make full, adequate utilization of this information. We also felt that the companies participating in the program should be informed about the Army's plans for issuing specifications, standardization, and procedure for qualification approval and so on. In addition, we are also going to give you as much information as we can release about the detailed plans for utilizing micromodules in our electronic equipment.

Our friends from other Government agencies who are here today, and who are interested in microminiature approaches will have an opportunity to obtain first-hand knowledge of our progress and present status. To them I would like to stress that, although you will hear a lot of discussion about our problems, these are production problems. We passed the research, development, and feasibility stages some time ago. Now we are trying to improve our production processes to give us better yields, higher reliability, and lower costs.

In planning this conference, we assumed that those attending it would already be familiar with the micromodule. Therefore, there is nothing in the agenda which covers the basic concept and configuration; but, for those who need a refresher course in what the micromodule is, we felt the exhibits on display in this room (photographs of several exhibits are shown in Figures II-1, 2, 3 and 4) would serve this purpose much more effectively than would a formal presentation. I should explain to those manufacturers who don't see their products on exhibit, that we had to limit the components to one of each type and had to choose those which were readily available when the exhibits were prepared. However, a complete list of all the suppliers on the program is on display for those interested (Figure II-5).

Figure II-1. Exhibits

Figure II-2. Exhibits

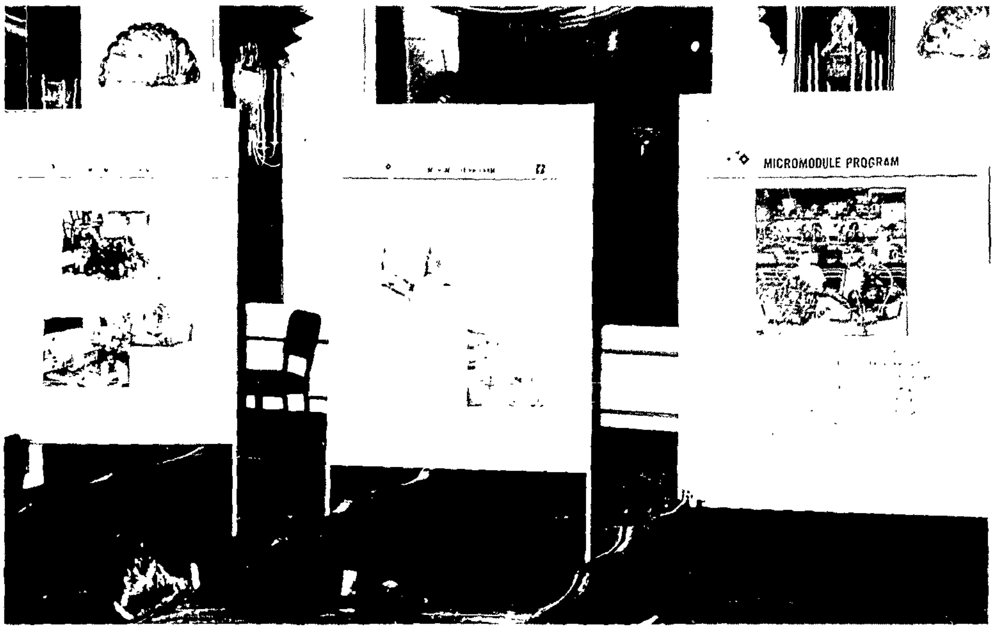

Figure II-3. Exhibits

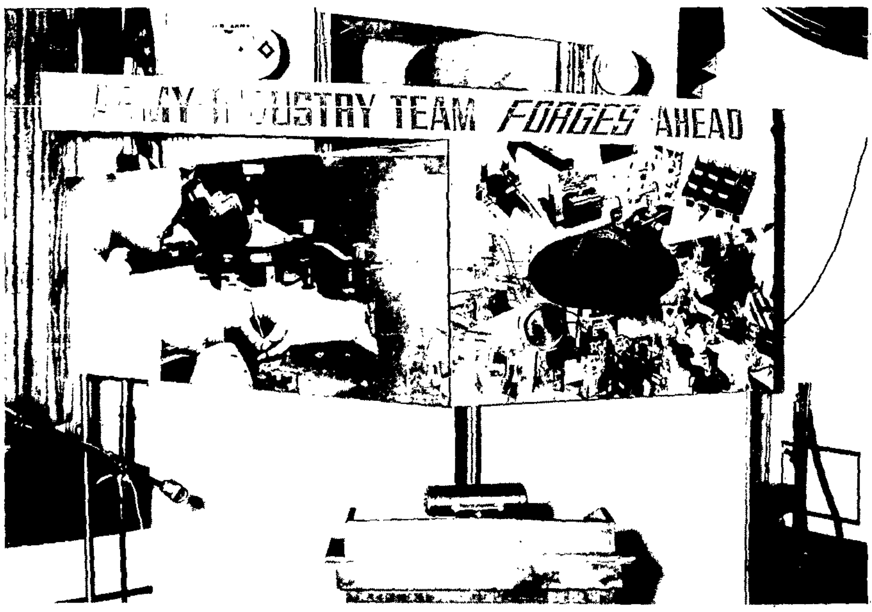

Figure II-4. Exhibits

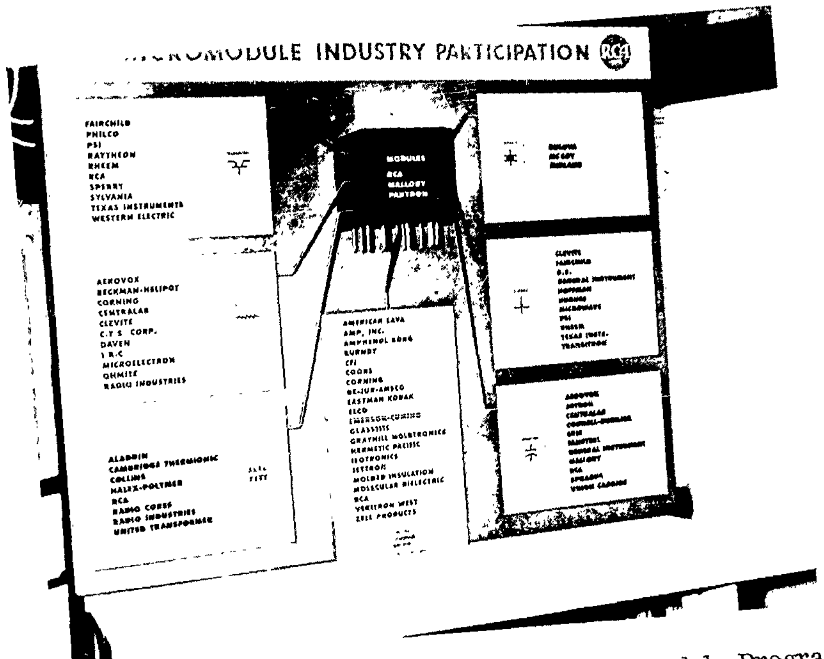

Figure II-5. Industry Participation in the Micromodule Program

III

MECHANIZED ASSEMBLY SYSTEM FOR MICROMODULES

S. M. STUHLBARG	*P. R. MALLORY AND CO.*
S. LEVINE	*PAKTRON DIV., ILLINOIS TOOL WORKS*
P. NYUL	*RCA*

III

MECHANIZED ASSEMBLY SYSTEM FOR MICROMODULES

S. M. STUHLBARG
P. R. MALLORY & CO.

INTRODUCTION

This discussion of the Mallory mechanized assembly system for micromodules is intended as a tutorial presentation. It is hoped that everyone concerned will become acquainted with the general operation and features of this system.

At the present time, most of the equipment which will be discussed has been designed completely. Actual fabrication is in progress. Some equipments have been delivered, while others are expected within the next several months. All equipment will be installed in a completely renovated, fully air conditioned facility at the Mallory plant in Indianapolis. Demonstration of the equipment is expected by the end of 1962 with full production operations underway during the early months of 1963.

EQUIPMENT OPERATION

Figure III-1 shows the various steps, fixtures, and accessories which make up the Mallory mechanized assembly system. These items will be discussed in detail as the system is described.

The photograph of Figure III-2 shows the Mallory microelement magazine. This magazine, which will be discussed in detail later in the program, has the following major features:

1. Microelements are protected fully during shipment and in-plant handling.

2. Microelements may be inspected fully and tested electrically by means of these magazines and associated equipment without operator handling of individual microelements.

3. The magazines facilitate rapid changes from one microelement type to another, or from one micromodule type to another, during production operations.

Test and Orientation Machine

Figure III-3 shows a diagram of the test and orientation machine which has been constructed and will be delivered shortly. On receipt of a loaded magazine from a microelement vendor, it is inserted in position number 1 of the test and orientation machine. It will be required of the vendor that all microelements be oriented in the same direction. As the magazine is stepped upward automatically, the individual microelements are slid along the track, one by one, in the direction of the arrow.

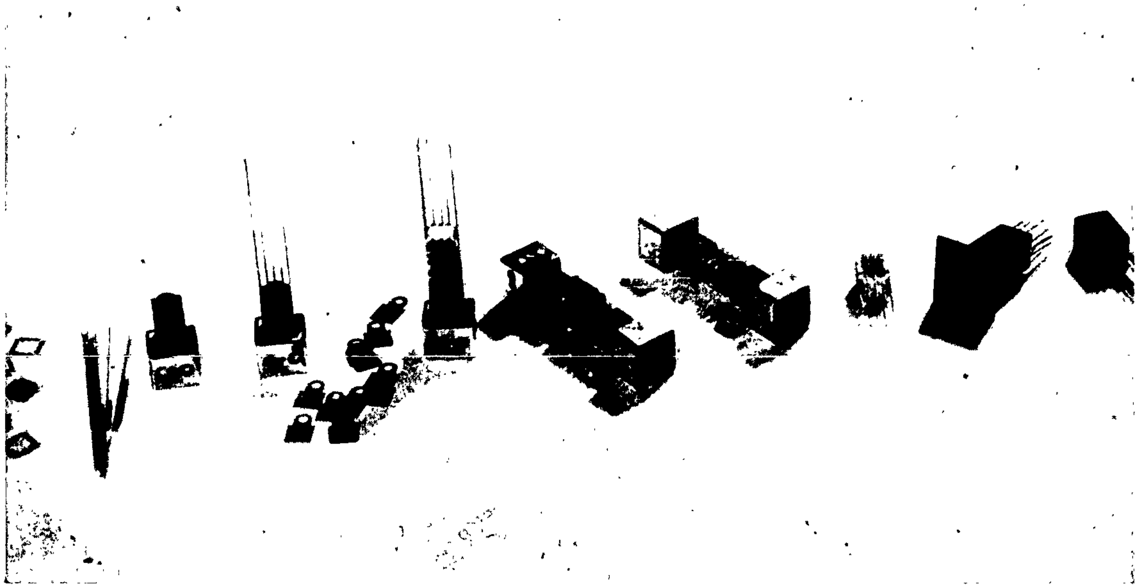

Figure III-1. Module Assembly Steps, Fixtures, and Accessories

Figure III-2. Microelement Magazine

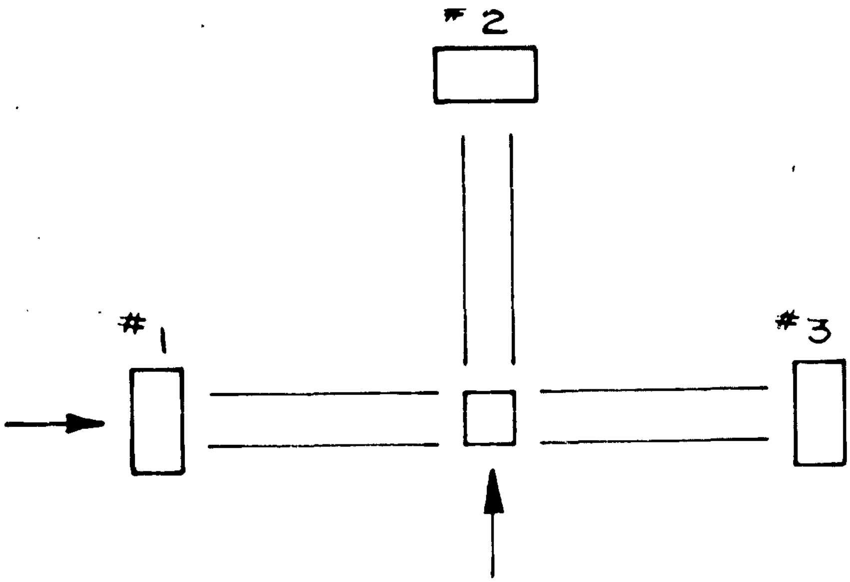

Figure III-3. Top View of Test and Orientation Machine, Block Diagram

Each microelement receives a go-no-go electrical test at the center position shown. Satisfactory microelements are slid into a magazine located in position number 2, while reject microelements are collected in a magazine located at position number 3. The satisfactory microelements will be oriented 90° with respect to their orientation when received. In this manner, the solder notches on two edges may be inspected after the test and orientation operations have been completed.

Figures III-4 and -5 are photographs showing the partially completed test and orientation machine.

Loading Fixture

The photograph of Figure III-6 shows the stacking base which holds the microelements during the assembly operation. Nine of the twelve riser wires form a nest into which the microelements are stacked by the assembly machine.

Figure III-7 illustrates the method by which the wires are assembled to the stacking base. In this machine, a subassembly which includes the stacking base, the nine riser wires, and a finger block is assembled automatically. The finger block is used to facilitate loading of the stacking base assembly on the assembly machine.

Assembly

The photograph of Figure III-8 illustrates the assembly machine which was used to demonstrate the feasibility of the Mallory approach. Visible in this photograph is the

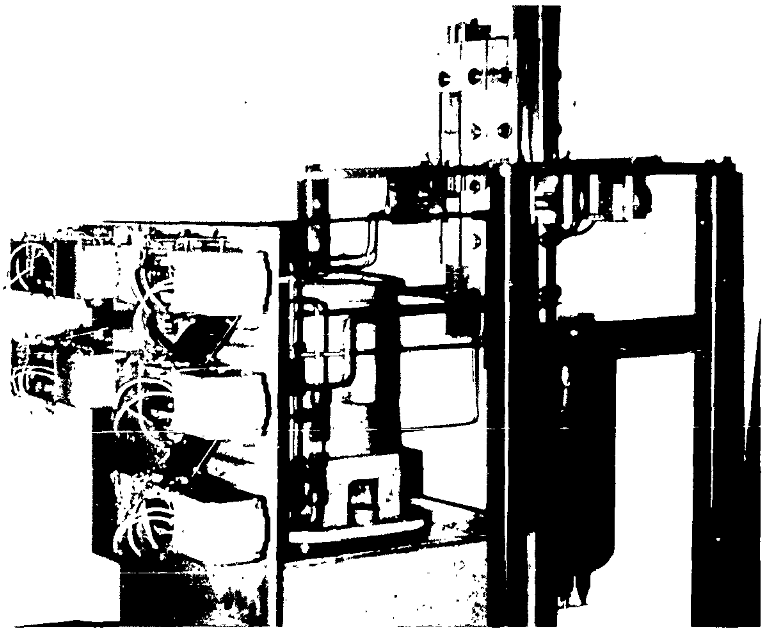

Figure III-4. Test and Orientation Machine, Partially Completed

stacking base assembly mounted in the finger block, the vertically mounted magazine, and the vacuum pickup mechanism. The vacuum pickup mechanism is used to insert the 6-mil stainless steel spacers to assure proper spacing between microelements.

Figure III-9 shows the assembly machine as it will appear from the top. This diagram shows the 36 finger-block stations, 15 magazine stations, and 14 spacer stations. As indicated, the turntable will rotate and index at each magazine or spacer station. A single microelement or spacer will be added to the stacks simultaneously from each microelement or spacer magazine. The machine may be stopped quickly at any time for magazine replacement or to program a new or revised micromodule. A major feature is the speed with which this machine can be programmed to assure full production flexibility. It is visualized that there will be little cost penalty for producing 100 modules of 10 different types as compared to 100 modules of one type. The complete stack assembly with spacers included is shown in Figure III-10. After soldering the wires on three sides, the spacers are removed by means of a small rod through the holes protruding from the micromodule stack. After this operation, the remaining wires are assembled and soldered.

Soldering

The photograph of Figure III-11 illustrates the technique which was utilized during the feasibility study. While this proved satisfactory, an improved method utilizing a solder wave has been developed for the final production machine.

Figure III-12 illustrates the operation of this solder wave.

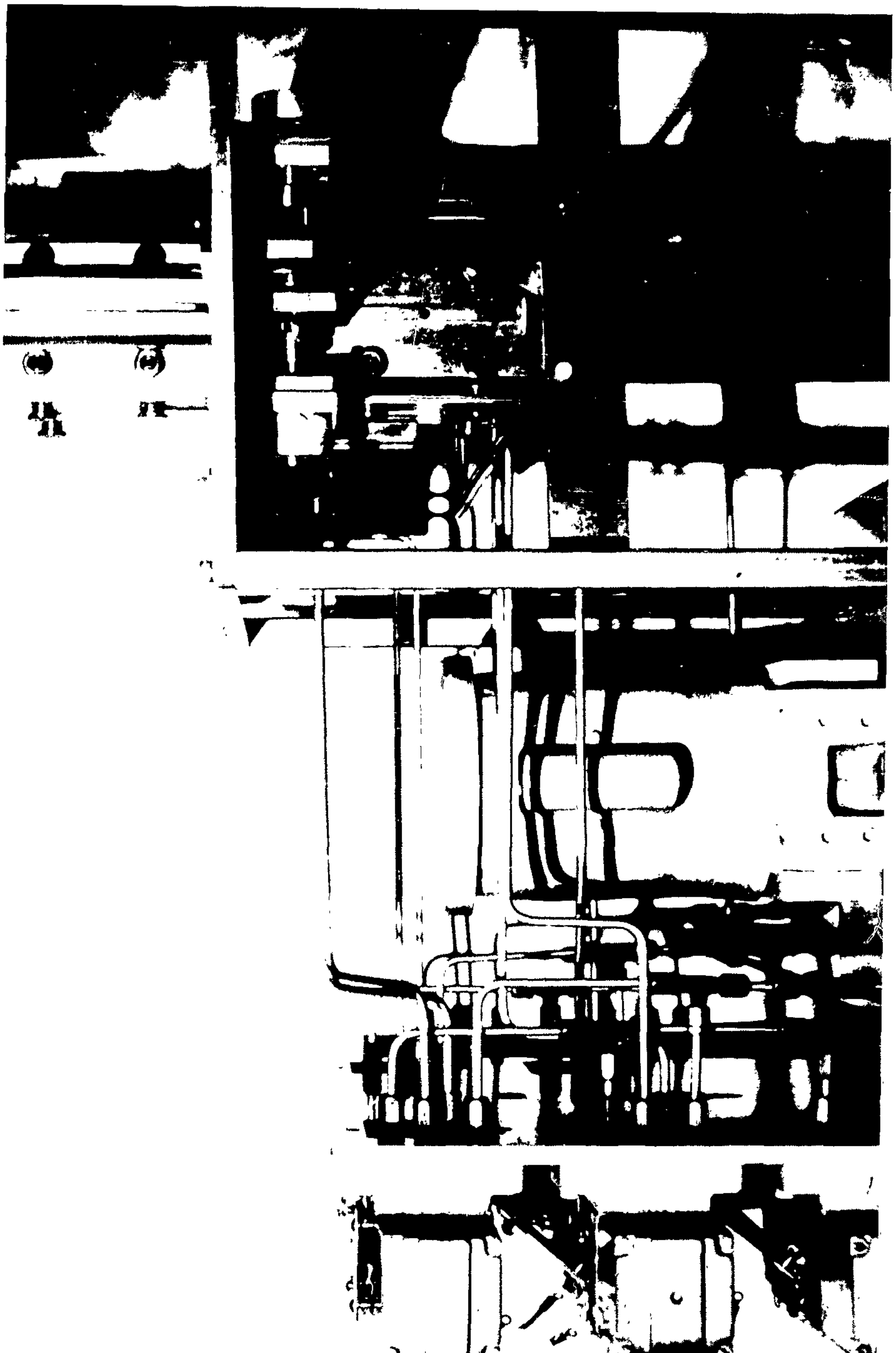

Figure III-5. Test and Orientation Machine, Partially Completed

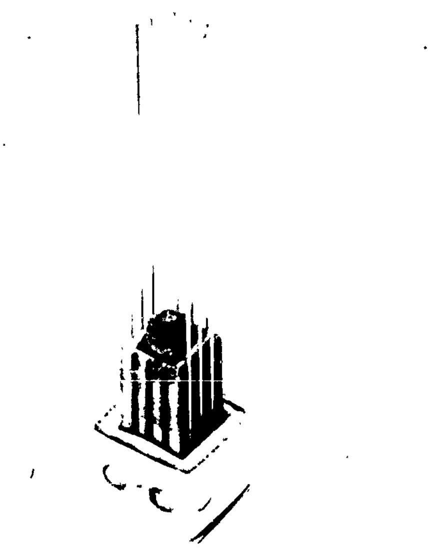

Figure III-6. Microelement Stacking Base

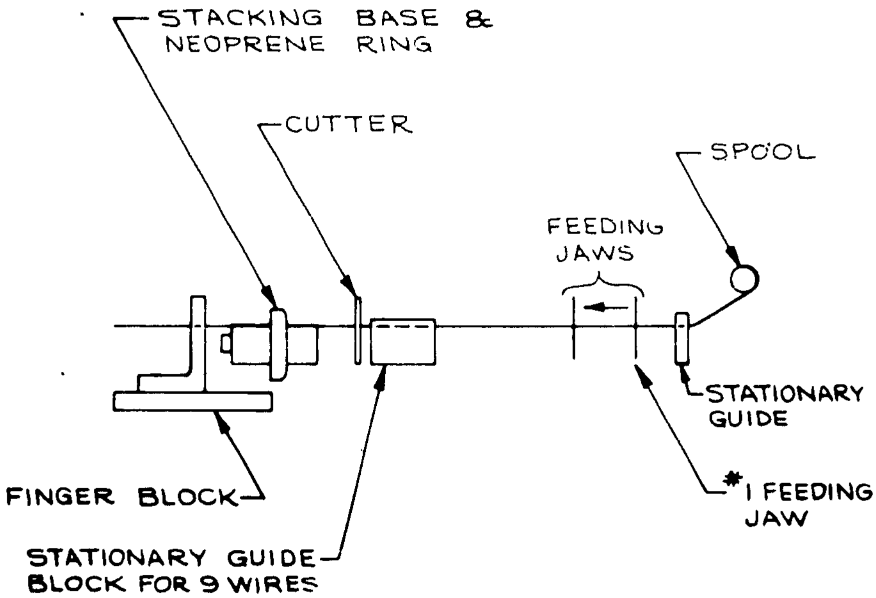

Figure III-7. Wire Straightener and Loading Fixture

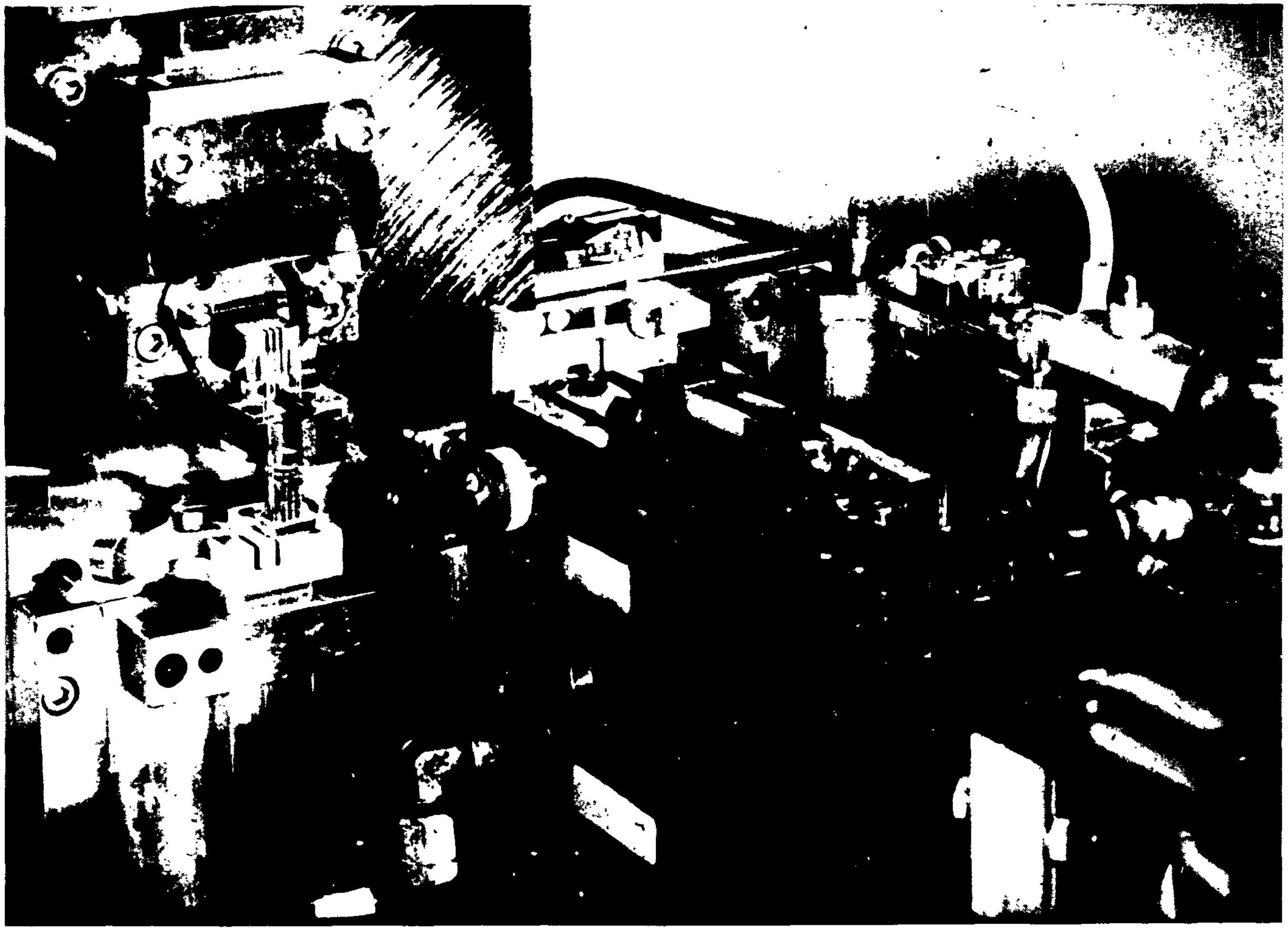

Figure III-8. Module Assembly Machine, Feasibility Model

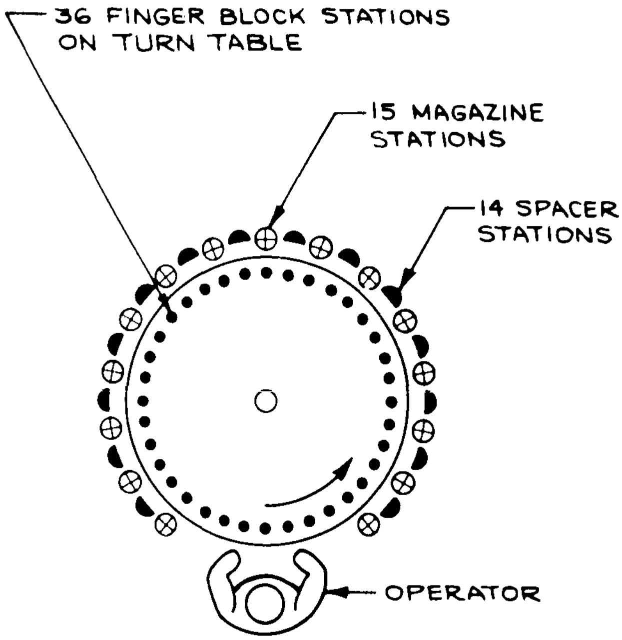

Figure III-9. Module Assembly Machine, Top View

The Micromodule Assembly is passed through this wave by means of the ferris wheel arrangement shown in Figure III-13. This ferris wheel has been designed so that the micromodule will be completely soldered if the operator replaces every third unit at the point indicated.

The photograph on Figure III-14 shows the solder wave in operation. A major feature is the dross-free condition caused by the clever utilization of an oil film which protects the melted solder.

A completed and soldered micromodule assembly is shown in Figure III-15.

Other Operations

Figure III-16 shows the ultrasonic cleaning machine which will be used to remove all foreign material from the assembled micromodules.

In completing the micromodule, it often is necessary to cut one or more riser wires between microelement wafers. The machine which will be used for this purpose will be similar to the unit shown on Figure III-17. This machine utilizes a special stationary cutting blade and a movable anvil. The Mallory cutting machine removes a tiny slug of wire without damage to the micromodule. No metallic residue can remain in the micromodule with this method.

The new machine utilizing this concept is appropriately mounted and includes a magnifying glass for ease of operation.

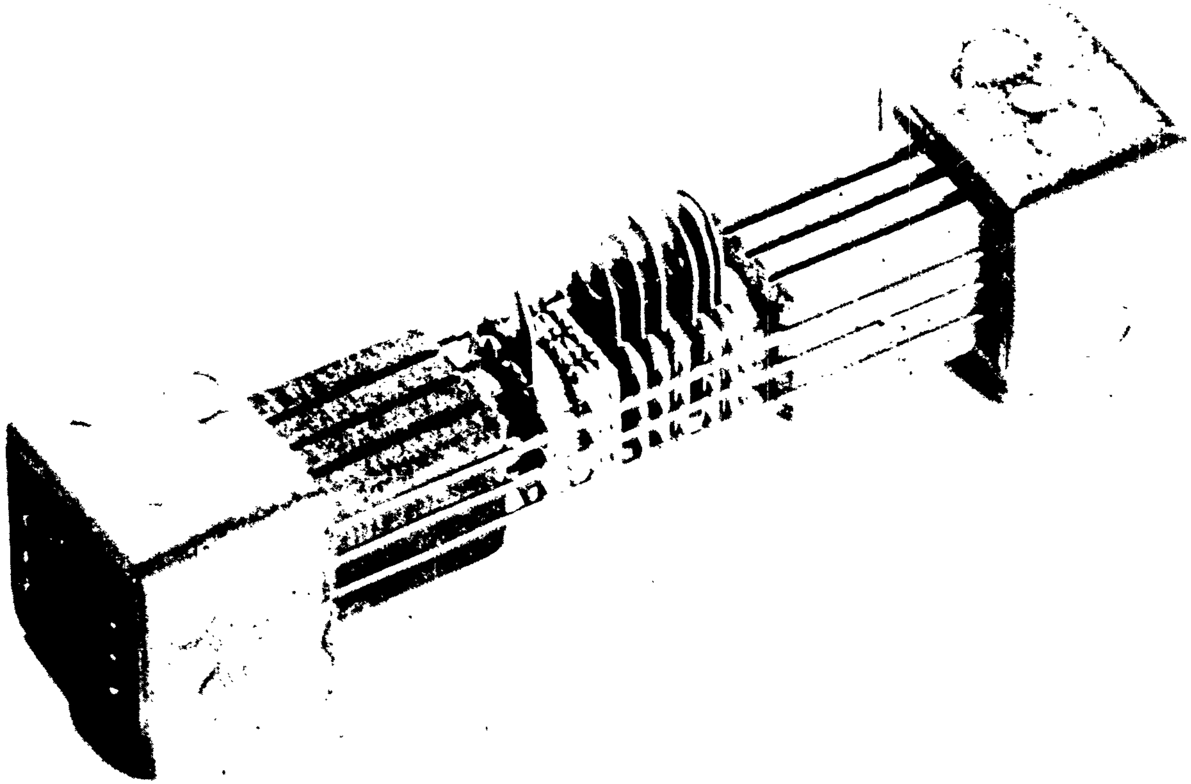

Figure III-10. Microelement Stack Assembly, With Spacers

Figure III-11. Soldering Machine, Feasibility Model

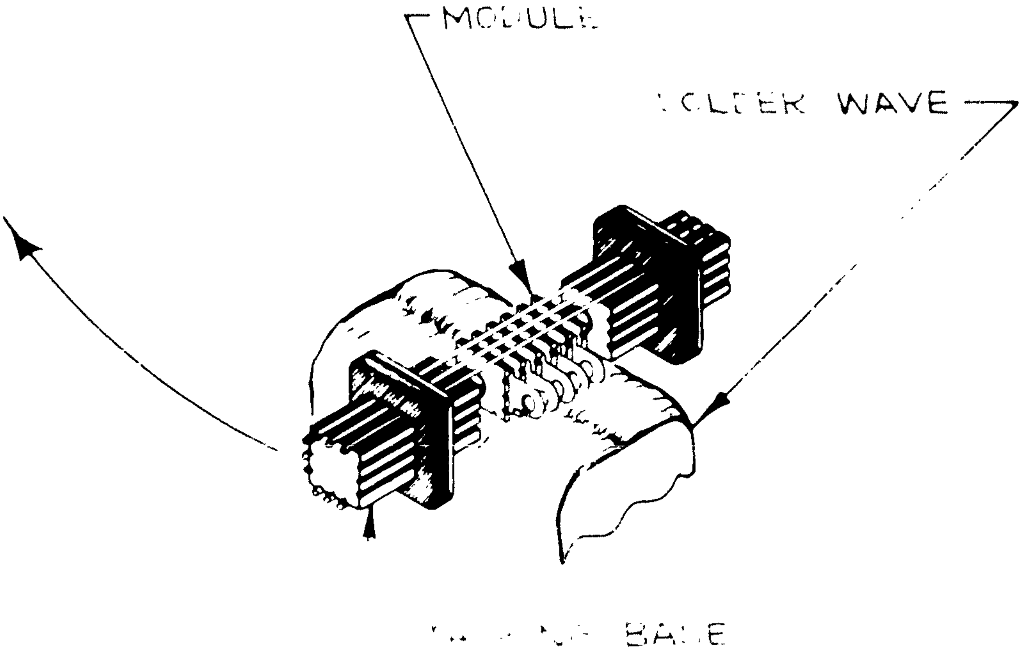

Figure III-12. Module and Solder Wave

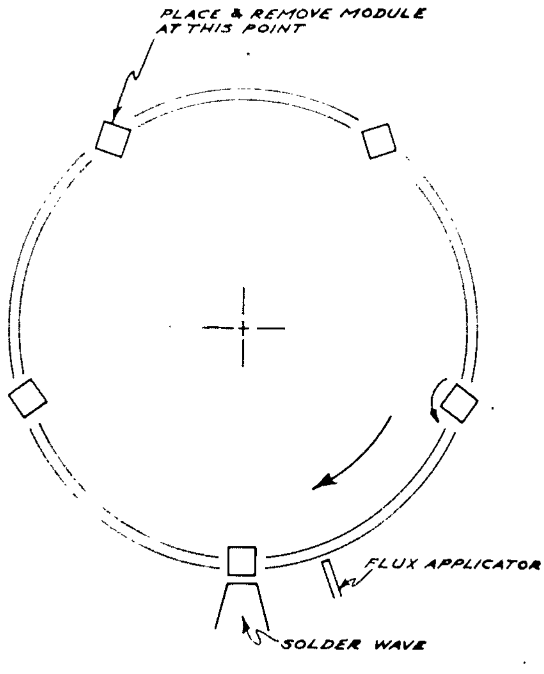

Figure III-13. Module Solder Machine

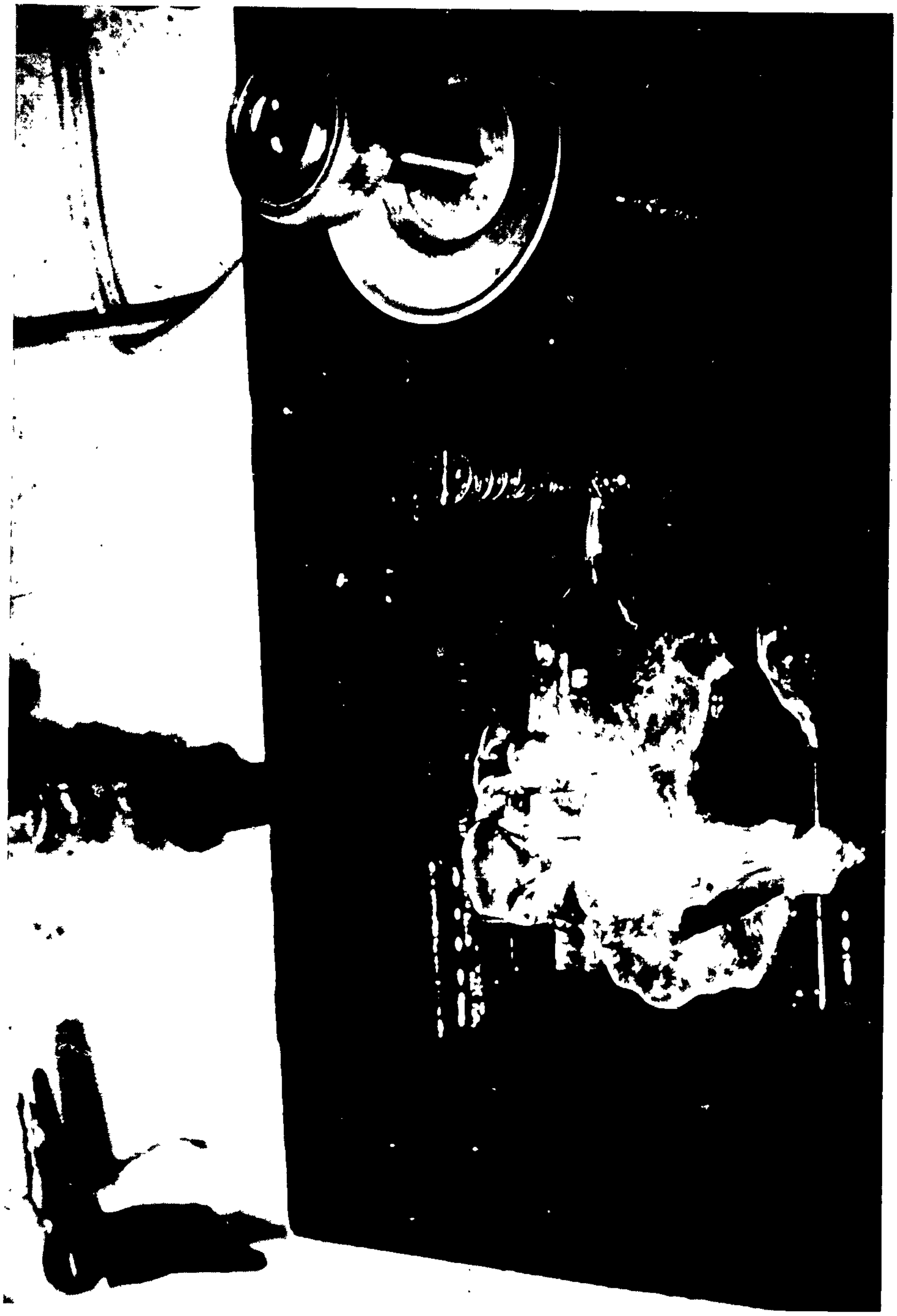

Figure III-14. Solder Wave in Operation

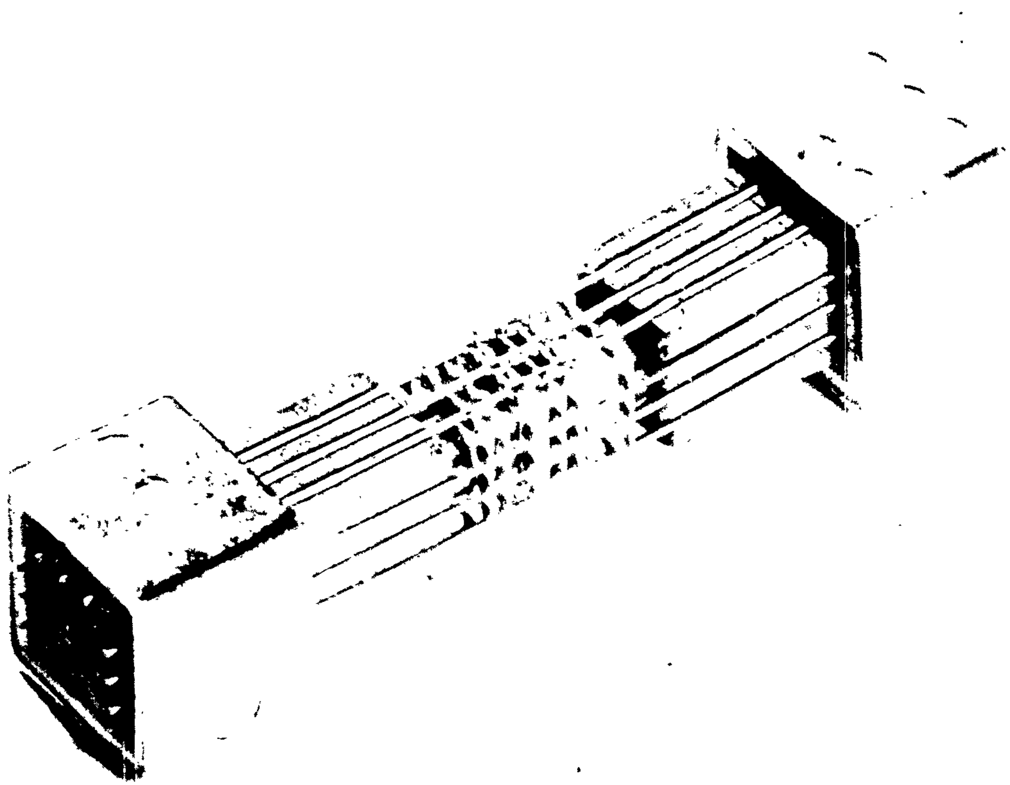

Figure III-15. Assembled and Soldered Micromodule in Module Stack Assembly

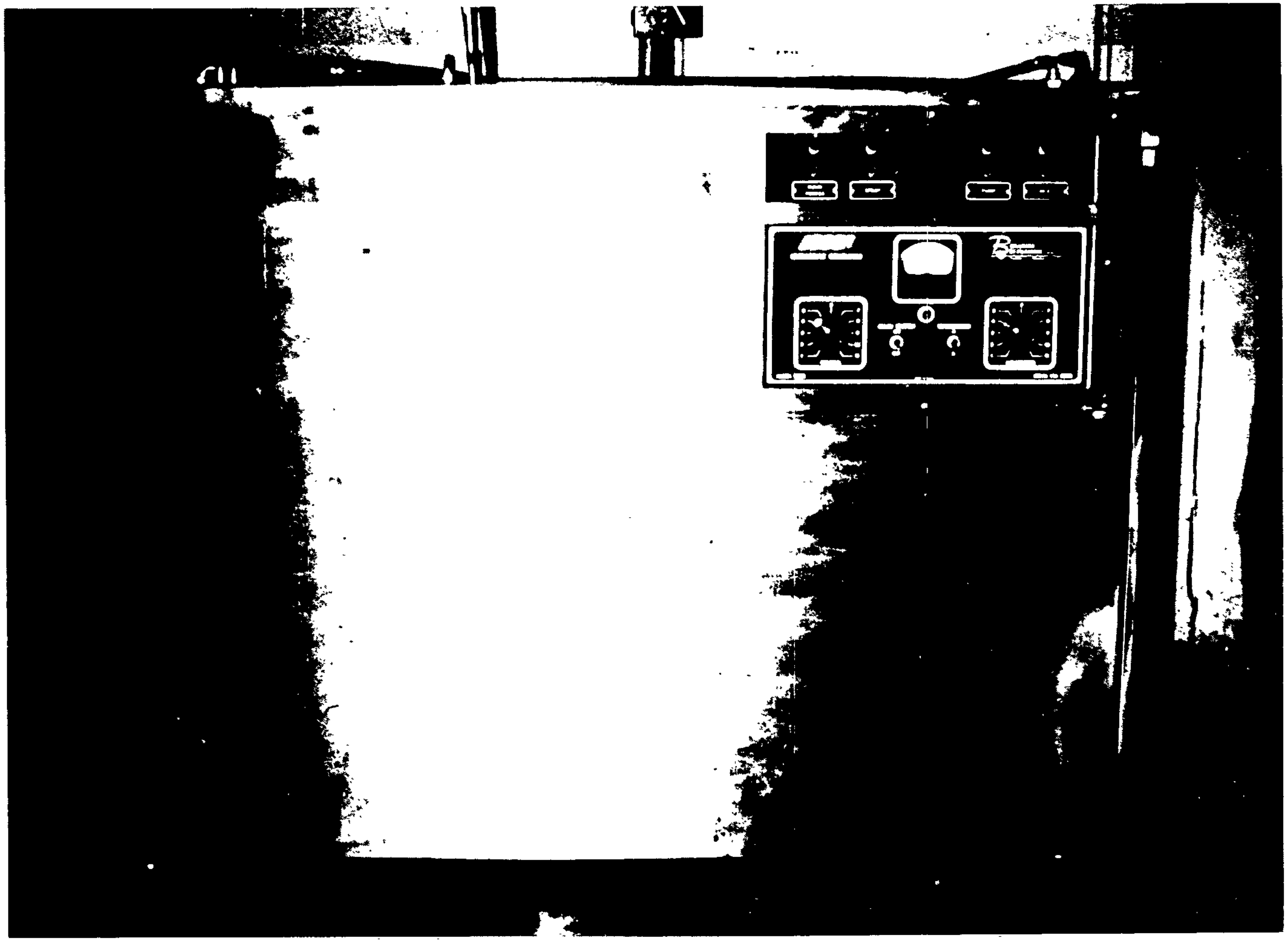

Figure III-16. Ultrasonic Cleaning Machine

Figure III-17. Riser Wire Cutter

Figures III-18, 19, and 20 illustrate the resulting micromodule assemblies as they appear during the testing and encapsulation stages.

CONCLUSIONS

The Mallory mechanized assembly system has been designed to produce at least 200 micromodules per day, readily expandable to more than 1,000 micromodules per day. This machine will permit a great reduction in the cost of micromodule assembly, while at the same time providing improved reliability, a high degree of flexibility with respect to circuit changes, and maximum uniformity of the finished product.

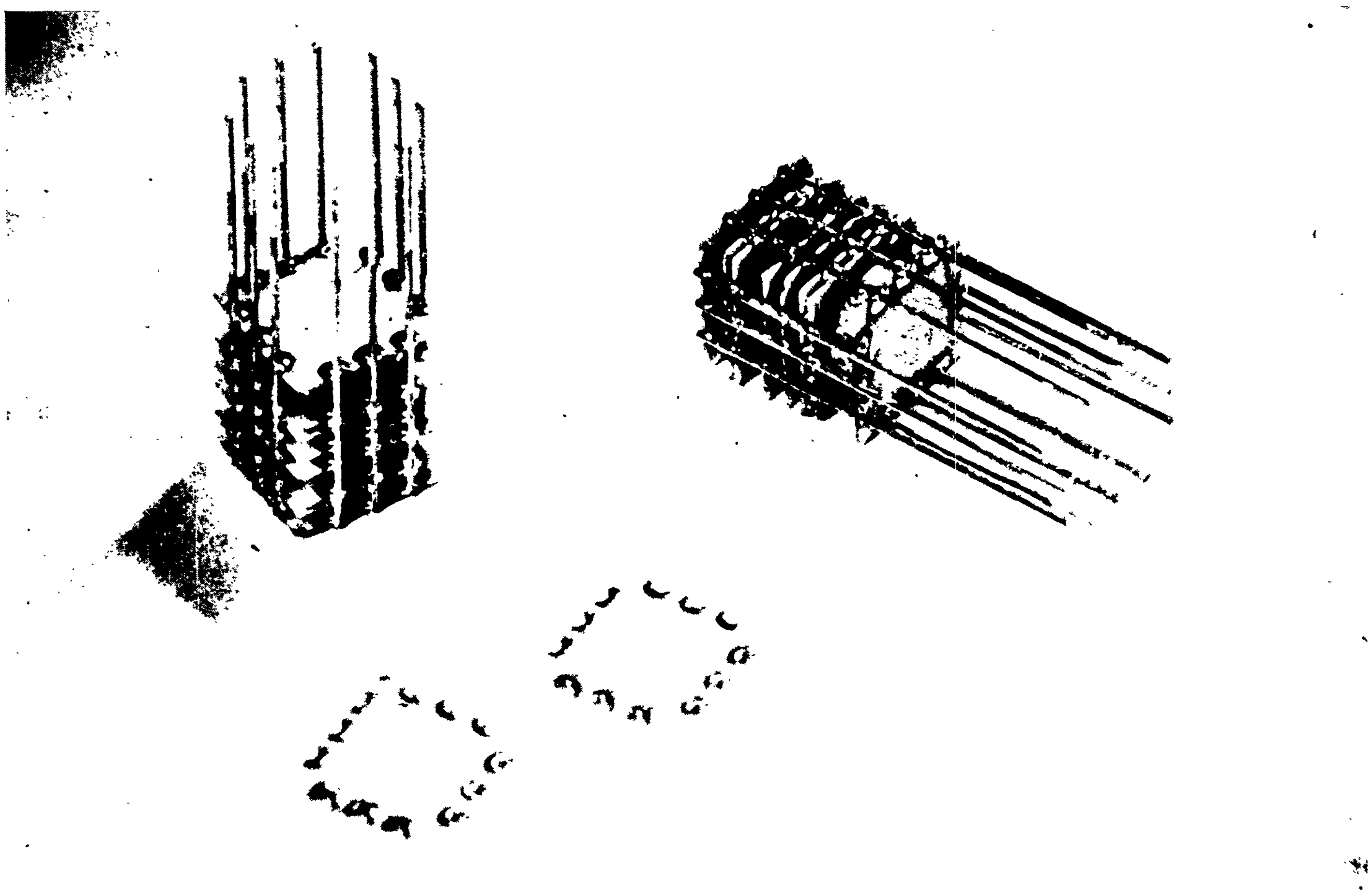

Figure III-18. Assembled Micromodule, Prior to Encapsulation

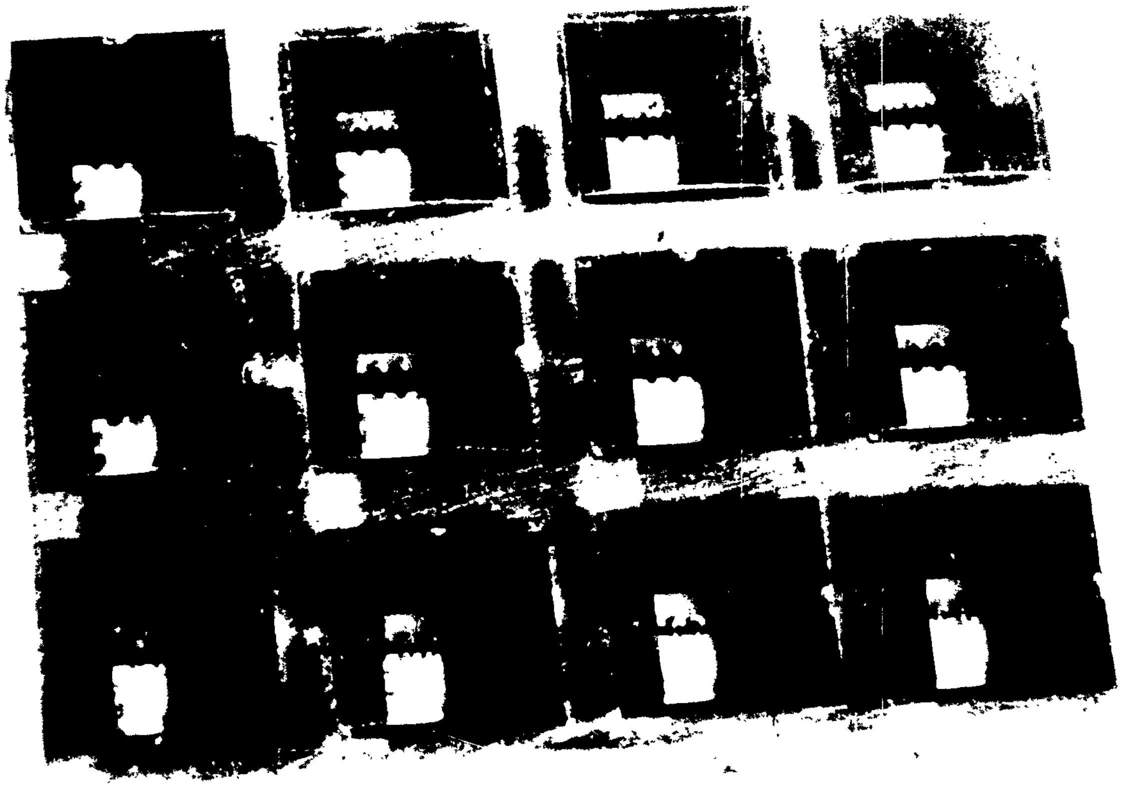

Figure III-19. Assembled Modules in Shells, Ready for Encapsulation

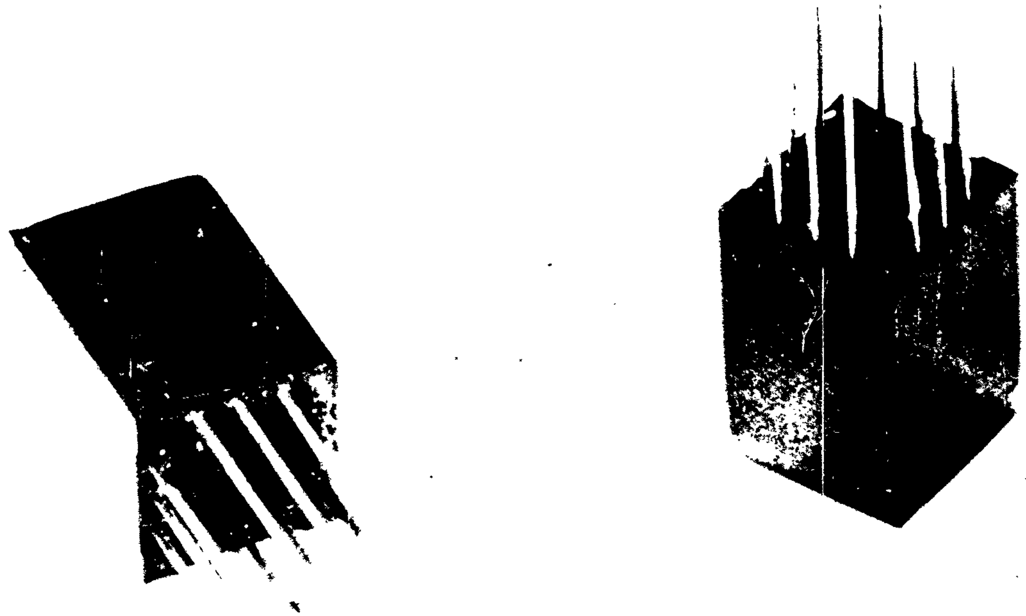

Figure III-20. Encapsulated Micromodules

MODULE ASSEMBLY METHODS AND REQUIREMENTS

S. LEVINE
PAKTRON

The Paktron assembly system for micromodules can best be summarized as follows:

1. Control

2. Chemically clean

Paktron's micromodule assembly system starts with a very stringent visual and mechanical inspection of the incoming elements. These elements are then loaded into a slave jig, which is a vehicle to take the element from one tester to another, the purpose being to reduce the handling of a part. The electrical incoming test is accomplished in six major test stations. After the part has been tested, it is loaded in an assembly block which, in turn, is mounted in the module assembler. The module assembler automatically solders six riser wires at one time. In the next step, the ends of the wires are clipped to the proper length. Then, although flux is not used and a vacuum tweezer pick up is used, both of which would preclude contamination, the modules are cleaned. After cleaning, the module goes to a post-assembly test where any elements that might have been damaged, or might have been defective in spite of the 100% incoming inspection, can be reclaimed.

After the post-assembly test, the module is ready for coating and encapsulation. The coating material is DC-271; it is used in a centrifuge. The encapsulation system differs from others, and will be discussed in detail by Mr. John Bodkin in the paper attached at the end of this discussion. After coating and encapsulation, the excess encapsulation is cut off, and the module is ready for final test. After final test, it goes to marking.

Paktron's module assembly facility area occupies approximately 500 square feet as shown in Figure III-21. The area to the left is the visual and mechanical inspection area. As wafers are received, they go through the visual inspection first. Next, they are tested for mechanical fitness on a go-no-go gauge. The wafers are then loaded in the slave-jig and are ready for test: insulation resistance test, and resistor, capacitor, inductor, diode and transistor tests. From this point, the wafers are ready for assembly. The various stations for micromodule assembly, wire cutting, trimming and segment cutting, post assembly, and noise testing for resistors, transistors, and crystals, are shown in Figure III-21.

The encapsulation and coating area, which occupies approximately 60 square feet, may be seen in Figure III-22. It consists of a fume hood, vacuum ovens, various curing ovens, a sink, centrifuge, and the coating area. The shell technique as developed by RCA is used for encapsulation, and the same stycast encapsulant is used (2651-40). In Paktron's assembly technique, the wafer notch is filled with solder and a wire is placed in the notch. A current is passed through the wire, causing it to heat up; in

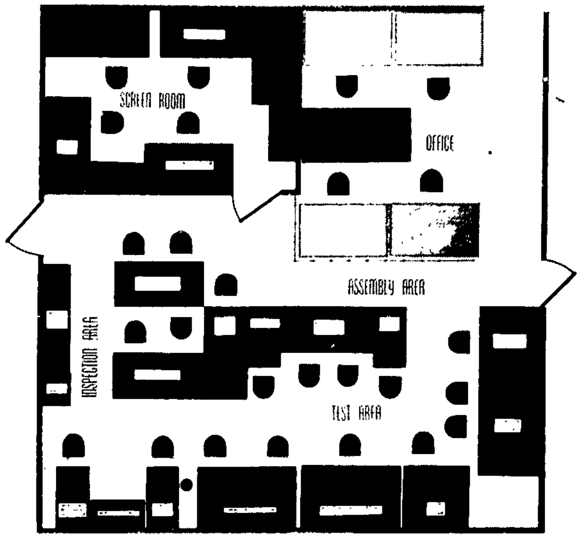

Figure III-21. Micromodule Assembly Facility

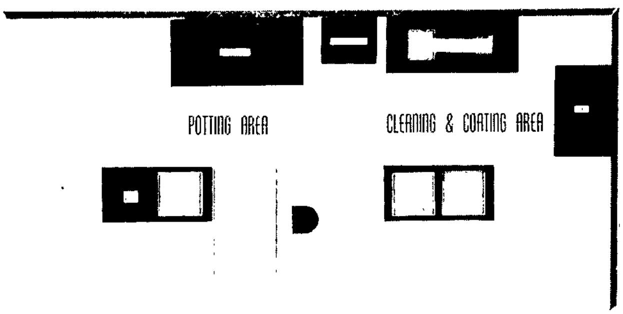

Figure III-22. Micromodule Coating and Encapsulation Area heating up, it melts the solder. Paktron refers to this as the Sink Impulse Soldering Technique; it forms the basis of the module assembler, which will be discussed in subsequent paragraphs. As stated previously, flux is not used because it is not needed. When the wire was heated, the solder that was exposed to the air may have had some contamination on it. However, the heated wire goes into solder that has been protectively coated by the outer solder for as long as it has been in the notch. Because no flux is used, the notch is chemically clean; therefore, the cleaning process is quite simple and will not be discussed in detail here.

One of the features of the micromodule assembler is the loading block and mylar spacer, which eliminates the problem of metal against metal on the wafers. After the assembly loading block has been loaded, it is aligned approximately. Its final alignment will be done in the assembler as it proceeds through it.

Another feature of this system is that the operations are controlled. The operator has the control, which is preset by the engineer; it governs the amount of time that current is passed through the wire and the amount of current that is passed through the wire. For each different module type, there will be an optimum amount of energy used, and Paktron's assembly system includes an integrating device that indicates, for a given type of module, the optimum amount of energy used.

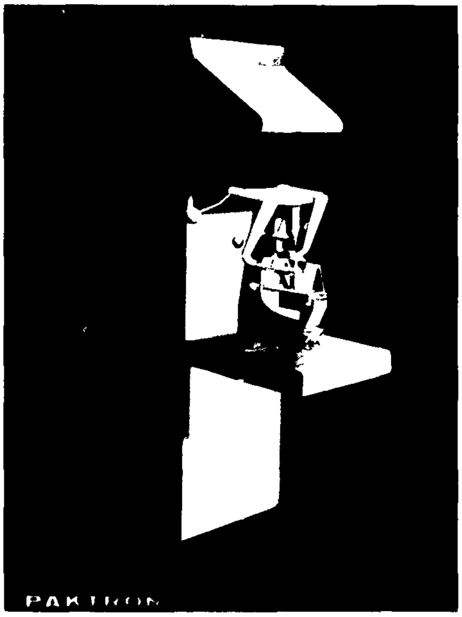

Figure III-23. Micromodule Assembler

The micromodule assembler is shown in Figure III-23, and includes the assembly loading block, and mylar spacers clamped in the block, which contains the microelement wafers. In operation the clamps - that is, the upper unit, the follower and the bottom head - are disengaged. This unit is placed in the assembly loading block in the downward position; six riser wires are placed in either side and are clamped in place. With the upper head clamped in place, the module assembly is soldered on two sides. By rotating the module assembly 90°, inserting another adapting block and repeating the above procedure, the remaining six riser wires are soldered in place.

Once the module is assembled, riser wire segments may have to be removed, for which purpose Paktron uses a riser wire segment cutter, shown in Figure III-24, which operates on the principle of a vibrating saw. With this system, very little solder build up occurs; therefore this operation, in which 0.005 inch is removed from the wire, is relatively simple. The operator lifts the clamps, and puts a pre-assembled micromodule into the fixture and clamps it in place; it is referenced against a referencing bank. The unit is moved to a vacuum pick up which removes any dust particles which evolve from the cutting operation. The assembly is moved toward the vibrator and actuates a switch putting the vibrator in motion. At this point, the cutter is within 1/16 inch of the wire. The operation is then observed through the microscope, a vernier adjustment is made, and the cut is made very accurately. However, a more sophisticated method has been devised for automatic riser wire cutting. A programming key is plugged into the system, which locates the cuts to be made with respect

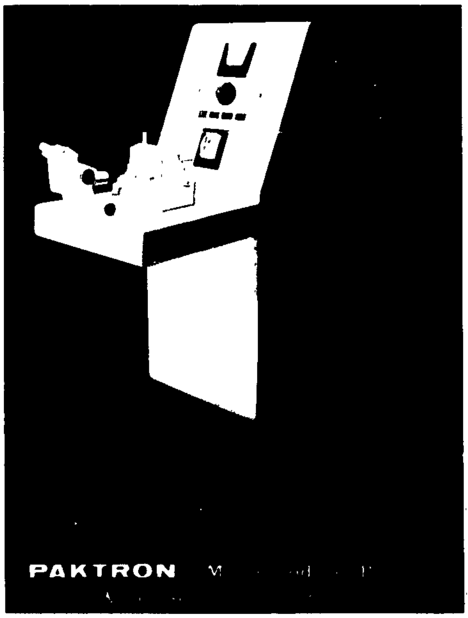

Figure III-24. Micromodule Riser Wire Segment Cutter to the horizontal and vertical axes; the operator merely places the unit in the correct position and the unit proceeds in graduated steps to the proper spot for cutting.

As with all assembly techniques, failures do occur, which gives rise to the question of how to save the module parts. For this purpose, a disassembler has been devised which operates as follows: by using the solder technique discussed above, in reverse, the riser wire is heated up and melts the solder, enabling removal of the wire. This effects disassembly. If by chance some melted solder is bridged between wafers after all the riser wires have been removed, the two wafers which are stuck together are placed in contact with a thin wire through which a current has been passed; the wire heats up and parts the wafers.

The next step in micromodule assembly is encapsulation, which presents the problem of trying to produce micromodules which are free of voids and shrinkage. Paktron has developed a system of vacuum pouring and vacuum encapsulation based on the principle that, if there is no air in the system to begin with, there is no air to remove. Mr. John Bodkin will discuss Paktron's encapsulation system in the following paragraphs.

J. BODKIN - ENCAPSULATION OF MICROMODULES

The original specifications described a method of filling a void using a piece of wire, and this proved to be a painful procedure. Because shrinkage and voids were two of the main problems we were having, a vacuum oven was developed so that they would be eliminated from the encapsulation system. The heat produced in the oven provided the feature of expanding the encapsulation material and the shell uniformly together. Therefore, when shrinkage is caused by cooling, both will stay together. The original approach of pulling a vacuum, pre-heating, and drawing, allowed the receiving member of the shell to cool off while the encapsulant was still hot. The present method involves the vacuum oven which is shown in Figure III-25 and a rotating platform which has 25 holes to accommodate the shells. A device extends through the oven wall and accepts a paper cup, which acts as a ladle. This set up includes a thermometer and a vacuum gauge.

The encapsulation material, Stycast 2651-40, is mixed in the paper cup at room temperature and a funnel is formed in the cup; this may be seen in Figure III-25. (The cup holds sufficient material to encapsulate 25 modules). Then the cup is inserted into the holder. The vacuum is pulled, at this point, up to approximately 5 to 6 inches of mercury and this closes the oven door; the oven is heated up to 85°C. It is worth noting that the walls of the oven are made of white enamel which, by radiation heating, eliminates hot spots in the oven. When the oven has reached 85°C, the vacuum is increased up to 20 inches of mercury. The encapsulant is poured into the shells under these conditions. The vacuum is broken and the pressure is allowed to return to atmospheric pressure; this forces the encapsulation through the module. The encapsulated modules are then cooled at 70°C. As stated previously, this system eliminates air, thereby eliminating the possibility of voids.

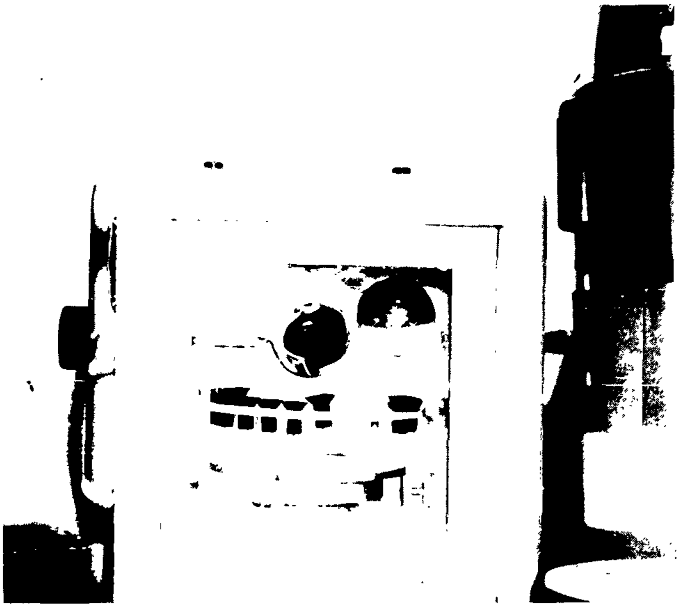

Figure III-25. Vacuum Encapsulation Oven

MODULE ASSEMBLY METHODS AND REQUIREMENTS

P. NYUL
RCA

During the past four years of intensive micromodule engineering, RCA has evolved process techniques for module fabrication which are suited to facilitation for the quantity production of modules. Under the Production Engineering Measure (PEM) phase of Extension II of the Signal Corps Micromodule Contract, funding has been committed by the U. S. Army for the process analysis and implementation of module production facilities at RCA and the two additional module sources.

Present engineering effort at RCA on the implementation task is directed toward the procurement, installation, and debugging of the tools and equipment which, in total, will become the RCA micromodule production facility. At this time, the module fabrication process which is being implemented under the PEM will be covered briefly.

The module fabrication process, though consisting of many operational steps, can be divided into seven basic elements or sub-processes. These are:

1. Element Testing
2. Wafer Stacking and Soldering
3. Cleaning
4. Coating
5. Encapsulation
6. Marking
7. Module Testing

In the area of element testing, key electrical tests have been established for each microelement type, and these tests will be performed in accordance with an approved sampling plan as outlined in MIL-STD-105A. The total incoming inspection operations, both electrical and mechanical, will be accomplished with seven basic test stations (Figure III-26). All sample microelements will be subjected to visual and mechanical inspection for conformance to mechanical requirements, after which the key electrical tests will be performed as noted in this Figure.

Wafer stacking and soldering is accomplished by a relatively simple operation requiring no special operator skills. Each assembly operator is provided with a supply of precision header jigs, straight and hooked riser wires, and soluble spacers, indicated in Figure III-27 as Parts A, B, C, and D, respectively. For each module design, a process sheet is provided to guide the assembly operator with respect to

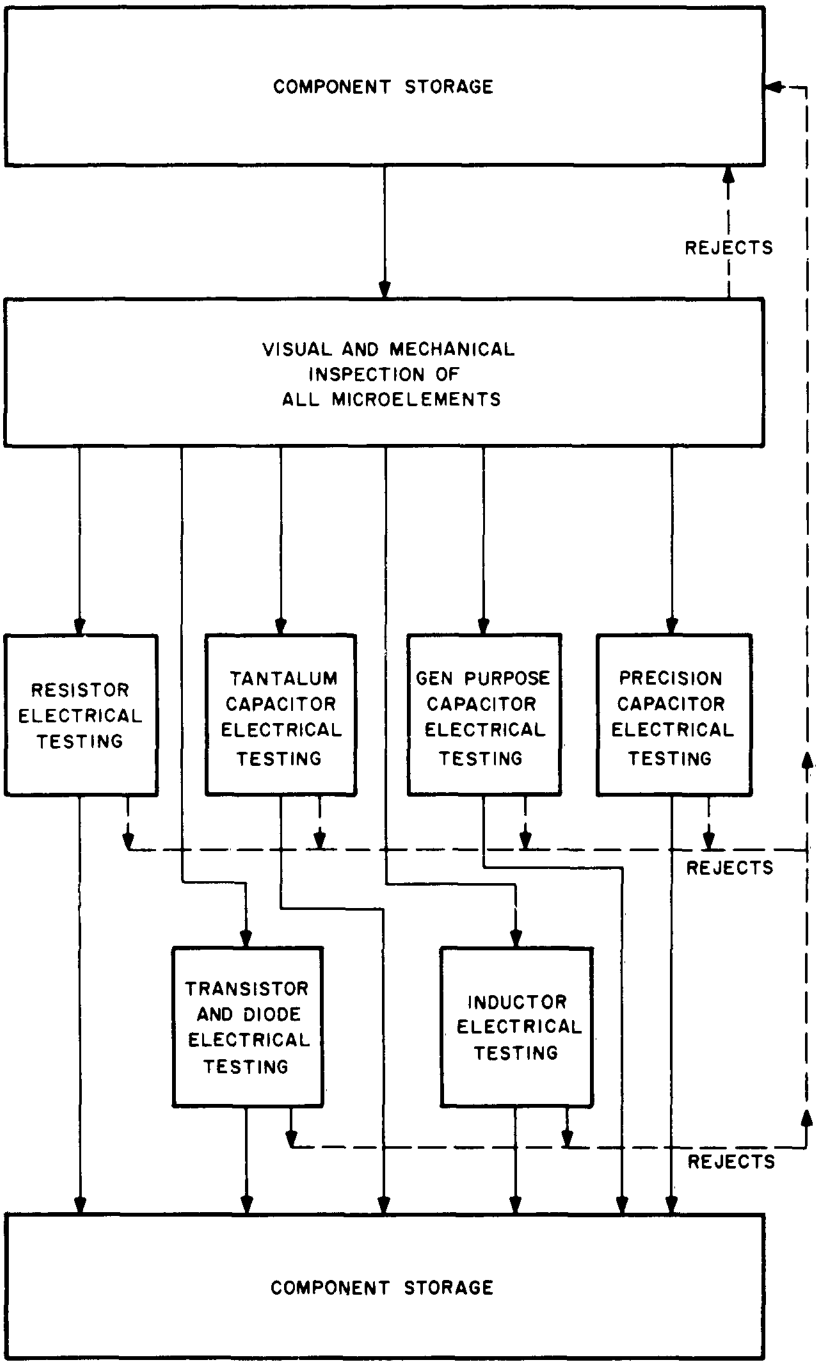

Figure III-26. Flow Diagram of Microelement Testing

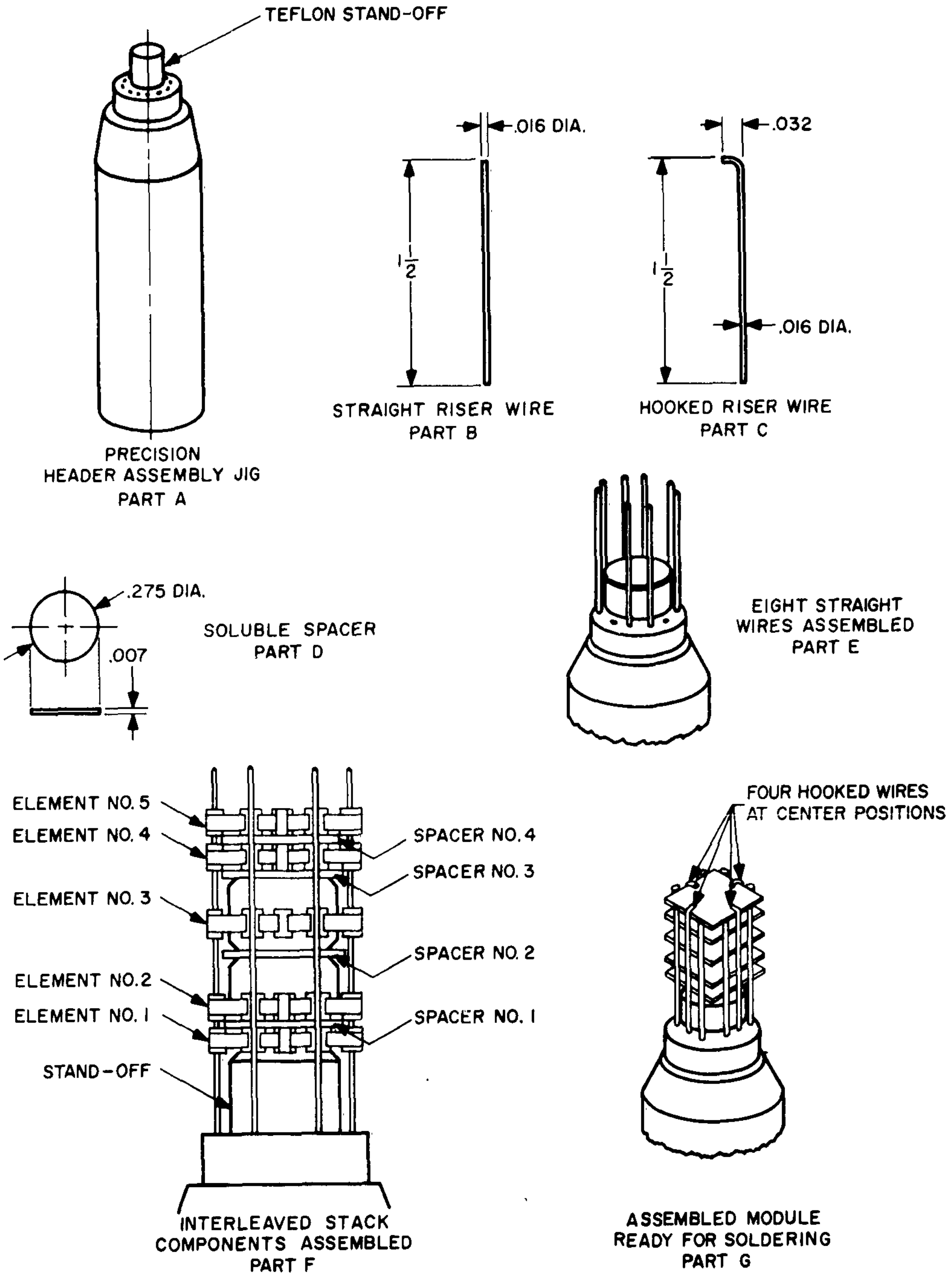

Figure III-27. Stages of Micromodule Assembly such module assembly variables as module layout, element spacing, and positioning of straight and hooked riser wires. In general, the assembly operator performs the following simple operations:

Eight straight riser wires are inserted into the header jig leaving the four center holes empty (Part E). Microelements and spacers are alternately positioned within the cage formed by the riser wires (Part F). (The microelements are presented to the assembly operator in containers with the elements pre-arranged in accordance with the module layout design). The four hooked riser wires are then inserted into the jig, and all twelve riser wires are pushed down flush with the top of the module stack (Part G).

Figure III-28 shows an actual photograph of the interleaved stack in the precision header. The assembly operator is about to insert the hooked riser wires. Soldering of the completed module is accomplished with the RCA cascade soldering machine. This machine is automatically heat-controlled and designed to provide a continuously flowing, dross-free area of molten solder.

For the implemented module assembly facility, a semiautomatic solder-dipping mechanism has been designed and constructed, and is presently being added to the RCA cascade soldering machine. This mechanism reduces the operator's responsibilities to simple loading and unloading. Critical factors, such as immersion depth, contact time, and withdrawal rate, are automatically monitored by the machine.

Figure III-28. Interleaved Stack of Elements and Spacers

After soldering, the module is removed from its header jig, the riser wires are trimmed, and the empty header jigs are returned to the assembly operators for recycling.

The module is now subjected to the cleaning operation for the removal of the soluble spacers and flux residues. The cleaning operation consists of the following:

1. Ten minutes mechanical agitation

2. Three minutes ultrasonics

3. Five minutes spray

4. Ten minutes mechanical agitation

5. Two minutes vapor drying

The cleaning solvent used in the first four steps of cleaning is PC Freon; TF Freon is used for the last step.

After cleaning, the modules are electrically tested and then subjected to the coating operation. The coating material is DC271, and it is applied as follows:

1. Modules are submersed in the coating material.

2. A light vacuum is drawn to remove air which may be entrapped within the module structure.

3. Modules are removed and placed in a centrifuge to remove the excess coating material.

4. The modules are then placed in a 90°C oven for cure.

Encapsulation of the module is accomplished with the aid of epoxy shells, which have funnel-shaped extensions at the top end to aid in filling. The modules are first inserted in the shells so that the leads protrude through the holes in the bottom of the shell. The modules are then lowered into a bath of hot thermoplastic material to form a seal around the leads at the shell bottom. After preheating, the shells are filled with heated encapsulant and a vacuum is drawn to remove entrapped air. These three process steps are shown in Figure III-29, 30, and 31. The modules are then placed in an oven for cure.

After the modules have been cured, the plastic seal around the leads is stripped off as shown in Figure III-32. The module is then cut to the specified length on a diamond-wheel cutting machine.

The encapsulation equipments shown in the preceding photographs are either of the prototype or laboratory type. The production facility equipments are based on these demonstrated techniques but have been designed to accommodate modules in rack lots.

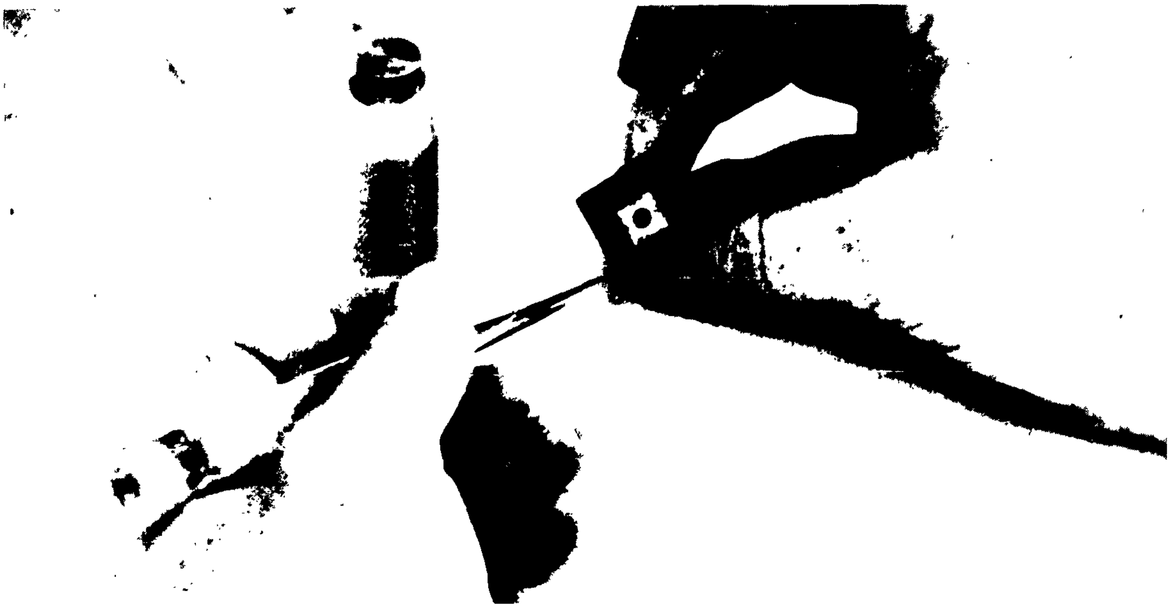

Figure III-29. Module Inserted in Shell

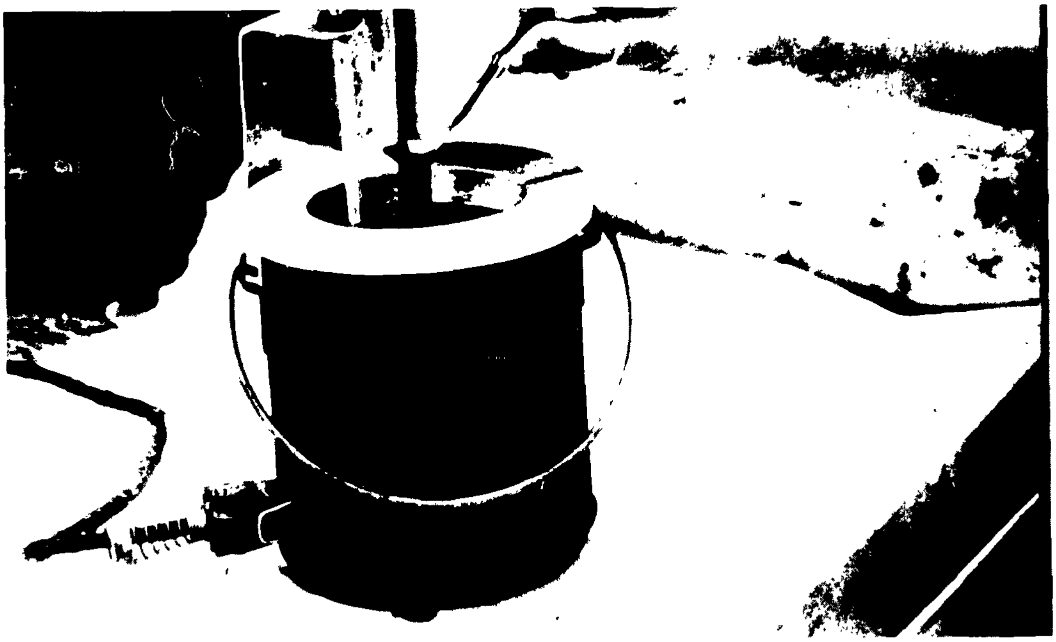

Figure III-30. Module Being Lowered Into Tool Dip

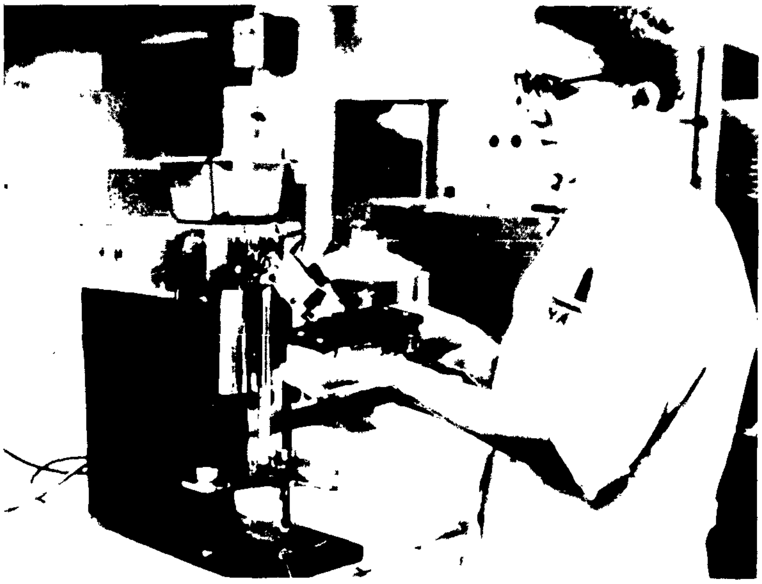

Figure III-31. Rack of Modules Being Encapsulated, Prototype Epoxy Dispensing Machine

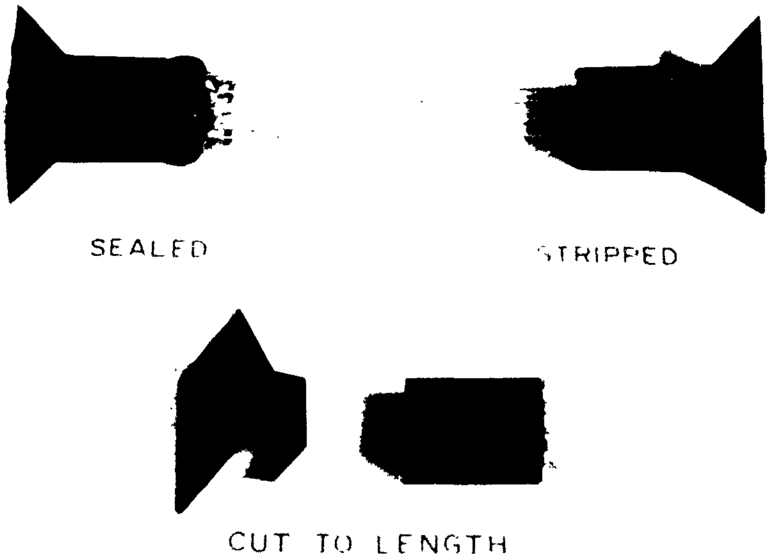

Figure III-32. Micromodule Finishing Operations

Following encapsulation, the module is marked with the specified identification coding and information, samples of which may be seen in Figure III-33. Marking is done with a heat-impression marking machine.

The completed modules are now subjected to final electrical tests. Modules are usually one of two types; that is, either digital or communications. Two test sets, one for each type, have been designed. The digital module test set is of the semi-automatic type and is designed to give a go-no-go indication. For digital modules of different types, changeover is accomplished by plugging-in a special fixture which programs the equipment and sets the test limits for the type module being tested. Visual scope display and digital read-out is also provided for monitoring and quantitative measurements as required.

The communications module test set is much more elaborate because of the types of tests to be performed. Audio, and intermediate-and radio-frequency signal generators and measuring equipments have been combined in one test console. Setup for a given communications module is by means of patch-cords, selector switches and plug-in fixtures. In operation, the operator inserts the module in the test socket, presses the appropriate buttons and makes a decision as to acceptability on the basis of meter readings and/or oscilloscope displays.

It is worth noting that modules are electrically tested twice during the fabrication process; the first time prior to encapsulation, and the second time after marking.

Figure III-33. Micromodule Heat Impression Marking

In-process modules will be routed through their respective test sets twice with the test limits adjusted in accord with anticipated process changes and the final test requirements.

In the preceding discussion, the essential steps which constitute the RCA module assembly process have been covered. Throughout the course of the assembly process, microelements are repeatedly subjected to thermal-mechanical stresses and chemical environments. Microelements meeting the requirements of established microelement specifications will withstand the rigors of this module assembly process without suffering degradation in performance or reliability. In addition to the electrical requirements, the individual microelement specifications reflect mechanical requirements, which are, to a large extent, dictated by the standardized micromodule assembly processes. The most important mechanical requirements of microelements as related to module assembly fall into one of two areas; namely, metalization or mechanical dimensions and tolerances.

The aspects of the microelement metalization requirements related to module assembly are solderability, bond strength, and compatibility with module assembly processes.

Solderability - Solderability is essential in that a multiple of soldered connections is made with one pass through the molten solder, and each soldered joint must be good the first time. The quality of the soldered joint between the riser wires and the microelement terminations depends to a large extent upon the quality and uniformity of the microelement terminal metalization.

Bond Strength - When measured in the prescribed manner bond strength defines the minimum acceptable adherence quality of the microelement terminal metalization to the microelement substrate. Since all twelve terminals of a microelement are not necessarily metalized, it is possible, in the limiting case, for a given riser wire of a module to be soldered to only the first and last wafer in a micromodule stack. The specified minimum bond strength is required in order to maintain structural rigidity, regardless of a module layout design, and to provide adequate joint strength to withstand module lead stresses during such subsequent module assembly processes - prior to encapsulation - as lead trimming, pre-encapsulation testing, and insertion into shells.

Compatibility - The microelement metalization must be compatible with the module soldering process. The RCA cascade soldering machine is operated at a temperature of 238°C ±2°C with 60-37-3 solder, and the microelement metalization must be such that it does not leech out during the soldering cycle. Metalization materials of gold-plated molymanganese and gold-platinum have excellent characteristics in this regard. In many instances, metalized wafers are used for the mounting of such components as coils and semiconductor devices. In these cases, the metalization is used to terminate both the component and microelement wafer. In some cases, high temperature solder is used to terminate the component on the microelement wafer; therefore, the metalization must be suited to high temperature soldering at the component termination area without degrading the bond strength or solderability of the wafer termination required for module assembly.

In the area of microelement dimensions, the dimensional tolerancing represents a compromise of component fabrication capability, the finished micromodule requirements, and the module assembly techniques and process variables. The RCA dip-soldering technique of module assembly requires that all 12 notches of a microelement be located precisely with respect to the .075 inch grid. Secondly, metalization and solder coating must be rigidly controlled to prevent excessive buildup which would interfere with proper element stacking. Clean wafer edges and a minimum of .015 inch clearance between metalized areas must be maintained to prevent solder-bridging from terminal to terminal, or from wafer to wafer, during the soldering operation.

The over-all dimensional tolerancing of the wafer relative to the notch is also critical in that, in certain processes, the wafer edges or corners are used for positioning reference in jigs and fixtures. Examples of such instances are the metalization of bare substrates, the mounting of components on metalized wafers, and microelement testing prior to module assembly. Secondly, over-all dimensional tolerances are important in the design of equipments for the automatic handling and orienting of microelements in fabrication, testing, or module assembly.

With respect to the module assembly process, another important aspect of the dimensions of a microelement is its final shape or envelope. The module assembly technique of stacking microelements, one on top of the other, with mechanical separators gives rise to an ideal microelement which has two flat, parallel faces. It is recognized that the ideal is not always attainable, but the final micromodule specifications and the established module assembly processes require strict control of deviations from the ideal. Protrusions, non-parallel faces, and wafer camber or twist can cause the microelements to assume tilt positions in the module stack which in some instances may become cumulative. Excessive wafer-tilt can cause or contribute to one or more of the following undesirable traits:

1. Increased module length with a resultant reduction in volumetric efficiency and possible rejection for non-conformance to micromodule requirements.

2. Marginal soldered joints which may result when riser wires are not fully seated in wafer notches. In extreme cases, an open circuit can result.

3. Solder bridging at undesired locations near wafer edges which no longer are spaced with the proper clearance from adjacent wafers.

4. Interference with proper completion of the remaining module assembly processes; specifically, cleaning, coating, and encapsulation.

In summary, though much of the finer details of module assembly has been purposely omitted, it is still apparent that the total module assembly process is a rigorous one, imposing stringent requirements on the microelements. In addition, the relationship between mechanical requirements of microelements and the module assembly processes have been discussed. In this respect, conformance to metalization and dimensional requirements was highlighted as being essential.

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IV

INCOMING INSPECTION

S. LEVINE — *PAKTRON DIV., ILLINOIS TOOL WORKS*
J. P. MORONE, JR. — *P. R. MALLORY AND CO.*
J. JENSEN — *RCA*

IV

INCOMING INSPECTION

S. LEVINE
PAKTRON

Most of you who are producing component parts have come to hear what we, the users, are going to require from you. Paktron is going to require and to assure, through testing, that the degree of reliability that RCA and the Signal Corps have produced to date is maintained; testing is 100% mechanical and electrical. Paktron may not "A" test fully in incoming inspection because of the time for environmental. "B" and "C" testing will not be done; however, the rigidity of our tests is about the same as that to which you have become accustomed.

The first step in incoming inspection is a thorough visual check; a magnascope of magnification between 4 and 8 times is used to inspect for cleanliness, metallization, potential shorts, and material that has not adhered to the substrate. If there is anything in doubt, the substrate is examined under another microscope, which magnifies up to about 80 times. The physical dimensions are checked in a go-no-go gauge. Then notch strength will be determined as follows: In each shipment of 100 parts for example, one or two metallized wafers which do not contain components, but which were made using the same method that would be used to make a transistor, capacitor, or resistor, will be subjected to a notch-bond test.

After the visual and mechanical inspection, the parts are loaded into the slave jig, which is a vehicle for transporting an element from one tester to another. This device was developed by the Jettron Company to prevent undue handling of a microelement. The microelement can be inserted into many different test stations for electrical tests. There are 6 major stations where insulation resistance, capacitance, inductance, and diodes and transistors are tested. A test station may be comprised of 2, or as many as 3 substations. This was done so that at the present state, where the requirements are not quite 1000 a day, one girl can perform many different tests; or 2 or 3 girls might be used depending on what the station is. As the requirements for production increase, incoming testing can be increased by merely using more girls at the various substations.

Insulation resistance is tested 100% on every item, that is, from each individual notch to every other notch. Any component on the wafer is shorted out, making that one more terminal. Parts are not handled by hand, or with tweezers; instead, a vacuum pick-up system is used. This does help to reduce handling and, in the last few months, breakage has been reduced very greatly. In fact, the problem we encountered a year ago with breakage of the parts has become almost miniscular.

Some of the parameters which will be checked are: precision and variable capacitors - capacitance at 1 mc, Q at 1 mc; general purpose and electrolytic capacitors - capacitance, dissipation factor, leakage current, flash-over and breakdown; resistors - noise and resistance; crystals - the frequency of oscillation, and series resistance;

inductors and transformers - inductance, Q, voltage ratio, and so forth on the various parameters.

The specifications Paktron will use to order by at the moment and, for the next 6 months at least, will be the same ones that have been developed by RCA. What is it that Paktron in particular needs in the way of individual specifications? Well, really nothing more than has already been said. One thing that should be stressed is this: it is mandatory, for the Paktron system to operate, that you have good metallization in the notch. It may be necessary because of the thermal conductivity of a part, or the part that goes with it, that the notches be half filled, or even completely filled with solder. This will be discussed individually as particular cases arise.

Briefly, then, the specification that Paktron will order from is the same one that has been in use up to now and, it should be reemphasized, good metallization is a prime requirement.

MICROMODULE INCOMING INSPECTION

J. P. MORONE, JR.
P. R. MALLORY & CO.

INTRODUCTION

Incoming inspection is an important integral part of the Mallory micromodule assembly system. A balanced combination of manual and automatic inspection and test schedules characterize the quality control operation. High quality is assured through the careful and thorough sequence of inspection procedures outlined below.

MANUAL INSPECTION

A full range of "A" tests will be performed on incoming microelements with manually operated test equipment and fixtures. The purpose of this series of tests will be to ascertain the quality level of parts relative to all "A"-test parameters as they are received from the vendor. Economic considerations generally favor sampling plans for this manual testing; however, initial shipments from vendors will be 100 percent inspected until such time as conditions and experience permit the more economical sampling approach.

AUTOMATIC INSPECTION

Automatic testing of microelements will supplement the manual inspection procedures; however, only a few carefully selected parameters will be tested instead of the full complement of "A" tests. The purpose of this automatic testing is to remove those grossly defective parts which are bypassed or overlooked in the manual test procedures. A secondary purpose is to check on microelement wafer orientation, for a misoriented wafer is equivalent to a defective wafer and can cause circuit malfunction as well as electrical damage to wafer assemblies.

The automatic testing of microelements is performed with the Test and Orientation Machine, which accommodates microelement magazines, (Figure IV-1) so that the microelements are automatically transferred from one magazine to another in the test operation. The diagram of this machine shown in Figure IV-2 illustrates the relative positions of the three microelement magazines used in conjunction with it.

The magazine in Position 1 contains microelements as they are received from the vendor. Magazines in Positions 2 and 3 are initially empty and accept microelements after they are subjected to tests in a test socket at the center of the machine. Acceptable microelements are transferred to the magazine in Position 2; rejectable microelements are transferred to the magazine in Position 3.

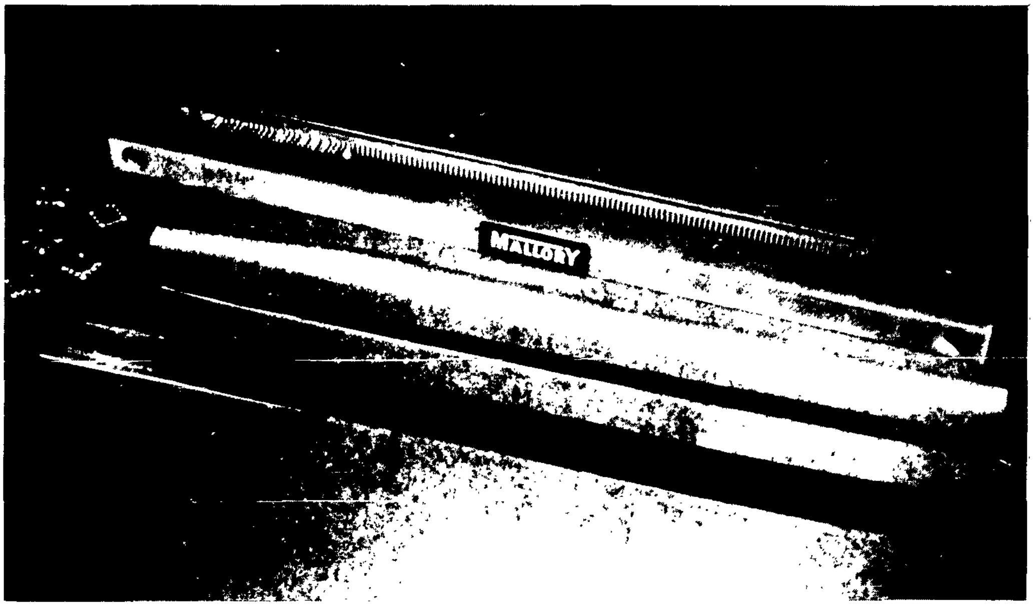

Figure IV-1. Microelement Magazine

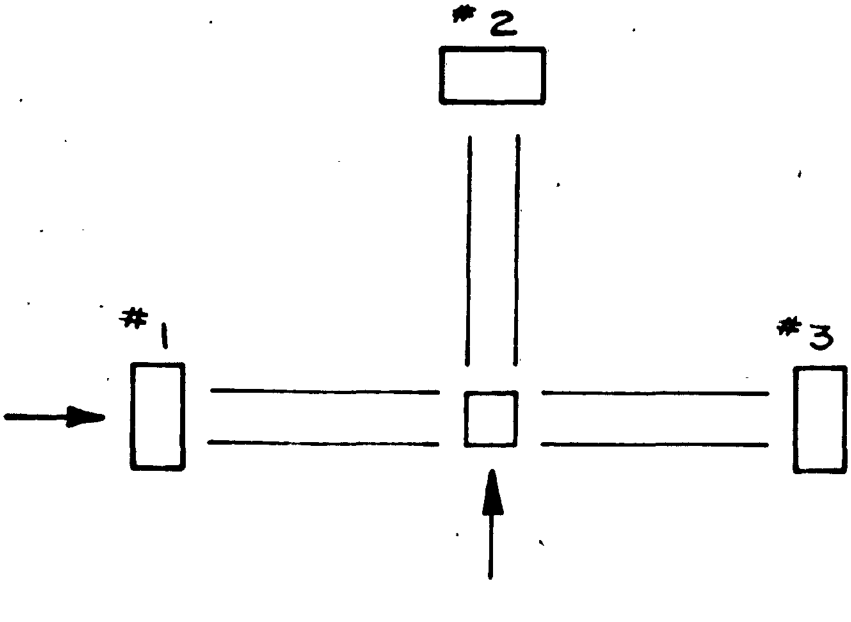

Figure IV-2. Test and Orientation Machine, Block Diagram

INCOMING INSPECTION SEQUENCE

The sequence of inspections in the Quality Control Operation is as follows:

1. Visual, mechanical, and electrical examinations per "A" test schedules and procedures as described above.

2. Visual examination of wafer notches in magazines as viewed from two open sides of magazines (metallization of notch is a critical factor in automatic wafer assembly).

3. Automatic tests of selected electrical parameters by means of Test and Orientation machine as described above.

4. Visual examination of wafer notches in magazines. (After T & O operation, acceptable wafers will have been reoriented 90° to their original position, so that the notches on the two previously hidden wafer edges can then be visually examined.)

5. Magazines loaded with microelements are sent to stockroom.

The sequence listed above takes economic advantage of sampling approaches to inspection, while at the same time 100 percent automatic inspection of a few critical parameters permits removal of gross defectives bypassed or overlooked in the manual test operation. This combination of test procedures is expected to provide a high level of protection at reasonable cost.

INCOMING INSPECTION

J. JENSEN
RCA

The proven techniques required to assure success in the PEM objective of controlled product quality revolve around three key factors:

1. Defect Detection
2. Defect Correction
3. Defect Prevention

The first key factor, defect detection, starts when the product arrives at incoming inspection.

The chart of Figure IV-3 illustrates product flow and the forms used to control this operation. Pertinent facts concerning the product are entered on the receiving report. The specification governing the procurement is one of the required entries. This number dictates to the Quality Control Inspector/Testor what written procedures must be followed for product evaluation. The next step is to determine whether specification requirements have been met. The measuring equipment and test techniques for the "Incoming Inspection" will be examined following the discussion of product flow depicted on the chart.

You will note an arrow pointing to the Data Processing Card. When quantities become sufficiently large the Vendor Rating System is computer controlled.

The next step after testing the product is to review the data and determine whether it falls into the accept or reject category. If the product is accepted, an accept ticket (yellow) is attached, the product is stamped approved by quality control, and the material is placed in stock. If, however, the product is rejected, purchasing and material control are immediately alerted that the material is discrepant and the exact areas of discrepancy are detailed. A reject ticket (red) is attached, the product is stamped rejected by quality control, and the material is placed in the "Hold Area" pending product disposition.

The inspection procedures previously mentioned are maintained in the RCA Microelectronics quality control manual. The procedures are quite detailed to minimize the possibility of inspection errors. The procedures include the exact sampling plans, list the equipment that must be used, and itemize the required data records in addition to the test techniques.

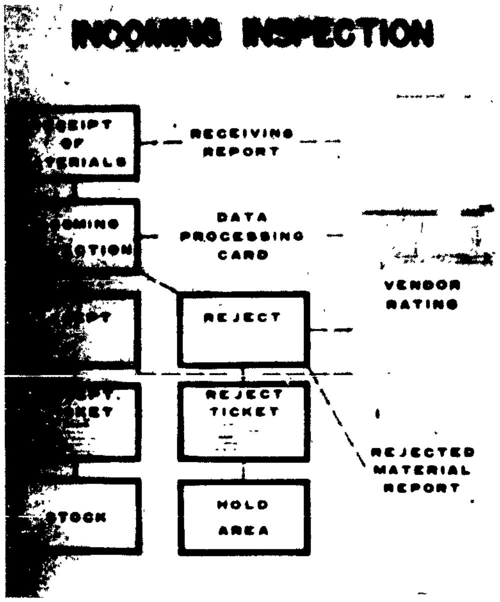

Figure IV-3. Incoming Inspection, Flow Chart

Product evaluation requires professional test equipment. Time does not permit a detailed presentation of all of the equipments but the same basic techniques apply. The equipment is generally selected to have a measurement accuracy of at least 1/10 that of the parameter limit being measured. The equipment operation must be simple enough for use by a relatively non-skilled operator. The equipment must be capable of meeting the required test rates. The microelements can be damaged by handling so, where possible, each part will be placed in test sockets and these sockets will be transferred between the test equipments. Examples of equipment meeting these requirements are illustrated in the following photographs. These are typical of the equipment that will be used to evaluate the quality of incoming parts.

Figure IV-4 is a picture of a 1 MC capacitance bridge. This bridge will be used to evaluate the electrical characteristics of NPO ceramic capacitors and perform some diode measurements.

Figure IV-5 shows a transistor test set. This test set will be used to test "h" parameters for transistors. Due to the low test rate required, the equipment will be set up and operated manually. Test results will be read on the meter.

The Beta test set shown in Figure IV-6 will be used to determine "Pulse Beta" characteristics. This is one of the equipments used for the "Special Test Station". Capacitance, high frequency beta, noise figure, power gain and power output will also be measured at this "Special Test Station" using various equipments.

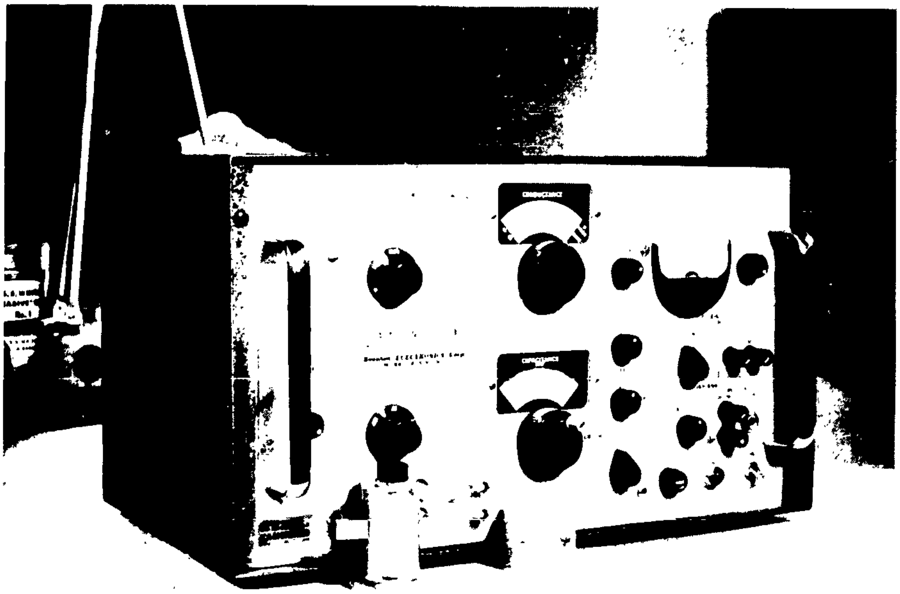

Figure IV-4. 1-MC Capacitance Bridge

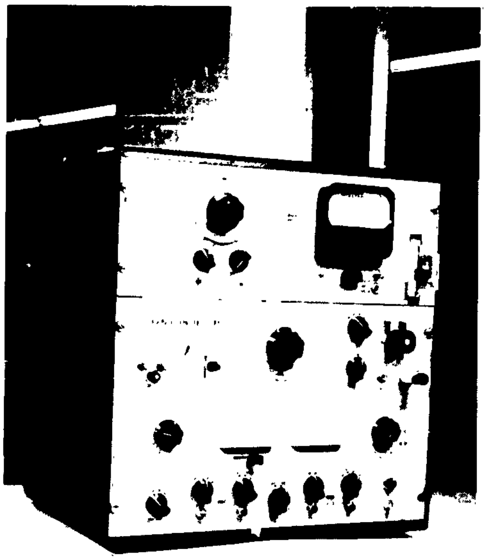

Figure IV-5. Transistor Test Set

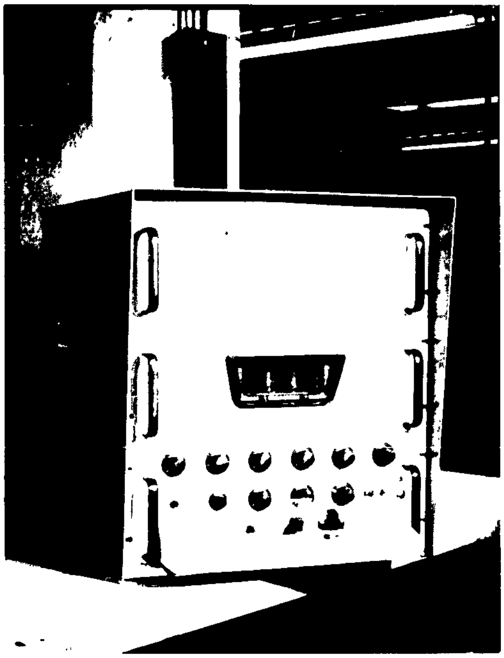

Figure IV-6. Beta Test Set

The resistor test set shown in Figure IV-7 combines a resistance measuring device and a current noise measuring device.

The equipment used to check incoming products will be calibrated by the semiconductor and materials division standards laboratory. The standards laboratory traces their standards directly to the National Bureau of Standards. Equipment is continually being circulated through the National Bureau of Standards as required by military specifications.

The calibration control schedules, used to insure that all equipment is properly calibrated, is maintained as shown on the chart of Figure IV-8, which is a picture of one of the actual charts used in the quality control operation. Each piece of equipment is listed on the left. The empty circles show when the gear is due for calibration, the black circles show that the calibration was performed. Calibration stickers are firmly attached to each piece of test equipment, including micrometers and calipers. The chart is conspicuously posted in the incoming inspection area.

This completes "Defect Detection."

Let's now turn our attention to "Defect Correction."

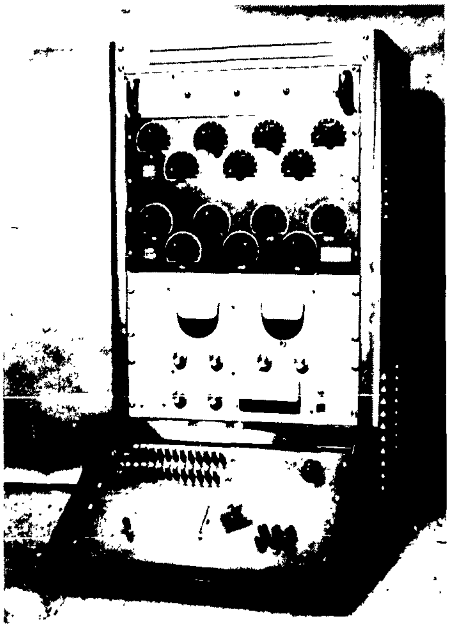

Figure IV-7. Resistor Test Set

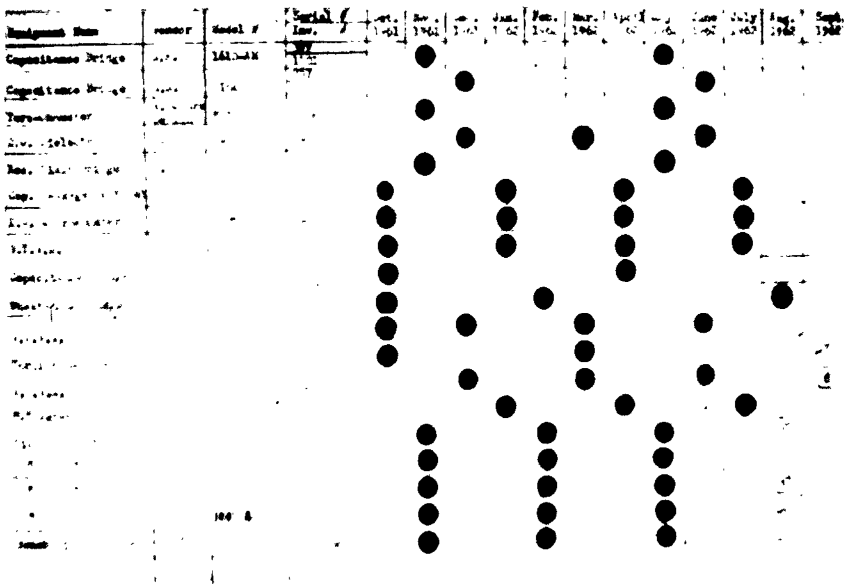

Figure IV-8. Equipment Calibration Schedule

Those of you who have worked with us in the past are familiar with the techniques used by RCA to assist in correcting problems. Every effort is made to determine the exact defect reason. The information obtained is fed back to you in order to initiate corrective action.

RCA facilities have been used extensively to help define failure modes and pursue corrective measures. Primarily, however, defect correction must be accomplished by you. Experience has shown that certain basic problems exist with respect to defect correction. Most discrepancies can be attributed to one of the following items:

1. Test equipment correlation

2. Misinterpretation of specification requirements

3. Mistaking "firm specifications" for "objective specifications"

The first item, test equipment correlation, can rapidly be corrected by continual exchange and measurement of correlation test samples. If you suspect that this is a contributing factor to your quality problems, we will gladly establish correlation procedures to aid your product evaluation.

The second item, misinterpretation of specification requirements, is more difficult. Every attempt is made to generate specifications which are concise and definitive. Considerable effort is spent in pursuing this objective in order to help you to know our exact product requirements. The rapid feedback of rejection reasons is intended to surface problems of this nature rapidly. It is felt that these areas can be recognized readily if the reason for rejection is not understood immediately. Specification revisions and changes will minimize these problems as our products mature. Let's not hesitate to discuss specification requirements thoroughly when there is even a remote doubt as to the intent. Misinterpretation costs money. Expeditious effort in this area can be most beneficial.

The third item, "mistaking firm specifications for objective specifications", can best be dealt with as follows. RCA considers one of the main keys to good quality to be "realistic specification - rigidly enforced." With this firmly in mind you must consider that the specifications you receive are "firm specifications" unless otherwise noted in writing.

Correction of the defect brings us a long way towards our objective. Correction however, must be followed by defect prevention in order to minimize expending effort continually pursuing the same problems over and over. The same basic techniques outlined here must be used throughout your operations. You must establish defect detection, defect correction and defect prevention on purchased material, in-process parts, and the finished product.

Finally let's review some past history and identify from it some costly errors that must be avoided. Figure IV-9 contains charts of actual problems that occurred

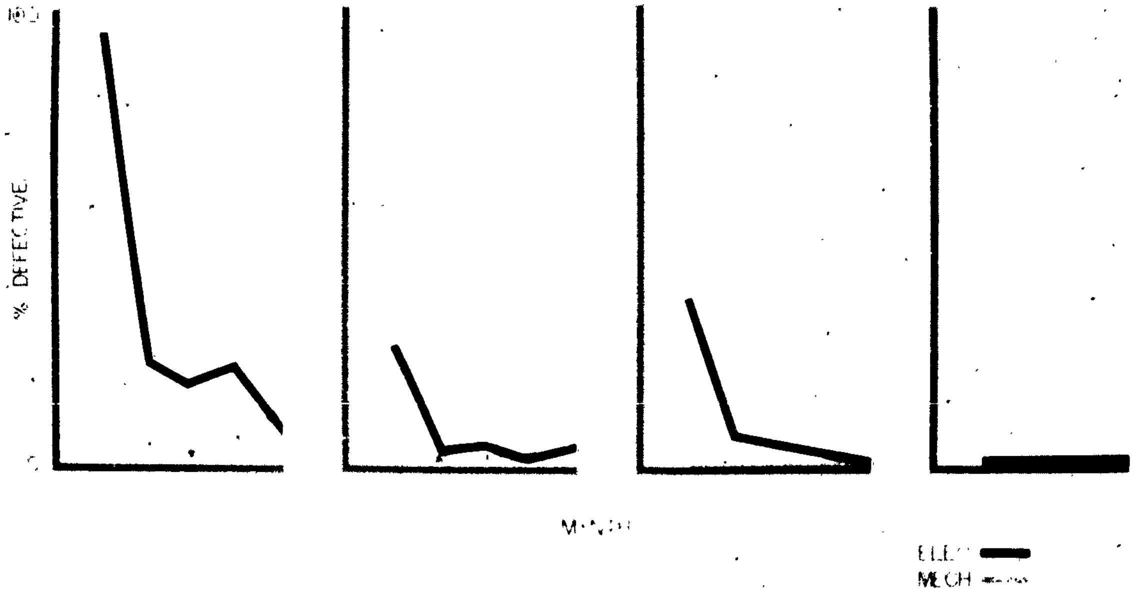

Figure IV-9. Quality Control Vendor Ratings

during the "final phase" of the program. The chart on the left depicts a vendor whose product was very good mechanically and very poor electrically. Concentrated emphasis on electrical criteria produced significant improvements of the electrical characteristics. This, however, permitted less effort to maintain adequate mechanical characteristics, with the results shown on the chart.

The second chart from the left illustrates a vendor who recognized his problems very early and corrected them. Following the best shipment, however, note the immediate rise in % defective product. Management effort had been focused on more troublesome products during this period. Considerable costs were incurred in regaining control.

The third chart from the left illustrates the response of a mature organization. Controls were established to prevent slippage of the mechanical characteristics while engineering effort was directed toward resolving the electrical problems.

The last chart depicts our PEM objective of controlled product quality. In pursuing this task, three things must be kept in mind:

That disciplined controls are required.

That there are no short cuts.

That we must professionally pursue and meet this objective.

V

TEST JIGS AND FIXTURES

R. A. FELMLY — *RCA*

R. RAGAN — *MICROLECTRON*

V

TEST JIGS AND FIXTURES

R. A. FELMLY
RCA

INTRODUCTION

- As many of you have discovered, the handling and effecting of electrical contacts to a microelement wafer requires an entirely new generation of test fixtures and techniques. The lack of the convenient leads and durable coating of conventional components, and relative fragility of the new parts call for much more sophisticated handling means than hereto were necessary.

- Microelement handling devices must generally permit positive contact with any and all of the twelve terminal areas of the wafer, provide a carrier for transfer of the part between test stations, permit multiple handling and testing of wafers, and adapt to mechanized test facilities.

- Fortunately, although I assure you it was by plan, the handling of the finished micromodules is as simple as plugging in a tube and responds generally to socket approaches. Adaptations to meet test arrangements is thus a relatively simple matter.

DEVELOPMENTAL HISTORY

It is interesting to take a look at the geneology of microelement fixture development. The first successful jig (Figure V-1) was simply a clamping device with two fingers to rotate and settle on the proper lands. This was a standard during early work on the program and, as a matter of fact, one or two are still in use.

Next (Figure V-2) came the early attempts to provide a cage to contact all notches at the same time--a marvelous idea but not as simple as it looks. As shown in Figure V-3, each contact was individually pivoted, however, it was difficult to keep the springs and flexible wires between the pivot and base intact. In addition, insulation resistance problems arose.

Following this came the teflon socket with a wire cage and compression contact shown in Figure V-4. The wafer was inserted with the cage open and it was closed by lowering the teflon ring which put each wire under compression. This fixture was quite successful and in particular resolved the insulation resistance problem.

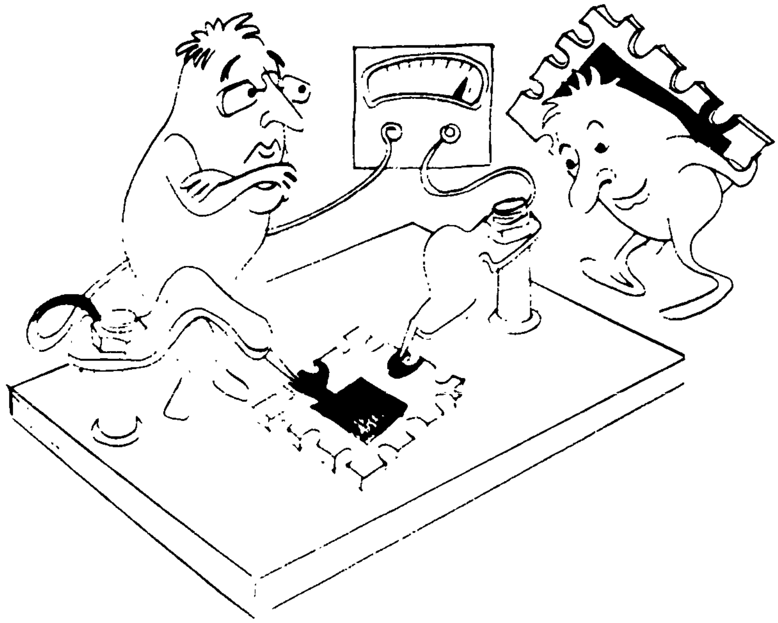

Figure V-1.

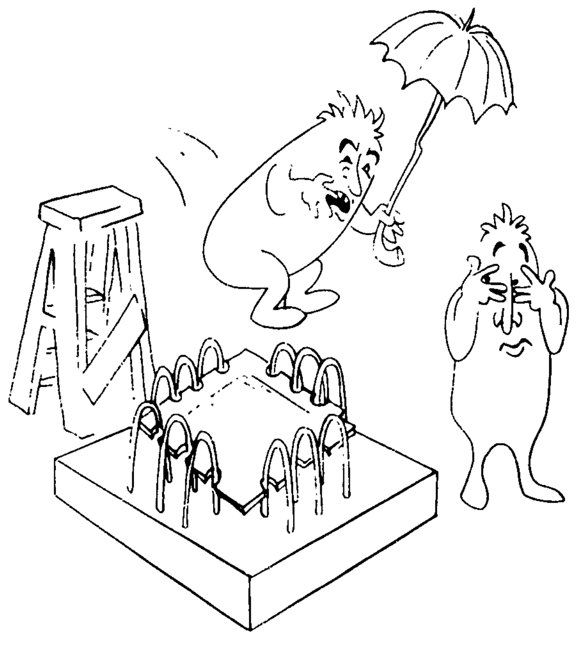

Figure V-2.

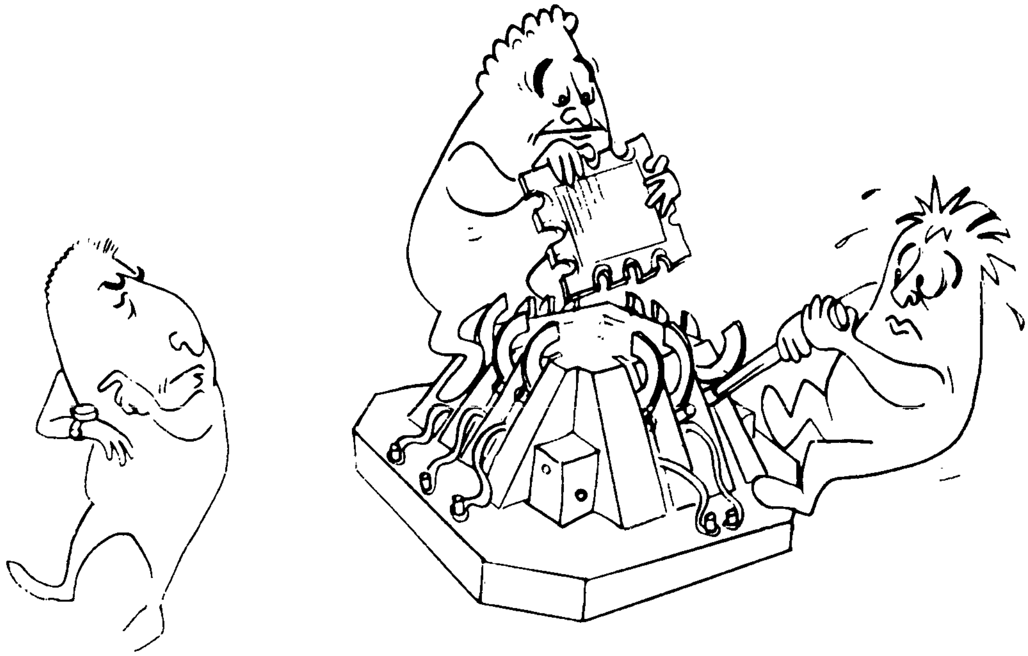

Figure V-3.

Figure V-4.

About this time the Jettron Co., who had become interested in the problem, proposed a socket (Figure V-5) which overcame the faults of previous types and could be produced for a reasonable cost. This socket provides a wire cage which can be expanded by inserting a plug. The wafer placed on the top of the plug is withdrawn into the cage and held by the spring pressure of the cage wires which are released after the plug is withdrawn.

Adaptations of the teflon and Jettron sockets are in use today.

Early module connecting fixtures were of the laboratory type (Figure V-6). But this was soon replaced by a plug-in type featuring spring contacts shown in Figure V-7. Today's socket is a further refinement, Figure V-8, featuring spring type contacts with wiping action. This is also a Jettron socket.

PRESENT SOCKETS

This brings us to the present state of the art.

The Jettron wafer socket is now used extensively by RCA for microelement measurements. These sockets are easily adapted to various test equipment applications both for laboratory type measurements and for production testing. The most common type, Figure V-9, utilizes a printed board with suitable card connector. Others are mounted on tube sockets for chassis type mounts. Special mounts incorporating switches to connect to multiple element wafers have been improvised.

An interesting adaption of 10 sockets permits individual testing of 10 microelements of the two terminal variety in one set up. This is accomplished by turning or flipping the wafer to obtain the necessary electrical division between the active terminals. The printed wiring of the board shorts all terminals together except for one edge gap and one corner gap permitting contact to any desired two terminals. This type is not 100% adaptable to polarized units and the effect of longer conductive paths must be considered for effects on dissipation factor of capacitors, on low value resistors, etc.

These sockets are easily and quickly loaded or unloaded through use of the spring-relieving plug which raises or lowers the wafer in the cage. These sockets have acceptable electrical and mechanical characteristics up to 125°C use. They are not recommended for use at higher temperatures and suffer from loss of spring tension from prolonged use at 125°C.

A printed board adaptation similar to that shown in Figure V-9, but using Elco terminals will be used in conjunction with the PEM contract test equipment. Immediate plans call for transfer of wafers from magazines to socket by hand with the socket plunger power-actuated. The present test rate of approximately 2000 elements per day can be handled on this basis. Automatic transfer of wafer from magazine to socket is now in the planning stage. For both laboratory and production testing the socket will be used as the carrier for the microelement wafer during the test sequences which involve several separate equipments or test set ups.

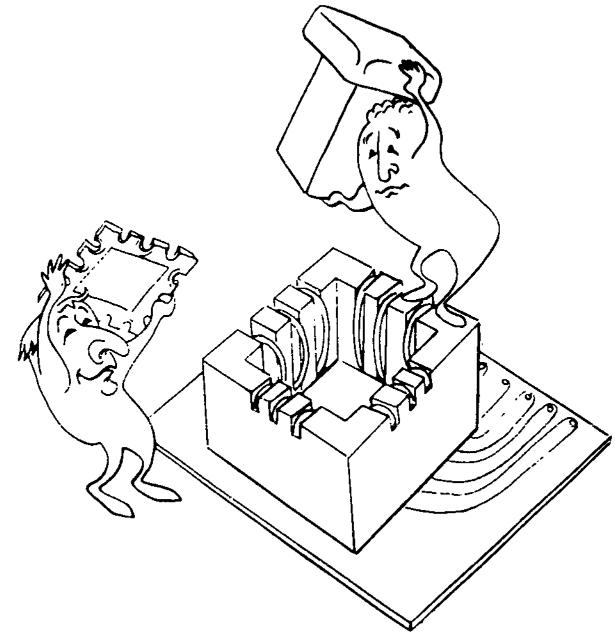

Figure V-5.

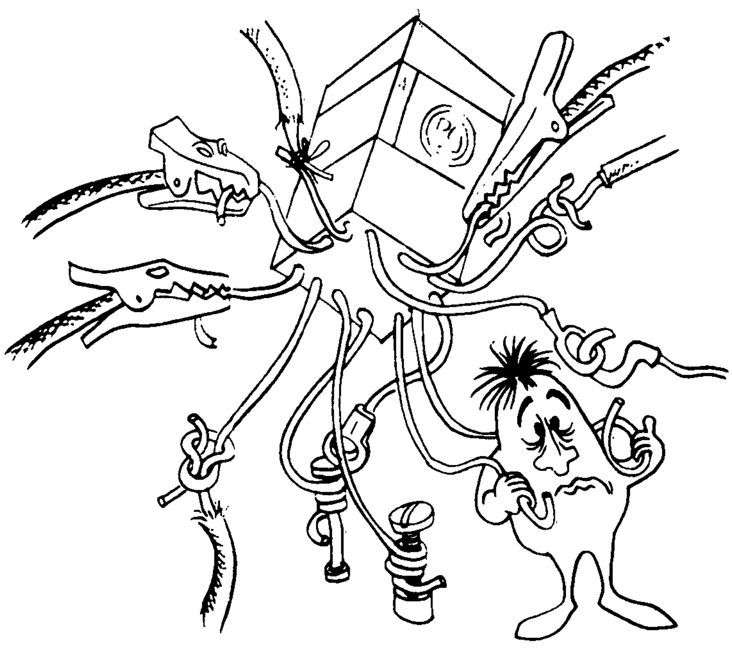

Figure V-6.

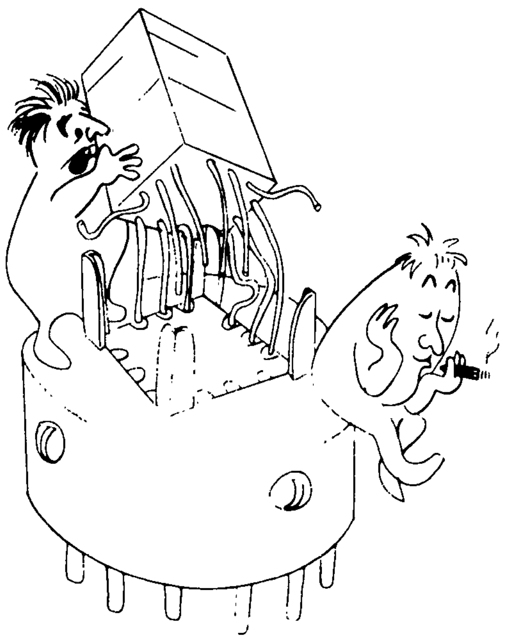

Figure V-7.

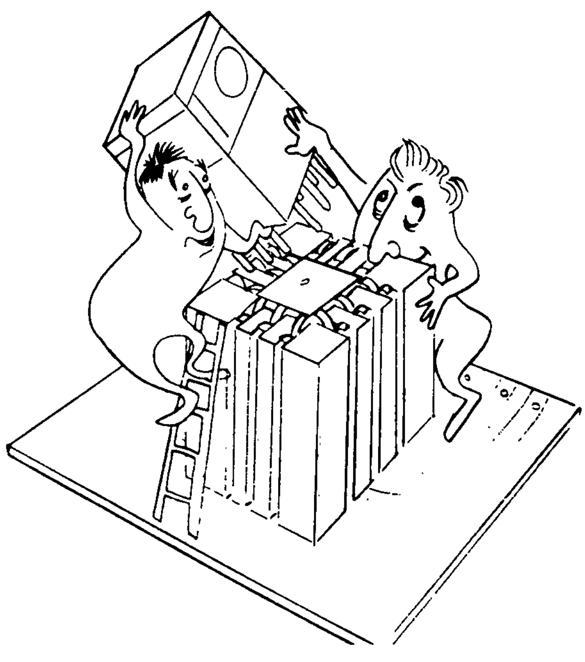

Figure V-8.

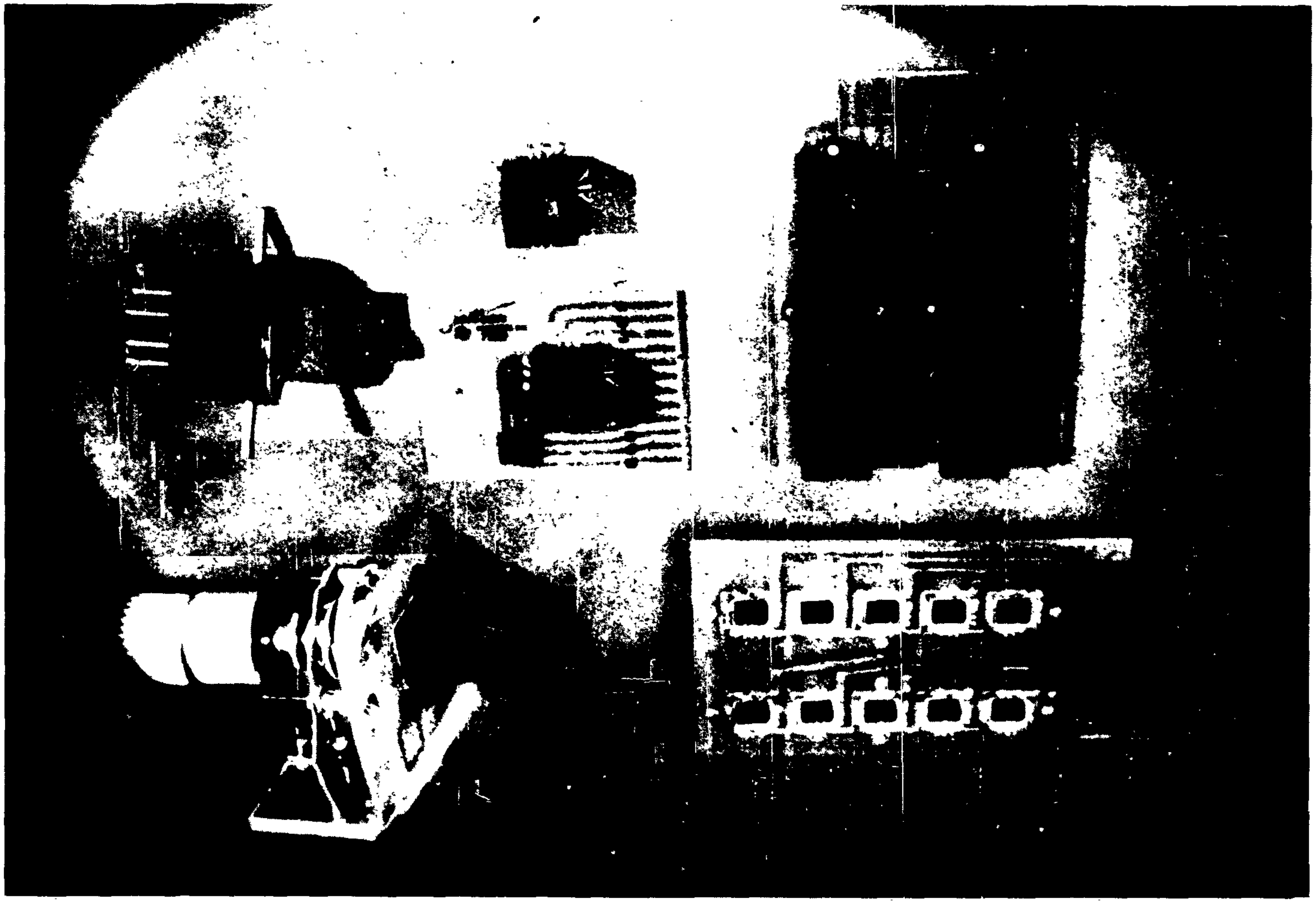

Figure V-9. Jettron Test Sockets on Printed Circuit Board

Experience has shown that a frequency limitation of approximately 1 KC exists on printed-board sockets. Above this frequency more direct connections to the socket are used or the leads are tuned. Capacitance measurements on random pairs of socket leads are in the magnitude of 0. 7 pf. Contact resistances vary due to shape of notch metallizing and pressures and are an influence where resistances below 25 ohms are involved. More critical applications respond to special techniques depending on the problem.

The Strato Tool Co. produces the teflon socket shown in Figure V-10, which is also easily adapted to test equipment applications. This socket is also provided in a plug-in style or special adaptations. Its primary advantage is its suitability to temperature above 125°C although it too will lose spring tension in prolonged exposure. It has also been used for insulation resistance measurements due to its very low leakage paths. While not as durable as the Jettron unit and considerably more expensive it does serve special test requirements.

The socket is easily loaded or unloaded by raising or lowering the clamping ring which applies pressure to the cage wires.

For module connections the Jettron module socket is preferred by RCA. This socket which may be seen in Figure V-11, is a very flexible unit, adaptable to various fixtures and equipments. For production testing, single sockets are mounted on circuit adapters for use on the universal digital or communication module consoles. Other adaptations include tube-base mounts and special types for testing microelement test modules where switches provide universal communications. These sockets are easily loaded or unloaded and also have good electrical and mechanical properties up to 125°C. Unlike the microelement socket, these are easily maintained or repaired.

Figure V-10. Strato Teflon Test Socket

Figure V-11. Jettron Test Socket, Showing Various Applications

TEST JIGS AND FIXTURES

R. RAGAN
MICROLECTRON

Microlectron has developed a system to facilitate the handling of wafers which may be of some use to those who may have handling problems in getting the wafers in and out of test fixtures. The initial concept was based on the adaptability of Microlectron's procedure to a two or three-phase operation. It was known initially that we would be making small quantities of a wide variety of resistor microelements, and that there would be an intermediate phase which would require rather extensive tooling. Also, it was desirable to make this system compatible with what would be developed at a later date to provide a fully automatic straight line operation for making microelements.

Microlectron's system is based essentially on the use of a work-holder, Figure V-12, which contains ten cavities which can, at a later date, be hooked in series or run on a continuous belt on the same spacing and using the same holding capability. Several varieties of these are used, one of which is illustrated here. The one at the top is used as a printing device. The cavity is 0.010 inch thick, the thickness of the wafer, and it contains a vacuum hole in the center. The work-holder moves through a channel beneath the screen which is our primary method of production and, as it arrives under the screen, a vacuum chamber is opened beneath the work-holder and the part is held in place during the printing operation. Then the part is indexed over to the next notch and the same operation is repeated. One thing that can't be seen in this figure is a ratchet notch which appears along the edge of all of these parts; this may be seen in Figure V-13.

The two parts on the bottom in Figure V-12 are identical and are used in our inspection department. The cavity in this case is 0.018 inch deep to accept a wafer which has been completed and solder coated; this depth maintains a proper position for the part during the inspection procedure.

Figure V-13 shows the work-holder in use in a read-out receptacle, and the ratchet notches that appear along the edge; these are all very precisely spaced and are within 0.0005 inch of the right position with respect to all edges of the wafer on top. The work-holder slides under the receptacle and, in effect, this is exactly what is done in a printing operation. It is a much more elaborate fixture, but the screen would be positioned where the receptacle is shown in this figure; it would be held in that position and printed, then indexed forward and printed again. The receptacle actually contacts the top of the wafer only, and with a relatively gentle touch, so that there is no mechanical damage or hazard to the part. The receptacle then is plugged into the programming circuit inside the equipment.

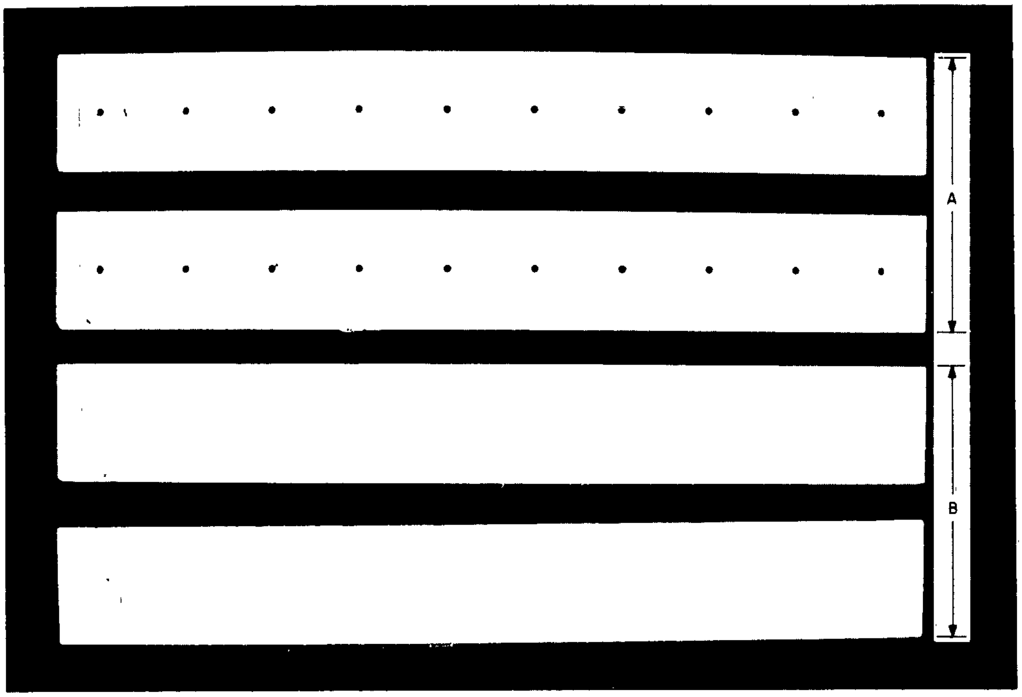

Figure V-12. Work Holders (A, Printing Type; B, Inspection Type)

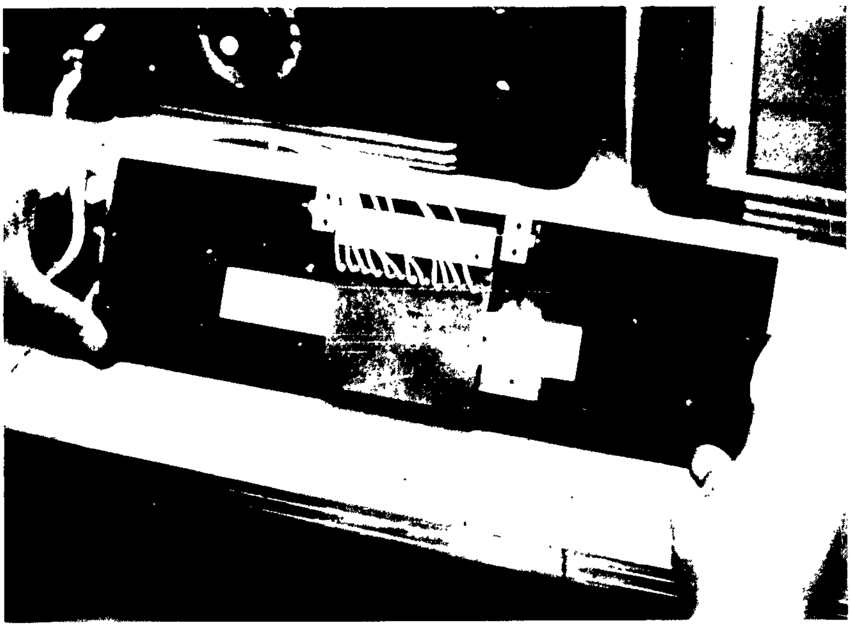

Figure V-13. Receptacle and Work Holder

Figure V-13 shows a very rudimentary receptacle that Microlectron built; modifications have been made to this device which provide automatic advancing mechanisms which pop the terminals up in the air, get them out of the way, then move the work-holder forward one notch and drop it in place again. The device shown here is held in place by two magnetic latches; it can be moved in two planes for adjustment and alignment, so that the fingers can be brought very precisely into position over the solder-coated land. These will run heel and toe in the advanced designs, which consist of a long continuous channel through which the work-holders proceed, one behind the other. In the inspection department they are taken in groups of 50, which include five work-holders, and a complete record of what happened to those 50 parts is maintained. That data is available for a later examination in the event that there is some trouble in RCA's incoming inspection department.

Figure V-14 shows the same receptacle in position in initial systems read-out station, which can simultaneously apply a short-time overload to all four resistors on a wafer. It provides a visual read-out and will record that information on a tape. The tape is torn off and then accompanies that particular work-holder through the rest of the process. A small program panel enables placement of the proper resistors in the circuit; a timer supplies the short-time overload for five seconds and the overload occurs through the switch when in the #5 position. Through positions 1, 2, 3, and 4, resistance is recorded.

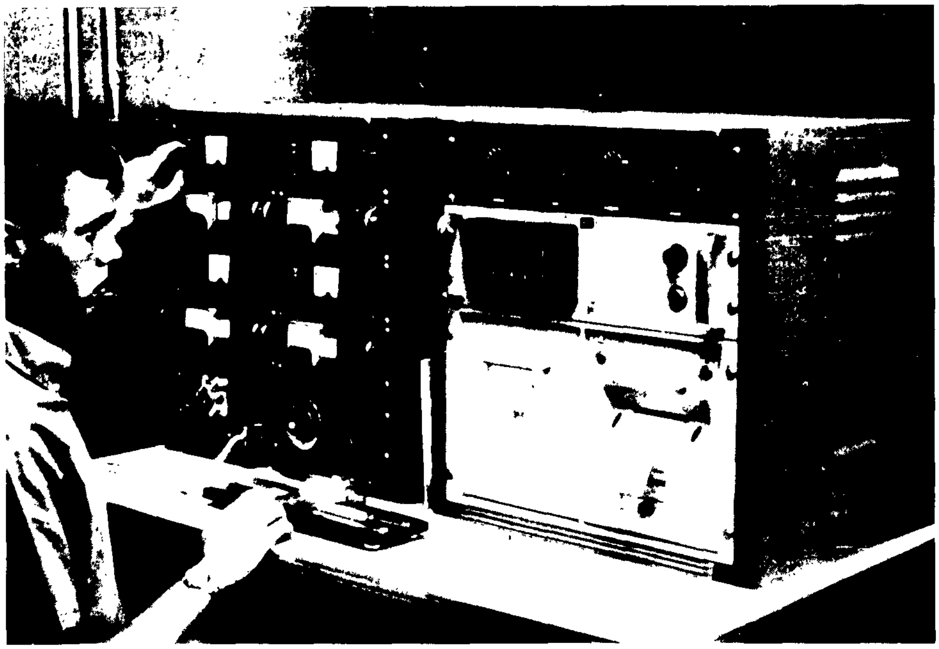

Figure V-14. Initial Resistance and Short-Time Overload Test Station

In Figure V-15 may be seen the insulation-resistance test station, which includes a program panel, the same read-out fixture, and a circuit which automatically rearranges the internal circuitry to apply the signal across one terminal to the other eleven, shorted into the same circuit. With 100 volts applied, a resistance greater than 10,000 megohms must be observed across each.

The dielectric strength tester is essentially identical to the insulation resistance tester except that this equipment is simply a high-pot tester. Those who have dealt with this problem will remember that the specification calls for one minute dwell at each of these test points; a total of twelve minutes. Needless to say, only forty parts could be processed in a day through the production line if the test were used as indicated. It has been proposed by Microlectron that, by using 600 volts ac and 1.5 seconds dwell time on each station, the part will, in effect, be processed in 18 seconds which is a satisfactory rate.

Figure V-16 shows Microlectron's noise-test station, a standard Quan-Tech noise meter which has been especially adapted to measure down to 10-ohm resistors. On the base of it, a circuit has been modified for programming the proper resistor through two switches. This receptacle also is standard, except that it is specially covered with a shield on top and bottom; the figure depicts the operator using a knurled knob which is an advancing mechanism. As the knob is turned, the receptacle lifts and gets the fingers out of the way, then the part advances and drops into the next notch. This equipment has proved to be a very useful research and development tool, but not an adequate production control tool. The desired degree of correlation between noise measurements and load-life expectancy have not as yet been achieved. However, potential resistor-path failures can be detected and removed; if the meter shows an abnormally high noise figure it will indicate a faulty connection, a thin place in the resistor, or something of that sort. The faulty microelement is then examined under a microscope to determine the source of the noise.

In Figure V-17 may be seen the final resistance test station which is identical to the starting point. A visual read-out is obtained, the information is recorded and by means of a program board, we can switch through the four individual resistor stations using the same receptacle.

The visual and mechanical test station is shown in Figure V-18; here too, the work-holder is used to hold the part. For this application, though, a vacuum pick-up has been added so that tweezers are not used at all. The nozzle of this device is made of polyethylene to preclude any possible scratching hazard to the surface of the wafer. The knurled knob permits the operator to rotate the part under the microscope and inspect all the notches sequentially. She can release the part by simply pushing, in a downward direction; this breaks the vacuum and allows the part to drop back into the receptacle.

In addition to the normal light that is visible on top of the wafer in Figure V-18, a light source is located underneath and the light is reflected upward. A wafer that might look very good where reflected light alone is used may be distressing when observed using the transmitted light. The part doesn't look quite as pretty this way, but the method is very good for detecting cracks and potential discontinuities in a resistor path. If there is a scratch in the surface, it will show up very dramatically as a streak of light through the normally dark resistor path.

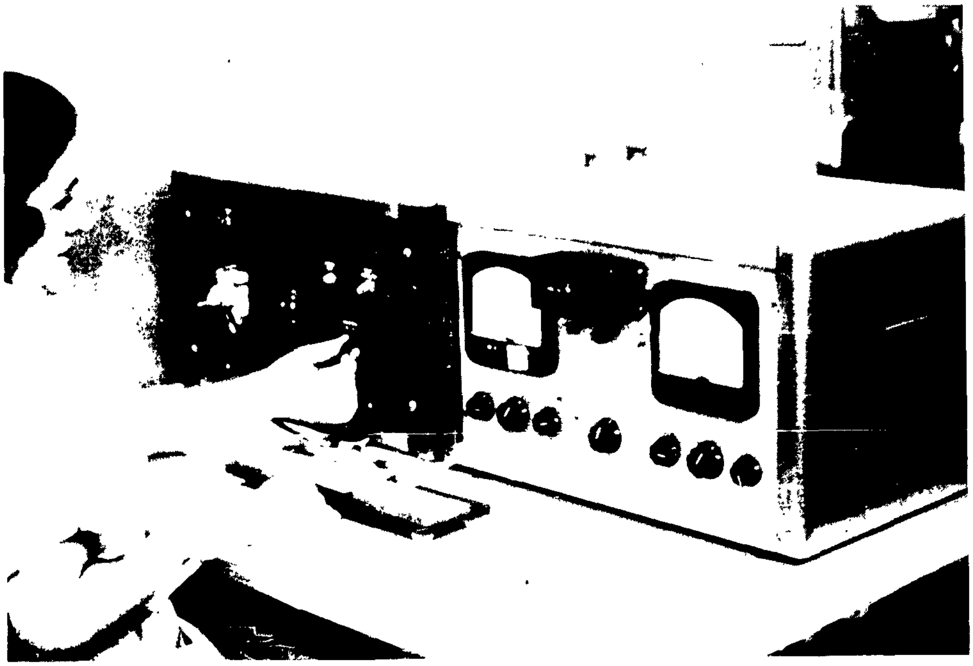

Figure V-15. Insulation Resistance Test Station

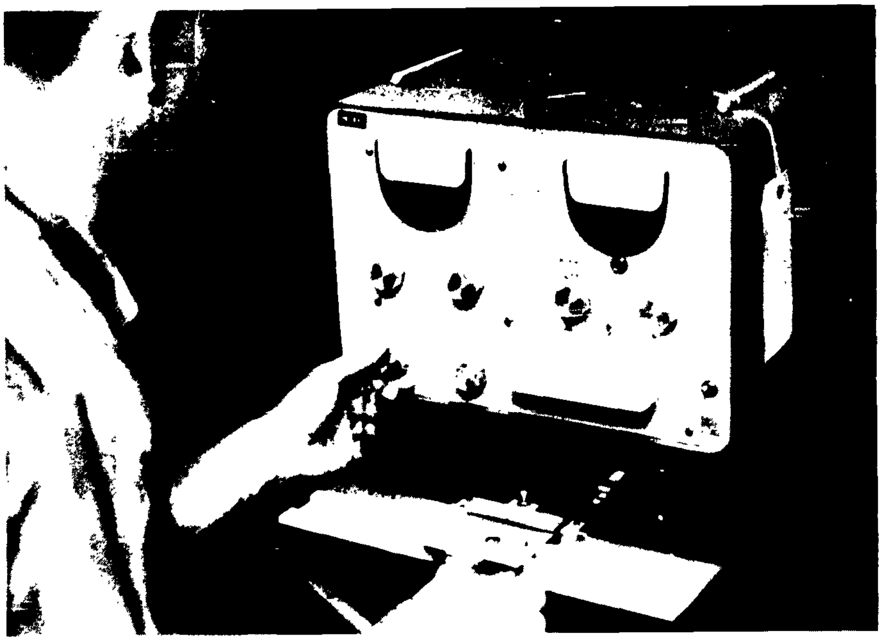

Figure V-16. Noise Test Station and Receptacle

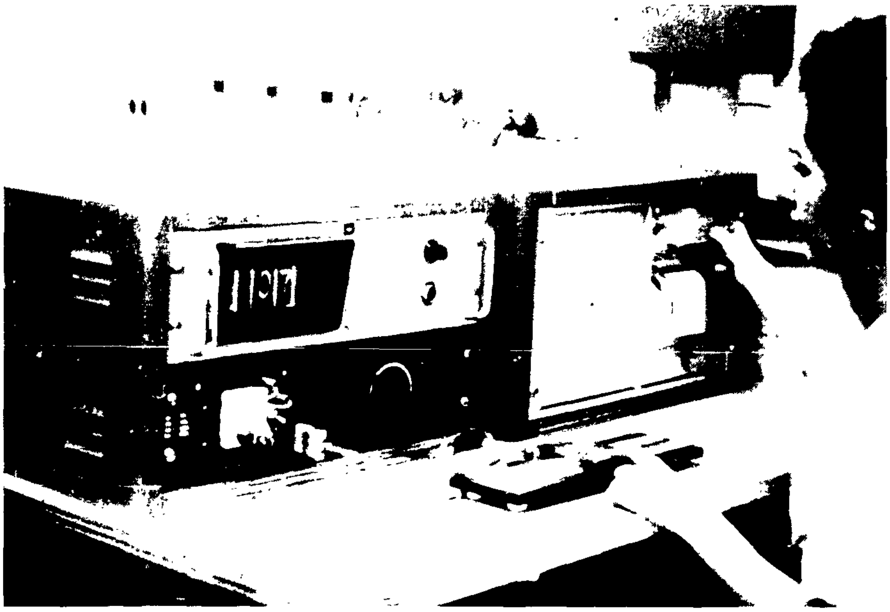

Figure V-17. Final Resistance Test Station

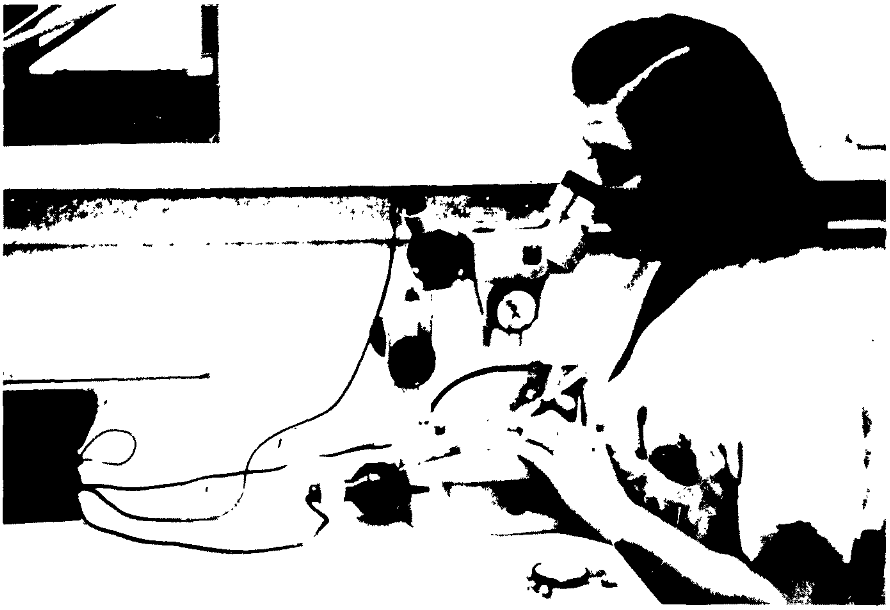

Figure V-18. Visual and Mechanical Inspection

In addition to inspecting the integrity of the resistor path, the operator is also checking the quality of the solder - whether it's continuous from land to notch, whether the notch metallizing and soldering meet the specification, and whether there are any problems with the dimensions. Normally, the dimensions are arranged so that they are right in the middle of the allowable spread; consequently, there seldom are any problems in this respect. If a part looks abnormally large or small, it is examined on an optical comparator to verify its conformance with, or deviation from the applicable specifications.

Figure V-19 shows the load-life test set-up which, when fully operational will have a capacity of 1000 micro-modules under load-life test at any particular time. The current to each resistor under test is monitored using an elapsed time indicator and a clock programmer, which regulates the power applied: 1.5 hours on and 0.5 hour off. The various networks which distribute power to the resistors in the drawer, and the power supply itself, can be seen in Figure V-19. In the future, a recording device will be added which will monitor all the temperatures and voltages inside the oven.

A finished wafer, resulting from this system, is shown in Figure V-20. This is an earlier version which does not comply, in this particular wafer, with the current specification, where a bevel is supposed to come to a point at an edge. Later ones of course, have been modified so that the requirements are satisfied. The numbering shown here is just the part number; currently, there is, in addition to the part number, a date code which identifies that part by month and year. The parts are processed in groups of 50. The shipment is made to the customer in a box which contains 50 parts, minus those which were removed in various inspection points; the parts are normally placed in the container in the same order in which they were processed so the customer may, at any later date, go back and pick up the complete history of that part.

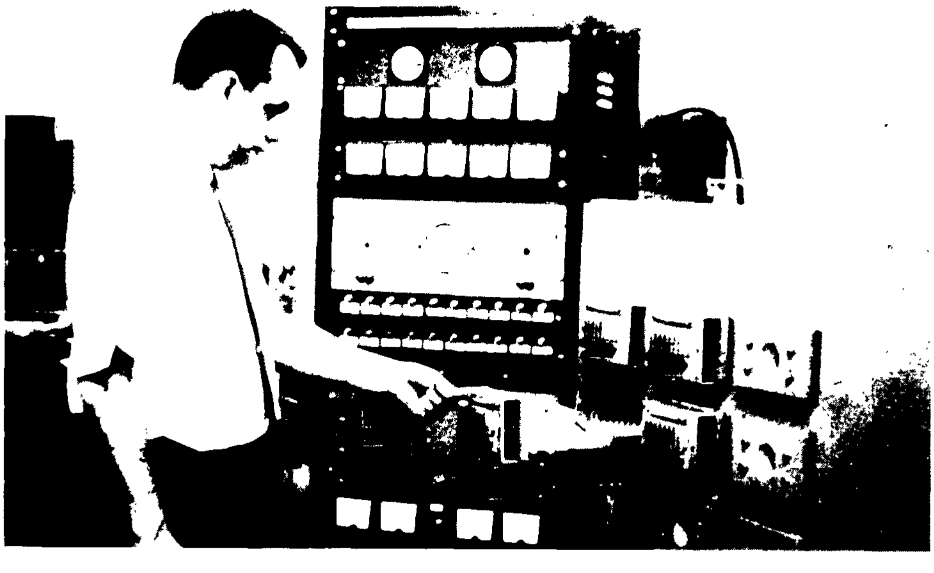

Figure V-19. Load Life Oven and Control Console

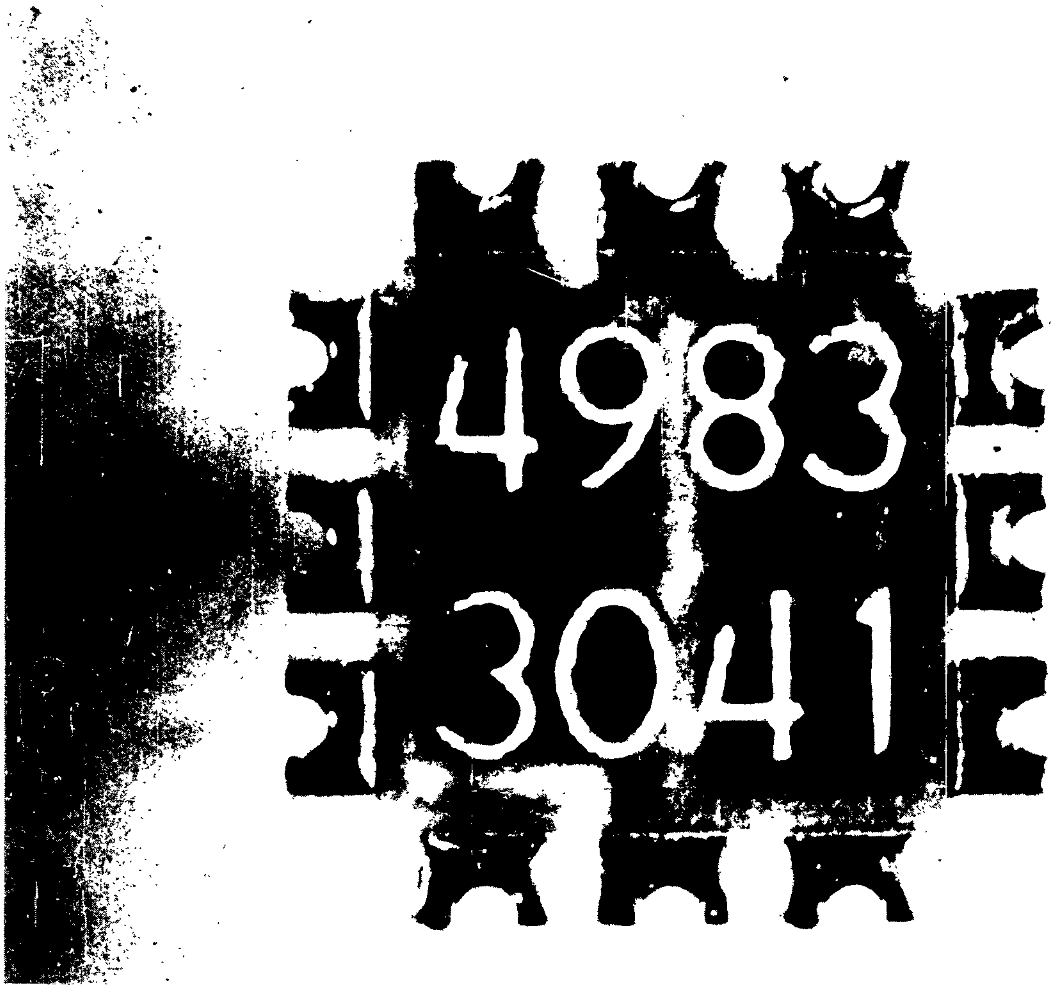

Figure V-20. Finished Resistor Microelement

VI

HANDLING OF MICROELEMENT COMPONENTS

O. E. ELMORE *P. R. MALLORY AND CO.*

VI

HANDLING OF MICROELEMENT COMPONENTS

O. E. ELMORE
P. R. MALLORY & CO.

MICROELEMENT MAGAZINE INTRODUCTION

The Mallory microelement magazines provide the means to protect and handle microelements in transport, storage, preassembly preparation and inspection; they facilitate semi-automatic visual and fully automatic electrical inspection and become an integral part of the micromodule assembly mechanism.

GENERAL DESCRIPTION

Figure VI-1 shows the magazine with covers closed. At one of the four corners, extending from one end of the magazine to the other, is a notch. This notch is provided so that a receptacle can be made whereby the magazine will only enter one way, thus eliminating the possibility for operator error.

The open magazine with all its parts laid to the side may be seen in Figure VI-2. The magazine is made using four parts: a molded portion, two covers, a hold-down strip, and a pad. The molded portion is made of general purpose phenolic and contains all of the slots in which the components are inserted. The covers are stainless steel with a plastic tape applied to the underside; the hold-down strip also is stainless steel. The pad is made of exploded polyurethane.

FUNCTION OF PARTS

The function of the pad is to immobilize the parts during shipping and handling. It was found during the testing that if the parts were permitted to move within their slots, some breakage would occur, and also magazine slot wear would result. To eliminate this, the pad has been provided to exert a light pressure on the edge of each microelement.

The hold-down strip provides the means for trapping the pad so that it will stay in place and not wrinkle when the cover slides on and off.

SIZES

Figure VI-3 is a photograph of one end of the magazine with the cover removed showing the slots. Microelements have infinitely variable substrate and overall thicknesses. It has been estimated that the majority of microelements will have a substrate and overall thickness less than 0.140 inch. The Mallory magazine will handle a total

Figure VI-1. Microelement Magazine Assembly

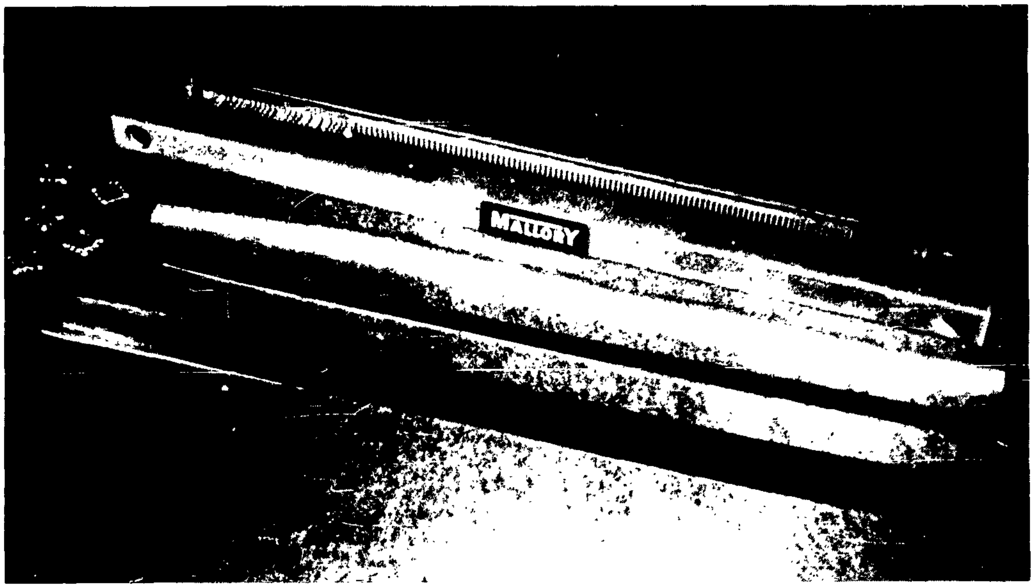

Figure VI-2. Microelement Magazine

substrate thickness, including metallizing and solder, up to 0.192 inch, and an overall height up to 0.225 inch; a reasonable safety factor over and above the estimated majority. The magazine will do this regardless of the increment in which the microelement increases in height.

To accommodate the various microelement thicknesses, eight different slot widths have been provided in the magazine design, so that eight magazine types will handle any microelement thickness up to 0.225 inch. Each slot width will cover a range of thicknesses so that microelements may be any thickness within that range. On the eight magazines, there are only four different center-to-center distances between slots --- they are 0.060, 0.120, 0.180 and 0.240 inch. This permits the equipment used in conjunction with the magazine to be set quickly to one of four discrete positions when a magazine change is made. Also, there is a common surface which is referenced from the lower side of the slots which is the same for all magazines; the magazine therefore always will be located properly in the equipment without further adjustment, regardless of which one of the eight magazines is used.

CONCLUSION

The Mallory magazine has been tested under Military Standard MIL-STD-202 "Test Methods for Electronic and Electrical Component Parts", using the most fragile components; those having 0.010 inch-thick "Hi-K" ceramic as the substrate material. No damage to these fragile microelements resulted from the tests.

Figure VI-3. Magazine, Showing Slots for Wafers

It is intended that the magazine be used as a shipping container, and as a handling device within the user's plant after receipt. The pad and the hold-down strip may be removed when the full magazine is stocked. At the same time, two edges of the micro-elements may be inspected visually. A broken microelement will readily be visible in the symmetrical line-up of microelements in the magazine. After the parts have been oriented 90° during testing or preassembly operations, the remaining two edges will be visible for inspection.

TEST AND ORIENTATION MACHINE INTRODUCTION

The Mallory Test and Orientation Machine will enhance the reliability and efficiency of any microelement facility by reducing the amount of operator handling, and by adding increased protection during magazine loading, testing and orienting.

DESCRIPTION

Figure VI-4 is a diagram looking down on the test and orientation machine. There are places to insert three magazines, numbered one, two and three; and a test socket, shown in the center. The magazine, full of microelements, is inserted at the number one station. This station is polarized so that the magazine can only enter one way thereby eliminating a possible error. The arrows indicate mechanical slides which move the microelements in the direction shown. Empty magazines are placed at stations two and three. Unlike the number one station, the magazines at stations two and three can be inserted in any one of the possible four positions. The capability has now been created whereby a microelement can be automatically removed from a magazine and placed in another magazine oriented in any of eight possible positions.

Two edges of the microelement were inspected upon receipt, while lined up like soldiers, in their respective slots in the magazine. With this magazine inserted at the number one station, the machine is programmed so that the mechanical slide, represented by the arrow on the left, moves the microelement to the test socket, lowers it into the test socket and initiates a "start test" signal to the adjoining test equipment. At the completion of the electrical test an "end test" signal is received. A "good" or "bad part" signal is also received.

If the check is satisfactory the microelement will be caused to move into magazine number two by the mechanical slide represented by the arrow at the bottom. This station has been chosen for good parts so that a visual inspection of the other two edges can be performed without handling individual components.

If the check is not satisfactory, the microelements will be placed in magazine number three. The mechanical slide on the left will move on across the test socket to station number three.

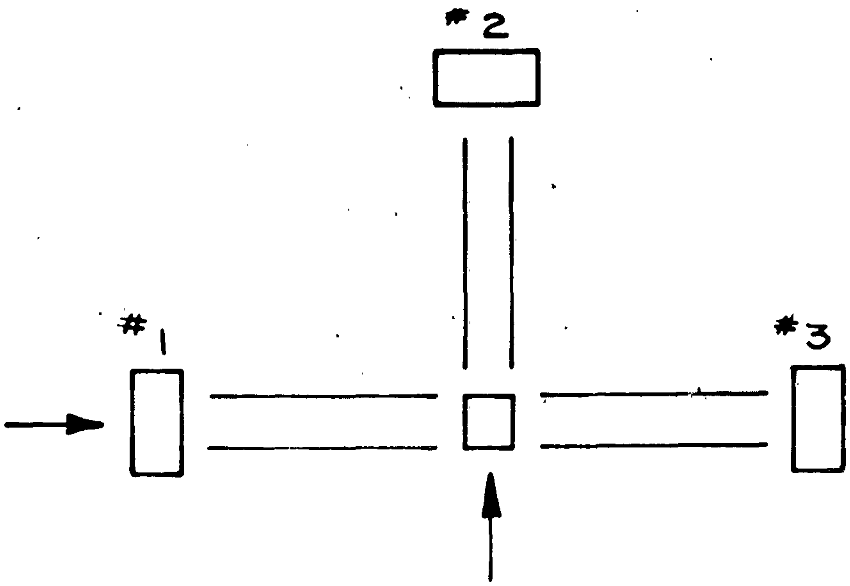

Figure VI-4. Top View of Test and Orientation Machine, Block Diagram

ORIENTATION OF MICROELEMENTS

When using the machine as an orientation machine the test portion of the cycle is omitted. The full magazine is placed at the number one station. An empty magazine is placed at station two or three; one station will not have a magazine. By leaving the one station empty the machine is automatically programmed to place the microelement in the magazine which has been inserted. Since the magazine can be inserted, at positions two and three, in any one of four different ways, we now have the capability for orienting the microelement in any of its eight possible positions.

Although the machine could be programmed to use number two or three for good parts, when testing, and thereby have the capability for electrical testing and orienting at the same time, it is the feeling that it would be more economical to standardize and always have the number two station for good parts. This approach permits visual inspection of the other two edges and the cost of orienting later is nil since the electrical test portion of the cycle would be omitted. Also it is reasonable to assume that the same microelement will be used in more than one module where the orientation will not be the same.

A LOADING MACHINE

This equipment can also be used as a means of loading microelements into the magazine by the microelement manufacturer. The microelement can be placed at the test socket and then placed directly into the magazine. The equipment can also be programmed to test and load by placing the microelement at the test socket and programming the machine so that the component will be caused to move into test position where it will be electrically tested and then caused to move into position in the magazine. While the microelement is under test, the operator can grasp the next microelement which is to be placed into the test socket for loading.

Figures VI-5 and 6 are photographs of the test and orientation machine which Mallory is now building.

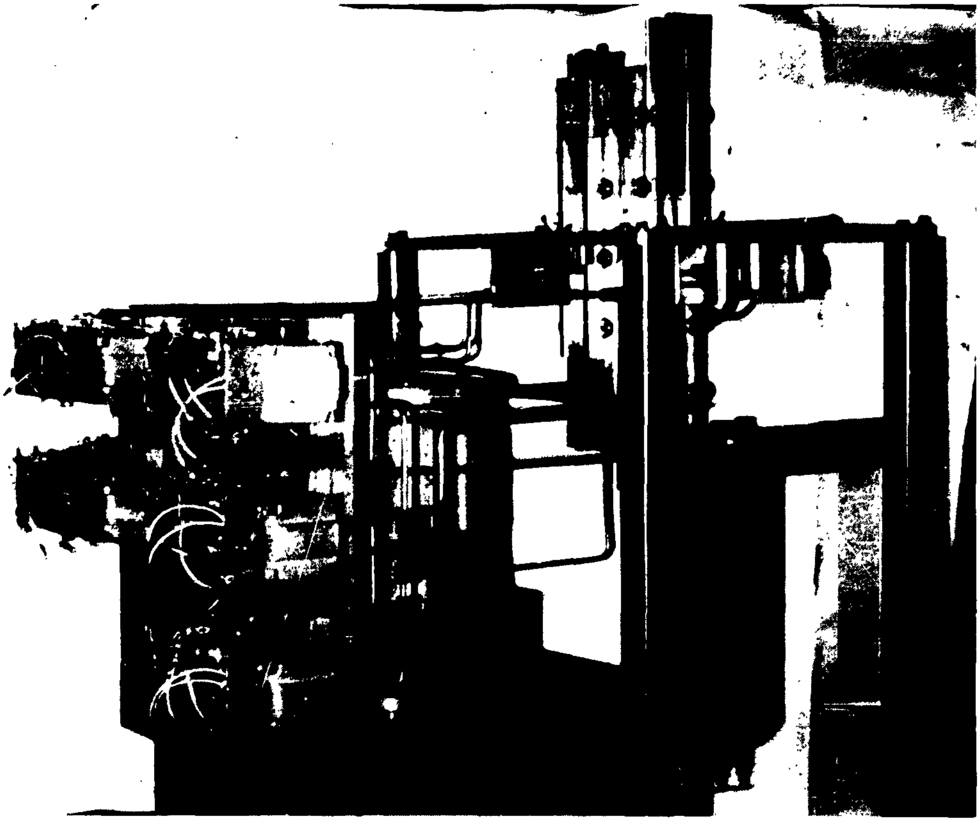

Figure VI-5. Test and Orientation Machine, Partially Completed

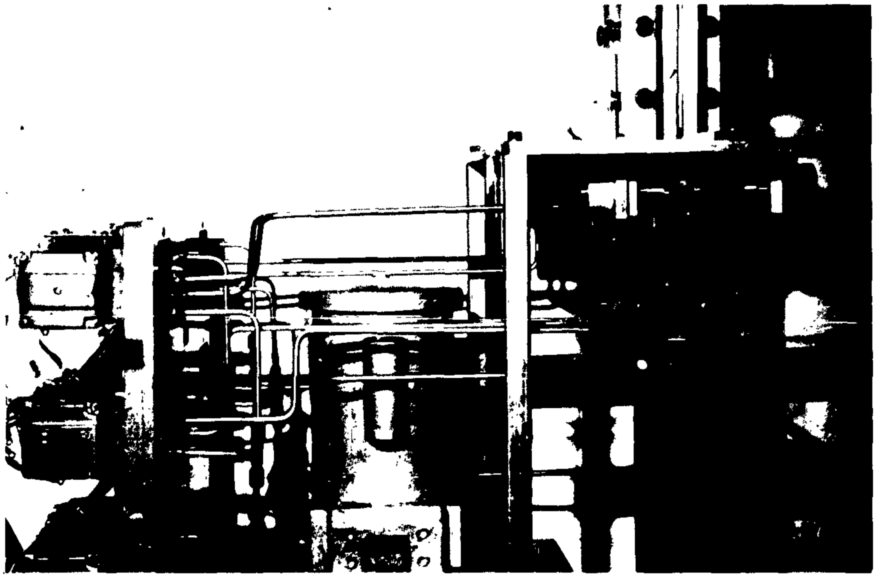

Figure VI-6. Test and Orientation Machine, Partially Completed

VII

SOME PROBLEMS ASSOCIATED WITH MEETING THE CURRENT "LAND AND LEAD" SPECIFICATIONS AND THEIR SOLUTIONS

W. OATES	*RCA*
J. CRONIN	*AEROVOX CORPORATION*
R. YOUNG	*SPRAGUE*
PROF. C. J. PHILLIPS	*RUTGERS UNIVERSITY*
J. LIKER	*MOLECULAR DIELECTRICS*
S. S. COLE AND B. A. SMITH	*MITRONICS*
D. L. KUHLKE	*COORS*

VII

SOME PROBLEMS ASSOCIATED WITH MEETING THE CURRENT "LAND AND LEAD" SPECIFICATIONS AND THEIR SOLUTIONS

W. OATES
RCA

Throughout the history of mankind, even the facts of life have been questioned. But although there are many people who would prefer not to discuss these facts, nobody concerned with the serious business of production can afford to ignore them. Much the same thing holds true for microelements, for it's a basic fact of life, that no matter how pleased you are with your particular device, its merit as a microelement can never rate higher than the performance of its termination.

"Land and Lead Specifications 492984" was created for the sole purpose of insuring good, uniform terminations, designed to fit quantity production methods and subsequent rigid field tests. The current revision thirteen is the result of considerable sweat, toil, and tears. But rather like the instructions for riding a bicycle, they make a lot more sense when you've seen other people trying it. Actually the requirements for sound termination are not difficult to understand, so long as you have a clear mental picture of a stack of microelements and not just one, single element. A particular unit can have any one of some fifty partners, on either side of it, and only seven mils away, the present average number of elements per module being about ten.

Microelement terminals are designed for soldering to the riser wires, and automatic machines process each side of the module in turn so that as many as forty-five separate connections are soldered simultaneously. In order to understand the practical reliability of this multiple soldering operation, let us assume that we have a stack of un-metallized wafers (Figure VII-1). You can see, that even when the stack is dipped quite deeply in the solder, the heavy surface tension will not wet the ceramic, and little, or no solder, will rise between the 0.010-inch gaps.

If the wafers are now metallized with solderable material and fluxed (Figure VII-2), the same stack formation will give quite different results with the solder being pulled up between the gaps; and if the metallizing is pre-coated with solder, not only are we certain of this wetting action, but a good production rate can be maintained without any sacrifice of reliability. If we now reconsider the first experiment with the plain substrates (Figure VII-3) and add some metallizing to form terminals, you can readily see that, unless the metallizing extends right up the substrate edge, the surface tension of the solder will not permit contact to take place, and no wetting of the metallization will occur.

We can now start to write a termination specification:

1. "All metallizing should extend to within five mils of the substrate edge, otherwise no soldering action will take place."

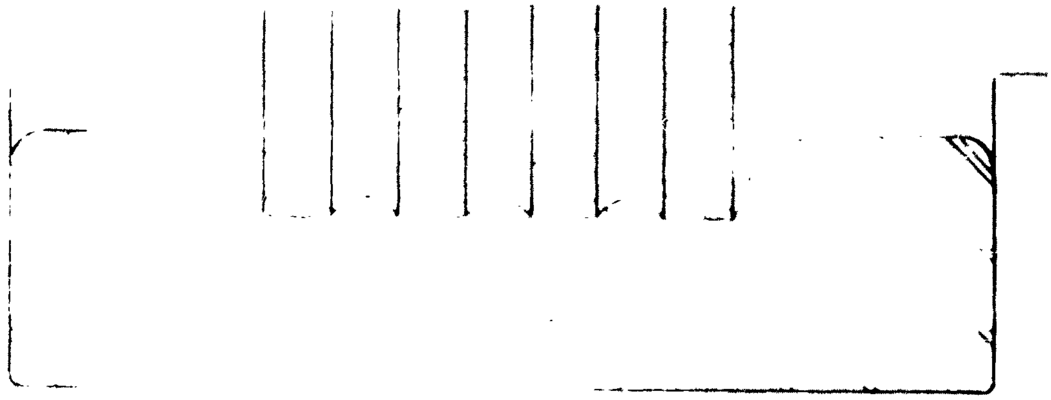

Figure VII-1. Unmetalized Substrates in Contact with Solder

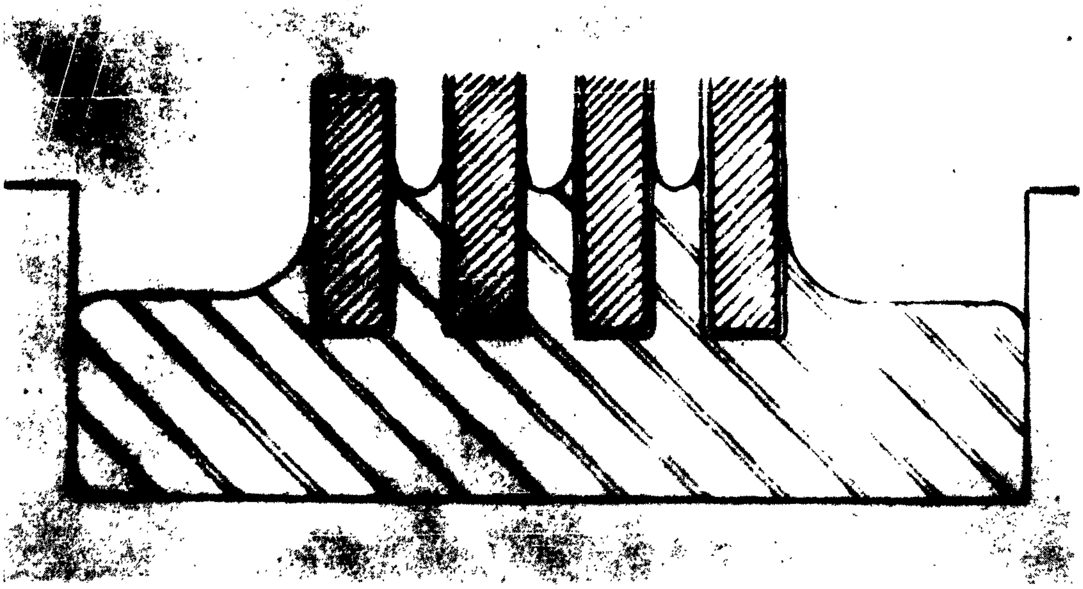

Figure VII-2. Metalized Substrates in Contact with Solder

2. "All metallizing should be pre-coated with solder to insure that it will solder with certainty at the required production speed."

3. In order to be sure of an adequate bond strength, we must give details of the temperature and alloy that will be used and specify a minimum pull test of 500 grams.

   We already have made considerable progress in writing a suitable specification for our needs. If we now turn the stack of substrates around (Figure VII-4) and consider the distance between terminals formed at the riser wires, picture the elements assembled and located in position by the twelve straight riser wires on the 0.075-inch grid centers. We know, as a result of experiments with the production machine, that it is not possible to solder-bridge two metallized areas if they are more than 0.010-inch apart.

So we can specify:

4. "That terminals must not extend more than 0.030-inch on either side of the grid centers." So that even with a random assembly of elements with maximum width notches in the extreme positions, the riser wire clusters of metallized substrates are always separated by 0.010-inch minimum.

   The riser wires are used for alignment purposes as part of the assembly process and must assemble freely in the notches.

So we must specify:

5. "Terminal notches must be free from excess solder," and as a practical test, we make it a requirement that all elements must assemble freely on a twelve pin gauge.

   As elements can be mounted on both sides of a substrate, they can also be connected to the terminals on opposite sides. But if the terminal lands of the same terminal are not connected to each other via the notch metallizing, a partial joint may occur during soldering which can cause a lot of fault-finding after assembly.

So we must further specify:

6. "At least 50% continuity must occur between the lands and notch areas of any one terminal."

These six items cover the general rules of metallizing, and as you can easily see, they are just plain common sense, nothing more.

Knowing the requirements for reliable termination is one thing, but the development of a practical, simple method of manufacture is quite another problem. However tempted we may be to relax these requirements because of the present state of the metallizing art, we can never compromise with module reliability.

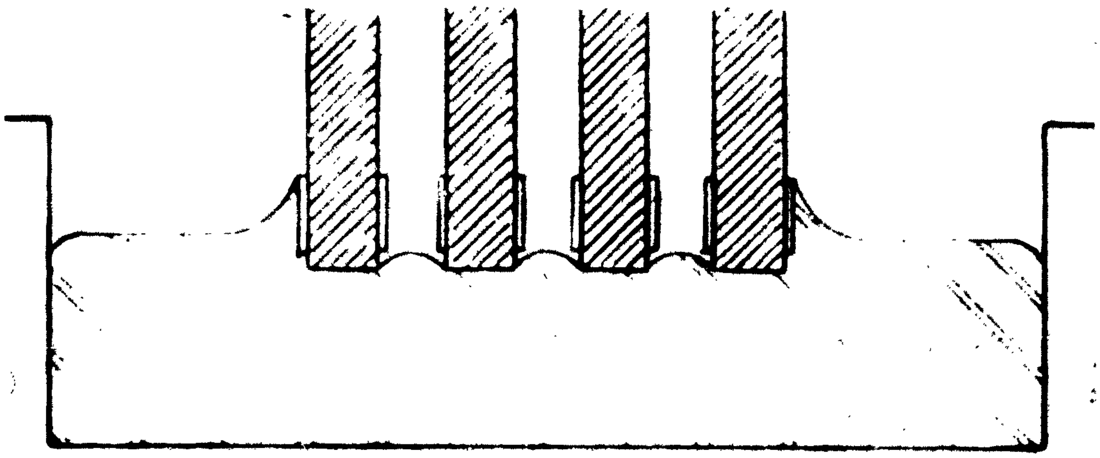

Figure VII-3. Insufficient Metalization in Contact with Solder

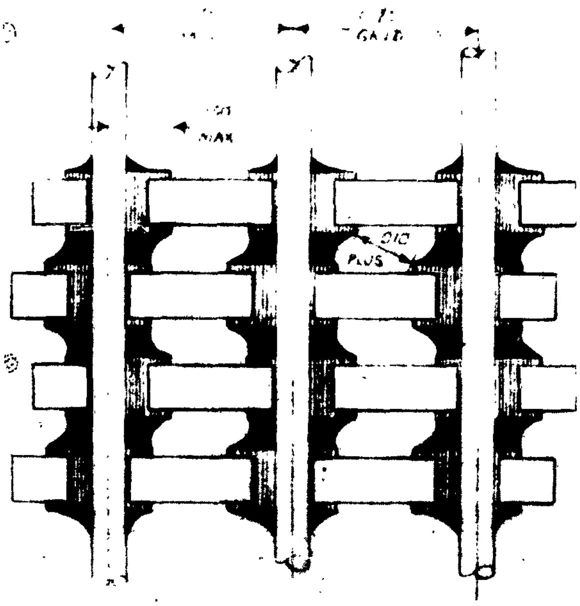

Figure VII-4. Terminal Dimension Requirements

Main Causes for Micro-Element Metallizing Rejections:

1. Metal spots and blemishes on non-metallized areas.
2. Poor silver metallization, with severe leaching at assembly and inferior bond strength.
3. Poor solder wetting properties, with inferior, patchy solder coating.
4. Excess solder in the notches. Elements will not assemble on pin gauge.
5. Metallized terminal areas located in excess of 0. 005 inch from the edge.
6. Land areas too wide; in excess of 0. 030 inch either side of grid.
7. Continuity between land and notch areas less than 50%.

The first item, "Metal Spots and Blemishes," was originally one of the major causes for rejection. It is still with us today but is rapidly diminishing with the improvement in facilitation brought about by our increased production demands.

The next item, "Poor Silver Metallizing," was another major headache. It has been responsible either directly or indirectly, for many module assembly rejections.

When we first started to make modules, silver metallizing was the only process readily available for substrate termination. The latent dangers of silver are not obvious from a visual inspection. Poor silver metallizing looks okay, and as long as there is no appreciable storage period and the soldering operation is performed quickly under ideal conditions, no apparent harm will result. But if the parts are not used immediately or the soldering operation is fumbled, or for any reason the parts have to be re-soldered (an occurrence that is not uncommon with modules built for engineering evaluation), then we are in real trouble.

When alternate materials can be used, we prefer them to silver every time, because silver is so susceptible to leaching or scavenging during the soldering operation, even with a silver bearing alloy. There are some elements where silver is the only apparent material that can be used. In these cases silver is acceptable, but the quality standards must be high.

The next item, "Poor Solder Wetting," is a fault that occurs from time to time with any metallization. Nobody can defend metallizing that will not take solder, and our pre-coating with solder requirement, although an additional operation, has eliminated more rejections at final module assembly than probably any other single item in our specification.

Item Four, "Excess Solder in the Notches," is purely a facilitation problem. There are many ways of solder coating the terminals, and the twelve pin inspection gauge has made this a simple black or white test.

Items Five, Six, and Seven are all problems associated with registration and can present major difficulties if your metallizing is a positive process. Most of the trouble comes from attempts to silk screen land areas around notches on a small 0.310-inch ceramic wafer having an over-all tolerance of eight mils. My only comment on this, is that there are many ways of metallizing, other than silk screening, and we know that this very important facilitation problem has been solved by a number of manufacturers.

In conclusion I would like to take this opportunity of mentioning the revised microelement substrate Dwg. 492950, Issue 15. The major change is a relaxation of the tolerance on the notch locations (Figure VII-5).

To simplify our incoming inspection and to be more compatible with our assembly requirements, we are using simple twelve-pin gauges based on the 0.075-inch grid. This modification does not mean any change in present tooling as parts meeting the requirements of Issue 14 will also meet the requirements of proposed Issue 15. The simplified requirement that "notch centers may deviate from the seventy-five mil grid by two mils maximum," should permit a higher yield of acceptable parts.

The other item changed is the method of index notch dimensioning. This change has been brought about because, up to the present time, we have been using the index notch only for visual reference. The increased production requirements now demand that plain substrates must be mechanically fed and oriented to the various automatic and semiautomatic metallizing machines. We have specified that the

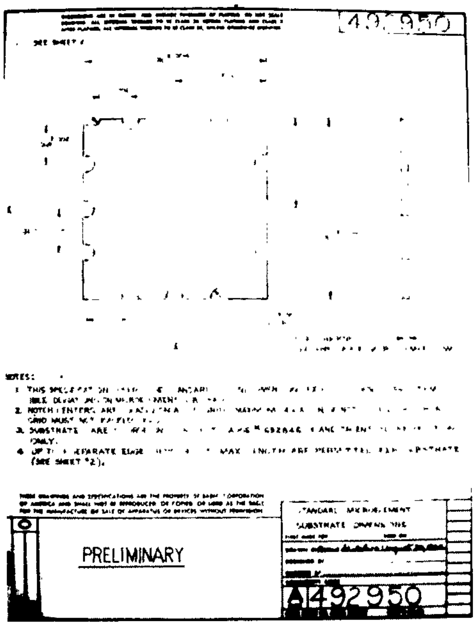

Figure VII-5. Standard Microelement Substrate Dimensions index notch be tied to the 0. 075-inch grid for this reason, and we are including an index notch location pin in our incoming inspection twelve-pin gauge (to make thirteen).

Incoming plain substrates must be capable of being assembled on this thirteen-pin gauge in one orientation position only. The gauge will be set up on a shadowgraph using at least twenty to one magnification, when the edges of the wafer must fall within a tolerance frame on the projection screen. The base of the gauge is made from lucite to transmit light for this purpose.

LAND AND NOTCH METALLIZING ON THE MULTILAYER MICROMODULE CAPACITORS

J. CRONIN
AEROVOX CORPORATION

The Hi-Q Division of Aerovox manufactures multilayer ceramic capacitors. These capacitors differ from the usual substrates in that their thicknesses generally range from 10 mils to 70 or 80 mils as a function of their capacitance. There is no actual limit to the possible thickness other than that imposed by cost as a function of yield.

The problem of metalizing the notches and lands was, of necessity, separated into two parts, since the technique of allowing metalizing material to run down into the notches as the lands are screened does not work with such thick elements. The decision was made to apply the land metalizing by screening, and the notch metalizing by means of a transfer mechanism.

Application of metalizing to the fired capacitors proved too difficult to be feasible for automation. The use of a doctor-bladed needle to transfer silver to the notch, and by means of lifting the needle in the notch applying the bottom land, and lowering the needle applying the top land, proved feasible only if the registration between the notch and the needle was perfect to within about one thousandth of an inch. On the Hi-Q capacitors this meant individual registration of the notch being metalized to the needle, as the shrinkage of the multilayer capacitors is not exactly uniform. The shrinkage variation occurs in part because the metalized areas do not shrink exactly as do the non-metalized areas. The location of the terminations thus affects the shrinkage and final shape of the parts.

The difficulties in locating the notches were overcome by metalizing the capacitors in the unfired state. The unfired capacitors for a given ceramic body are absolutely uniform in outline dimensions. When the ceramic body is changed, the unfired size differs to compensate for a different shrinkage rate. A set of four unfired sizes covers the general run of capacitors.

Samples were made by hand using notch and land metalizing on the green ceramic. The land areas proved easy to apply by screening and presented no problems. The notch metalizing, if too thin, would not accept solder. If too thick, the metalizing actually pulled away from the ceramic due to a greater shrinkage rate, and formed a thin section of metal. The correct amount of notch metalizing gave excellent results, tested against both mechanical and electrical requirements.

Machine design was begun, based upon handling the capacitors in multiples after they were loaded into holding jigs.

The machine shown in Figure VII-6, consists of a carriage sliding on Thompson linear ball bushings upon two hardened ground shafts obtained from that company. This assures excellent accuracy and repeatability of the path of the carriage through space, so that the path of the carriage is repeated well within one thousandth of an inch.

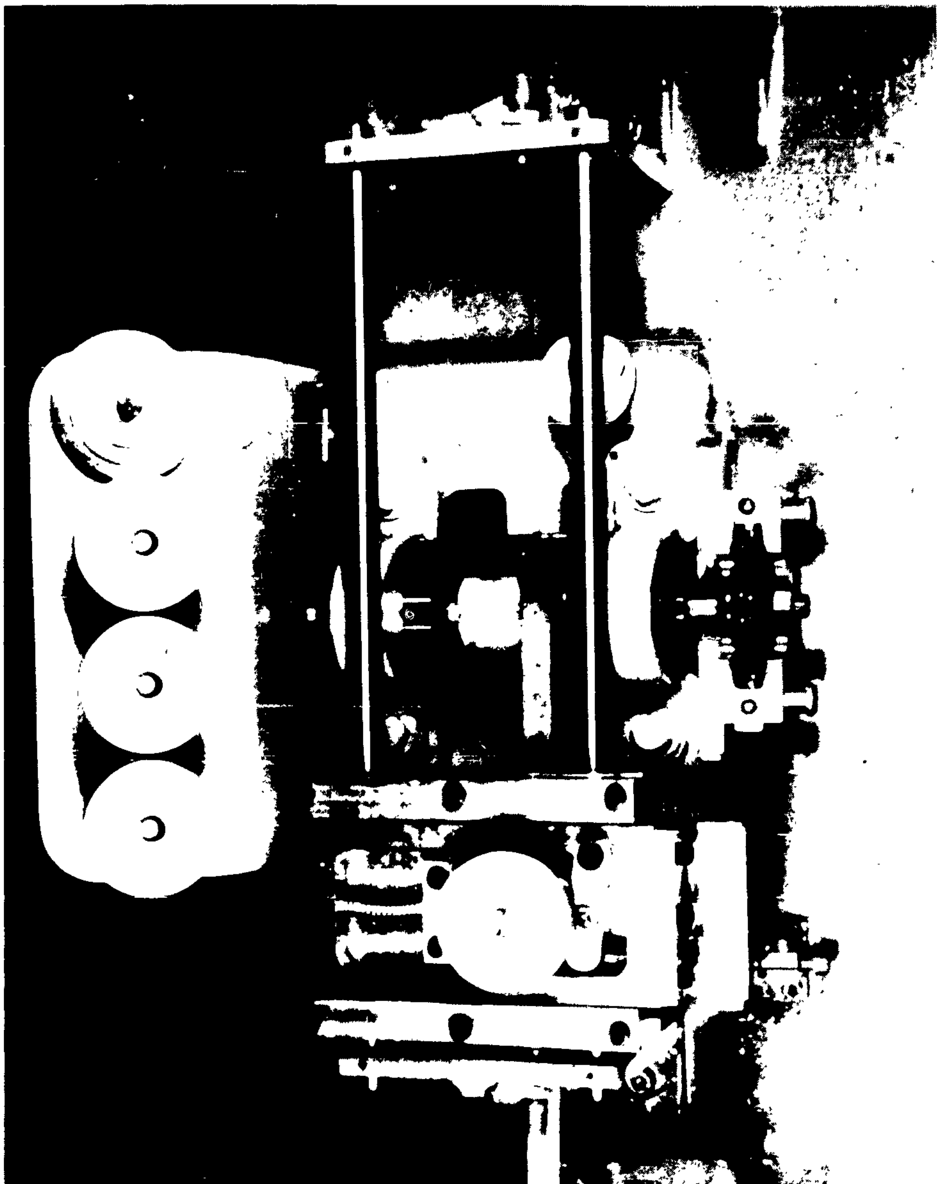

Figure VII-6. Notch Metalizing Machine

A slide mechanism located on the carriage operates at right angles to the direction of travel along the shafts. This slide is positioned by a three-position cam. The handle of the cam can be seen in the photograph, and three other cams sit behind the machine. These cams position the slide to correspond to the particular column of notches to be metalized. Each cam is machined for one particular shrinkage rate corresponding to the ceramic body with which it is used. The front part of the slide has a pair of magnets which hold the capacitor-bearing jigs in place on an accurately machined ledge on the front face of the slide. The line of the ledge formed by the intersection of the faces is very accurately made parallel to the long axis of the hardened ground shafts upon which the carriage slides.

A transfer wheel, rotating in a reservoir of metalizing material, has a set of doctor blades which regulate the amount of metal carried.

The machine drive is obtained from a reversible electric motor mounted beneath the table. The motor, through gears, drives a shaft which has mounted upon it the transfer wheel and one-half of a friction clutch. The drive shaft rotates continuously, and through the friction clutch drives a gear which in turn drives a rack pinned to the carriage. The carriage thus is normally driven against one side of the ground shaft supporting plates. Upon pushing the operating button, the motor direction is reversed, and the carriage is driven in the opposite direction across the shafts to the other shaft support plate. Because the drive shaft has reversed, the transfer wheel now drives in the same direction as the carriage travels. It has a speed equal to that of the carriage, at the point of contact between the wheel and the elements that are being metalized.

The carriage actuates a microswitch after it has traversed the shafts. This causes the motor rotation to reverse again, and drive the carriage back to the original starting point.

To use the machine the capacitors are loaded into a jig, as shown in Figures VII-7 and 8. The jig is designed so the two exposed edges of each capacitor extend beyond the end plates of the jig. The end plate of the jig shown in the front view has been removed for the purpose of the photograph. It is held to the jig by screws, and has mounted through it a screw which is adjusted to place a slight pressure upon the capacitors to hold them in the jig. As can be seen in the side view, the capacitors are separated from each other by spacers. This permits a small amount of metalizing to run up the faces of the capacitor onto the land area. This helps in metalizing the sharp edge formed by the notch and land. Such a sharp edge is always relatively difficult to metalize well.

The jig containing the capacitors is placed on the ledge on the front of the slide so that one set of capacitor edges is in the down position, and the appropriate three-position cam is inserted into the machine. The height of the transfer wheel is variable, with respect to the columns of notches of the particular size of unfired capacitors being metalized, by means of a screw which raises one end of the plate upon which are mounted the drive motor, shaft, transfer wheel, and friction clutch. The amount of adjustment needed is very small - about fifty thousandths total. The other end of the plate is supported by precision pivots. Figures VII-9 and 10 show two views of the machine in operation.

Figure VII-7. Wafer Carrier Jig, Front View

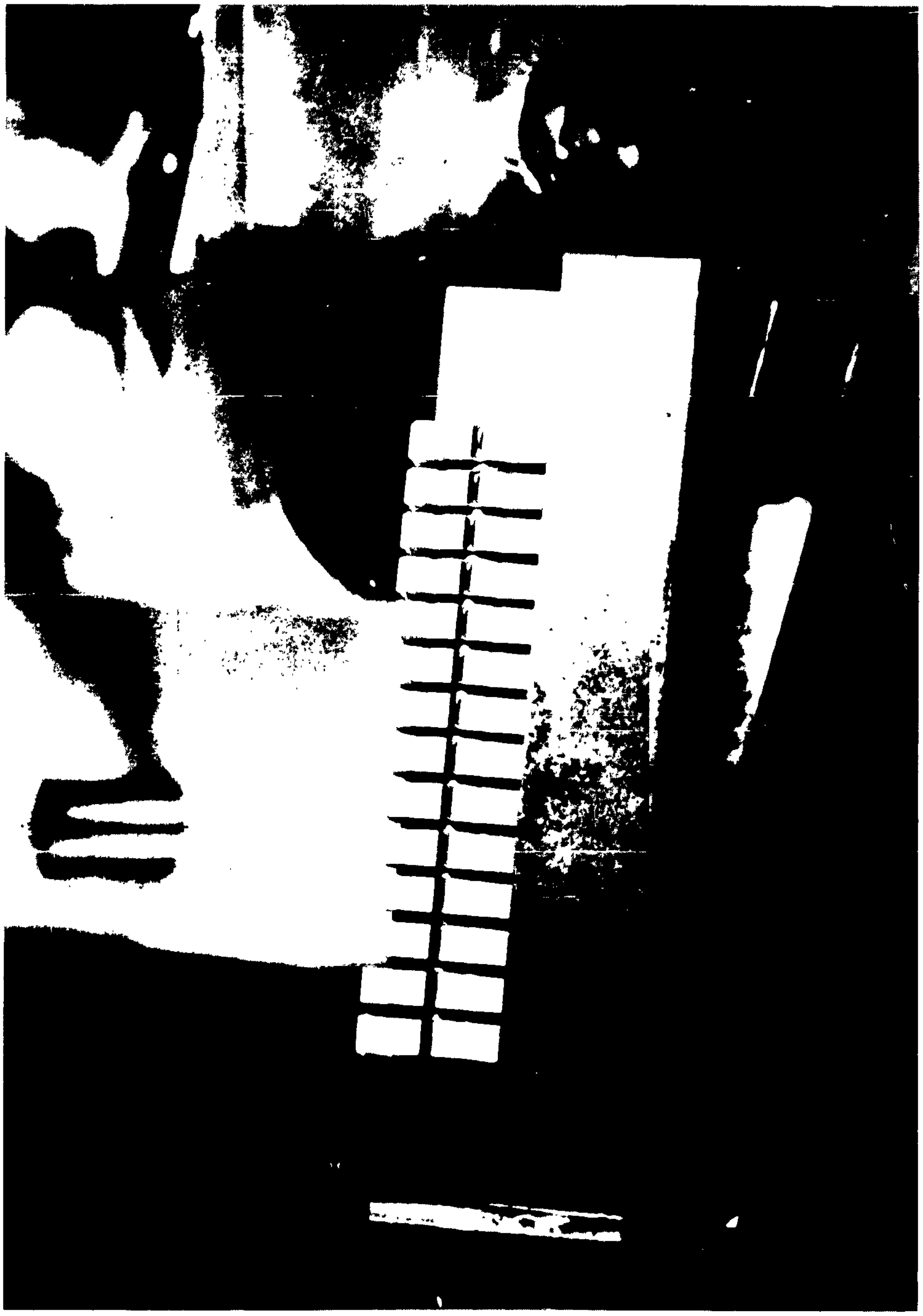

Figure VII-8. Wafer Carrier Jig, Side View

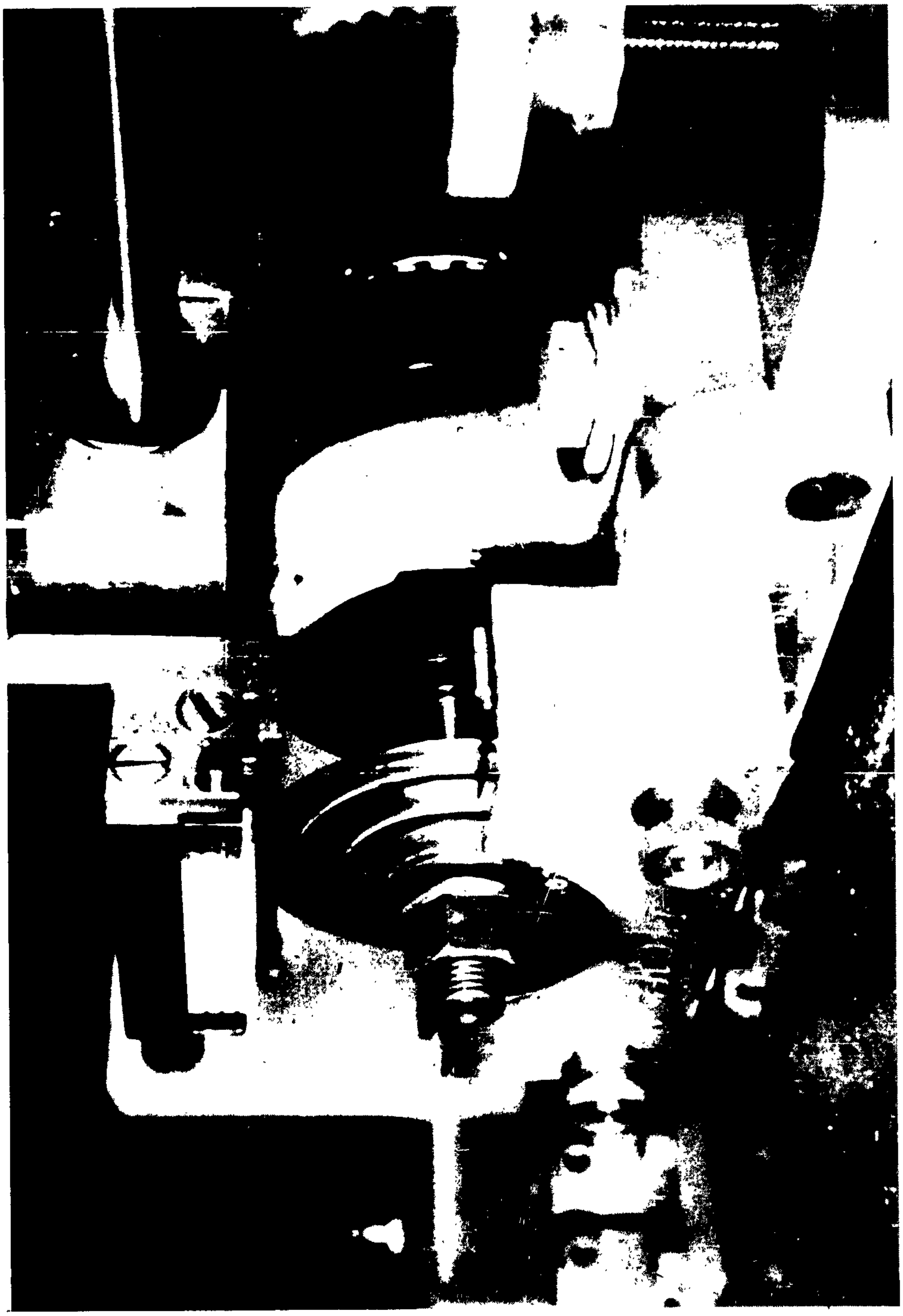

Figure VII-9. Side View of Notch Metalizing Machine in Operation

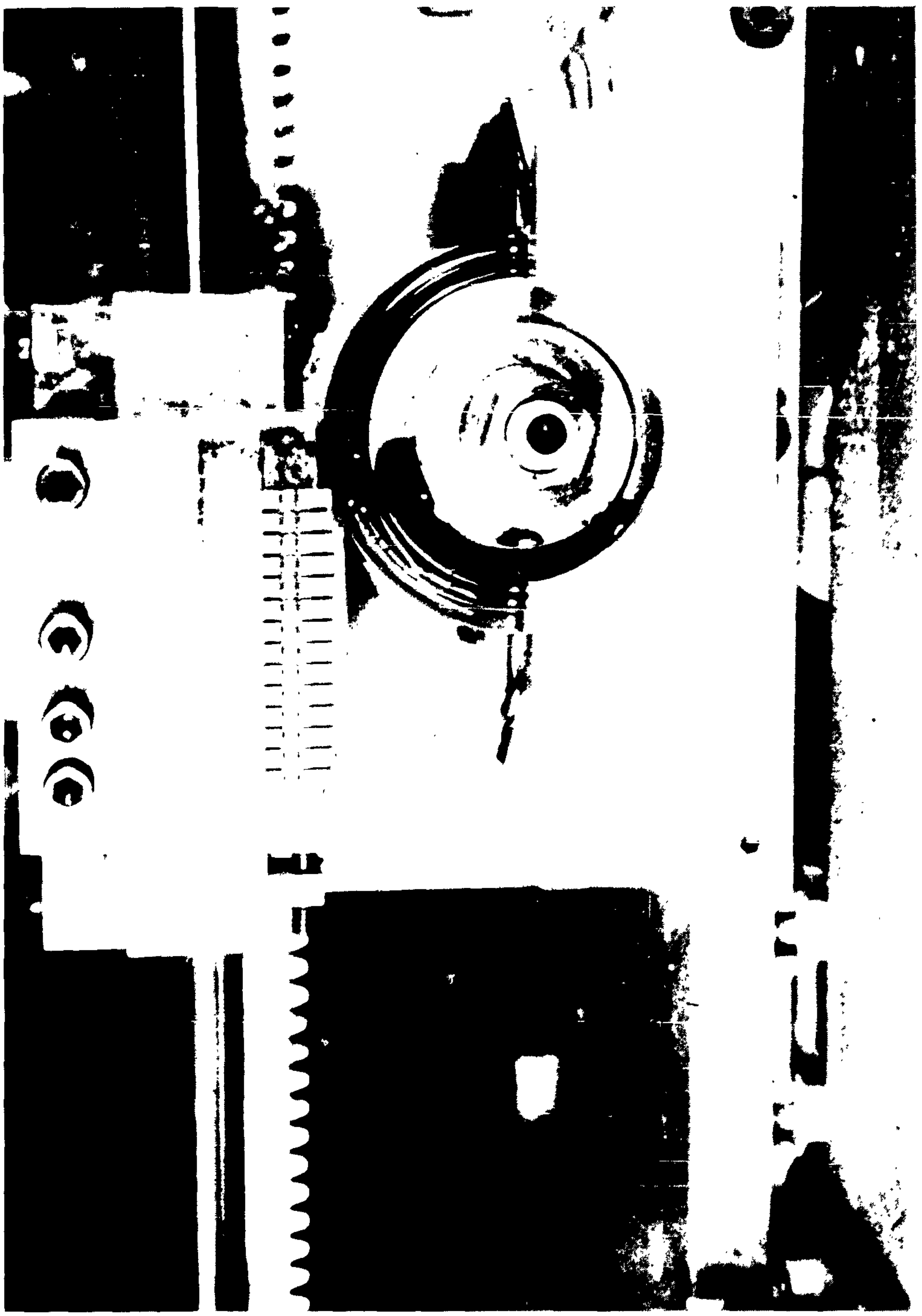

Figure VII-10. Front View of Notch Metalizing Machine in Operation

By means of the three position cam, which positions the slide, any or all columns of notches on the downward capacitor edges may be metalized. The jig is then removed and the other exposed set of capacitor edges is placed in the downward position, and the columns of notches are metalized in the same manner. The jig is set aside and the metalizing is allowed to dry. The jig is then positioned above a similar jig, and the capacitors transferred so that the two unprocessed edges are exposed. These are then metalized in the same manner.

The appropriate lands are then screened onto the capacitor faces, and the units are fired to mature the ceramic. Metalization of the capacitors is now complete.

MATERIALS, METALLIZATION, TINNING AND HANDLING

R. YOUNG
SPRAGUE

Sprague entered the capacitor portion of the Micromodule Program very early in the game, having received Signal Corps funding during the first year of the program for three types of microelement capacitors. These three types were: solid tantalum capacitors, ceramic multilayer general-purpose capacitors, and ceramic multilayer precision capacitors. This, of course, meant immediate involvement in problems with substrate materials, metallization, tinning and handling, which is the title of this session.

Because the tantalum capacitors consisted of a tantalum capacitor element and a separate substrate, the substrate problems were passed on to the vendors. Consequently, Sprague's problems with the tantalum capacitor were mainly those of making reliable connections between lands and leads, and with getting enough protection to the tantalum piece so that it would stand rough handling. The early approach to this problem was a flat substrate with the tantalum element sitting on top of it. The latest approach, which was developed in connection with Task 28-4, involves a new substrate which is essentially a square sleeve with a square hole, so that the tantalum element is completely surrounded by ceramic and epoxy. This gave the substrate manufacturers a bit of a problem in that some of the required lengths were excessive. For example, the maximum size involved in Task 28-4 is a 42-microfarad, 10-volt capacitor at a 125°C rating, and this requires a substrate that is 250 mils long. A further refinement of this, which is planned for use in the facilitation phase, is the utilization of a solid surface on one end of the sleeve; this provides a rugged configuration, with the tantalum nested down within the cup.

The substrate problems associated with the ceramic multilayer capacitors were much more severe than those associated with the tantalum. The usual problems were incurred; that is, insuring that the outline dimensions and shape were exact, and that a precise and continuous metallized pattern on the surface of the substrate was achieved. However, there was an added problem, in that the internal multiple electrodes had to be very precisely aligned with the specific notches involved for the particular connection. The first approach was die-stamping the green or unfired parts, and the yield was very disappointing. These parts, when subsequently fired, are subject to shrinkage and warpage, and although the die-stamping is potentially a very high production process, the yields were so low that the production rate was quite disappointing. Sprague completed the contract with die-stamped parts, but since then, ultrasonic machining has been adopted.

With the ultrasonic technique the parts are fired, then they are cut with a Cavitron cutting tool; the result is a very accurate outline with notches of the right dimensions in the right location. Furthermore, the Cavitron cutting tool is positioned with respect to lines or marks that are made by the same machine that locates the internal electrodes so that alignment with the specific notches is very good. With these accurately shaped pieces, a precise metallizing pattern was applied to the two major surfaces using a screening process. However, the surface was still rough because of the camber which occurred when the ceramic pieces were fired. So, another production processing step was added to surface lap both surfaces and to fire the ultrasonically machined pieces. This provides a flat surface which accommodates screening very well. Other steps included changing from a 200-mesh screening with a silver paste to a 354-mesh screening with a platinum-gold paste. With this combination of fine-mesh screening, the platinum gold paste and a flat smooth surface, a very satisfactory metallizing pattern is now achieved.

To summarize then, Sprague has a tantalum design which is very suitable for just about any production rate, and a ceramic capacitor design which is very fine, except that the production rate is not quite as satisfactory for the highest production rates visualized for a few years hence in this program.

THERMAL CONDITIONING OF CERAMIC MATERIALS

PROFESSOR C. J. PHILLIPS
RUTGERS UNIVERSITY

INTRODUCTION

During the past seven years much work on thermal conditioning has been done by the School of Ceramics at Rutgers University, under the sponsorship of the U. S. Army Signal Research and Development Laboratory, Fort Monmouth, New Jersey.

Thermal conditioning, abbreviated to TC, is a process for increasing the strength of ceramic bodies. The experimental procedure is similar to that employed in the tempering of glass. The specimen is heated to an optimum temperature which varies with body composition and is then rapidly quenched in a stream of cool air. In some bodies strength increases of more than 60% have been recorded. The process is now receiving commercial attention.

EXPERIMENTS WITH RODS

All samples were industrially manufactured rods 6" or 8" long having the characteristics shown in Table I.

TABLE I

Material	Lot Number	Nominal Diameter	Transverse Bending Strength (MOR) "as received"
75% Alumina	1	0.500"	26,600 psi
85% Alumina	1	0.372"	35,000 psi
85% Alumina	2	0.500"	36,300 psi
85% Alumina	3	0.500"	30,800 psi
94% Alumina	1	0.500"	36,700 psi
94% Alumina	2	0.500"	35,300 psi
99% Alumina	1	0.500"	48,000 psi
Steatite	1	0.500"	16,800 psi
Steatite	2	0.500"	17,600 psi

Originally, thermal conditioning work was done with a gas-fired muffle furnace. Rods were heated at approximately 500°F per hour to the desired temperature, held for 30 minutes and then quickly placed in a blast of room temperature air from a small fan. In later work, a Kanthal electric furnace was used. The results did not differ appreciably from those attained with the gas furnace.

In addition to the fan, other methods of cooling have been employed. In some tests a small, direct driven blower has been used, with the rods held approximately 6 inches from the outlet. In other tests the rods were allowed to cool in still air, supported near the ends by preheated, light-weight, refractory brick.

Figure VII-11 summarizes the thermal conditioning results. S(2)A means Steatite - Lot 2 - cooled in still air. 75(1)F means 75% Alumina - Lt. 1 - cooled with fan. 94(2)B means 94% Alumina - Lt. 2 - cooled with blower. The other legends may be interpreted similarly.

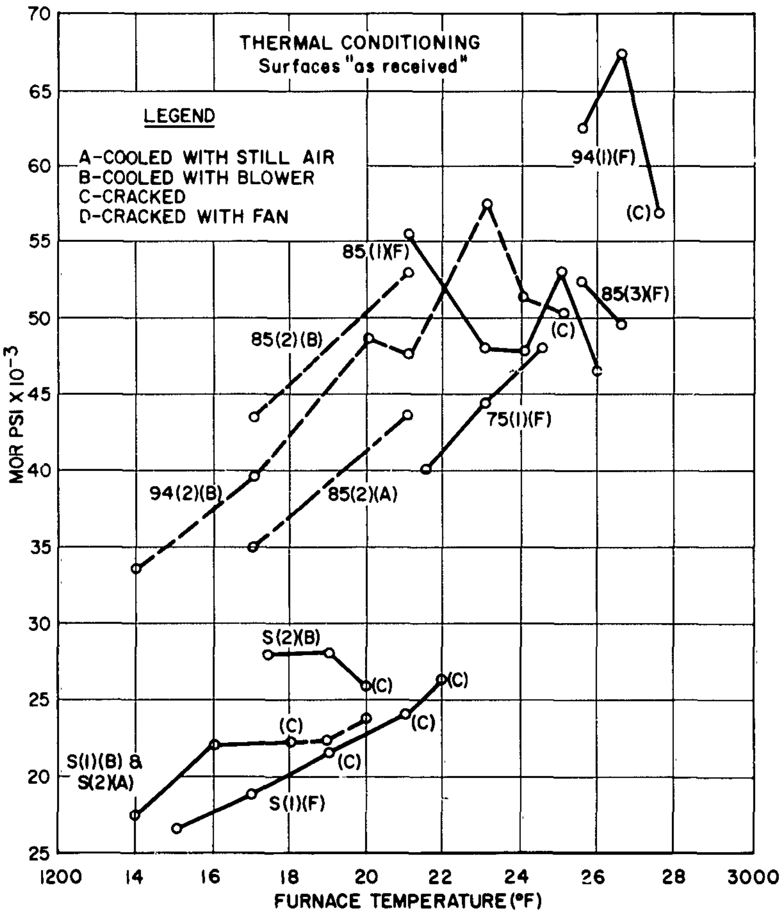

Figure VII-11. Results of Thermal Conditioning on Alumina, Steatite, Titania, and Barium Titanate

EXPERIMENTS WITH MICROELEMENT SUBSTRATES

At the request of the U. S. Army Signal Research and Development Laboratory, Fort Monmouth, New Jersey, investigation of the effects of Thermal Conditioning upon microelement substrates was commenced in the winter of 1959-60. Conditioning of these small ceramic wafers, used in the fabrication of miniaturized electronic components, represents a practical electronic application of the exploratory work done on rods. Because of the small size of the wafers, special equipment to determine transverse bending strength had to be designed and built.

Random samples from a variety of wafer compositions have been studied. The traverse bending strengths (MOR) of the wafers as received from the manufacturers are summarized in Table II.

Thermal conditioning of microelement wafers was accomplished by heating the test pieces in a vertical-tube, externally wound platinum furnace and quenching them in a stream of cool air, at a distance of six inches beneath the orifice of a small blower. During heating, the wafers were supported by a pedestal of refractory brick. The notches were arranged in a symmetrical five-pointed star pattern to insure that all wafers would be brought to the same temperature.

DISCUSSION OF RESULTS

Of the wafers available, six groups were analyzed for response to conditioning. The results are summarized in Table II.

EFFECT ON CAMBER

It was anticipated that the stresses induced by conditioning might result in changes in wafer camber. The results are shown in Table III. Camber induced by thermal conditioning is well within a 1.0 mil tolerance.

EFFECT ON ELECTRICAL PROPERTIES

It was also anticipated that phase changes resulting from conditioning might alter electrical properties. Q-meter measurements have verified this. Five wafer random samples of 94 - 96% Al_2O_3, Steatite, and TiO_2 - II were measured for power factor (%), dielectric constant and loss factor (%) before and after conditioning. Measurements were made on clean dry wafers, at room temperature, and at one megacycle. The results appear in Table IV.

EFFECT OF METALLIZATION

As components of complete electronic devices, microelement substrates must be metallized in a pattern appropriate to their function. The metallizing composition and the method of application are determined not only by wafer composition but by other

TABLE II

COMPARISON OF THERMAL CONDITIONED (TC) STRENGTH WITH "AS RECEIVED" STRENGTH

Body Composition	94-95% Al_2O_3		96-98% Al_2O_3		TiO_2-I		TiO_2-II		Steatite		$BaTiO_3$	
	"As Rec'd."	TC at 2500°F	"As Rec'd."	TC at 2600°F	"As Rec'd."	TC at 2000°F	"As Rec'd."	TC at 2150°F	"As Rec'd."	TC at 2350°F	"As Rec'd."	TC at 2350°F
Mean MOR (psi)	34,000	55,400	38,600	46,800	15,300	18,300	11,600	24,800	18,800	26,500	11,700	14,600
Maximum MOR	47,100	71,300	47,800	56,500	21,700	28,500	14,700	29,200	22,600	33,400	15,600	23,100
Minimum MOR	16,000	35,300	22,300	37,400	8,700	13,400	9,300	18,100	14,800	17,200	9,600	12,000
Range of MOR	31,100	36,000	25,500	19,100	13,000	15,100	5,400	11,100	7,800	16,200	6,000	11,100
Number of units tested	25	10*	10	5*	10	8*	10	5*	25	10*	10	10*
Number of units within ± 10%	7	3	4	1	3	2	4	2	13	4	4	4
Number of units within ± 20%	19	8	6	3	4	4	8	4	23	6	8	9
Increase over "As Received" MOR	-	63%	-	18%	-	20%	-	114%	-	41%	-	25%

*Only the size of sample run at the optimum TC temperature is shown. In most cases, an equal number of samples was run at each of several temperatures above and below the optimum temperature.

TABLE III

EFFECT OF TC ON CAMBER

Body	Camber change resulting from optimum TC, average of 5 wafer sample	Maximum value
94-96% Al_2O_3	0.1 mil	0.1 mil
TiO_2 - I	0.1	0.1
TiO_2 - II	0.3	0.5
Steatite	0.2	0.3
$BaTiO_3$	0.2	0.6

TABLE IV

EFFECT OF TC ON ELECTRICAL PROPERTIES

	Property	"As Rec'd"*	After TC*	Change due to TC
94-96% Al_2O_3 Body	Power Factor %	0.12	0.06	50% decrease
	Dielectric Constant	10.65	10.78	1% increase
	Loss Factor %	1.29	0.69	47% decrease
TiO_2-II Body	Power Factor %	0.08	0.11	38% increase
	Dielectric Constant	18.09	18.59	3% increase
	Loss Factor %	1.47	2.02	37% increase
Steatite Body	Power Factor %	0.08	0.11	38% increase
	Dielectric Constant	7.37	6.54	11% decrease
	Loss Factor %	0.58	0.75	29% increase

* Mean value, sample of 5.

factors as well. In all cases the metallizing must be fired on and matured over an extended period of time. If the firing temperature is greater than that at which thermal conditioning has been carried out, it is to be expected that the effects of conditioning will be reduced or nullified. For this reason it was important to observe the effects of thermal conditioning when added as the terminal phase of the metallizing procedure.

Accordingly, twenty 94-96% Al_2O_3 wafers were metallized with a compound requiring a firing temperature of 2550°F. At completion of the maturing period, the wafers were removed from the furnace and quenched. It was found that their transverse strength had been increased on the average by 39 per cent. Examination of the sample statistics and of the TC curve led to the conclusion that in removing the samples from the furnace they had cooled about 125°F below the optimum TC temperature. Had the quench actually started at 2500°F, rather than at perhaps 2375°F, the improvement in strength would probably have been near the expected 60 percent.

SUMMARY

The flexural strength of rods and of wafers fabricated from ceramic materials can be increased as much as 60% by thermal conditioning. Data are given for two compositions of steatite and seven of alumina, made as rods, and for two compositions of alumina, two of titania, and one each of steatite and barium titanate fabricated into microelement substrates. The substrates can be thermal conditioned after metallizing without serious alteration of electrical properties. The thermal conditioning process is believed to be a practical method of strengthening ceramic components of diverse size, shape, and composition.

GLASS-BONDED MICA AS A SUBSTRATE MATERIAL

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MOLECULAR DIELECTRICS, INC.

Molecular Dielectrics, molders and fabricators of glass-bonded mica, has recently been selected as a source for micromodule substrates. Since glass-bonded mica is new to the program, this paper will explain what it is, why it is being used as a substrate, some of its advantages, and a brief explanation about manufacturing techniques and some unique properties of glass-bonded mica which make it useful for future modules.

1. What is glass-bonded mica?

Glass-bonded mica is a moldable and machineable inorganic thermoplastic material, made up of inorganic binders and synthetic mica. The inorganic binders and synthetic mica are mixed together in varying proportions. The mixture is then heated, allowing the binder to become molten and, thus, able to flow. At this point the material is either compression- or transfer-molded under extremely high pressures. The molded product is a dense, hard ceramic-like material but not a ceramoplastic material, and has many unusual properties.

Some of the exceptional properties of glass-bonded mica are as follows:

a. It is dimensionally stable, even with change in time, temperature and environment.

b. It does not outgas, as it is completely inorganic.

c. It has a coefficient of expansion close to that of most metals. This property enables us to mold-in metal inserts at the same time the configuration is made.

d. It is arc-resistant.

e. It does not absorb moisture.

f. It is resistant to thermal shock.

g. It has a low electrical-loss factor.

h. It is radiation resistant.

i. It is reproducible in volume from abundantly available raw materials.

2. Why is Glass-Bonded Mica used as a Substrate?

The unique ability to precision-mold to extremely close tolerances in thin or heavy sections, is one of the properties which favored the use of glass-bonded mica for substrates. Molecular Dielectrics then developed a technique of metalizing glass-bonded mica, which enabled it to fulfill the micromodule substrate assembly and test requirements, and aroused further interest in this material. Because glass-bonded mica does not have such high tensile strength or flexural strength as does an alumina body, it is not recommended for use in substrates which have to be thinner than .022 inches. However, RCA found that substrates up to approximately 3 tenths of an inch thick were required in many module units. A substrate was then molded with an outside configuration conforming to the micromodule substrate Drawing #492984, except that the thickness was adjusted to conform with RCA's requirements and the inside portion was contoured as required.

One of the component assembly problems mentioned by many of the speakers was that a flat and parallel top and bottom of the substrate component assembly is desirable so that a minimum height can be attained after the components are stacked. When a component such as a transistor is mounted on top of a wafer, the transistor's outside configuration now becomes a factor in the flatness of the element. With the use of a hollowed substrate which is slightly higher than the transistor, the flatness of the element and the height of the module are now dependent on a controllable dimension - that of the substrate. Thus a commercial transistor or other component can be purchased and placed inside the substrate without requiring that the component itself have a flat shape.

Because of the unique injection-molding methods which Molecular Dielectrics developed to mold glass-bonded mica, extreme accuracies in flatness, parallelism and squareness can be obtained in thin or thick substrates. The addition of holes or contoured shapes, such as barriers or depressions, can usually be accomplished within the substrate. We have molded wall thickness as thin as 6 mils on substrates 5/32 of an inch high. This wall thickness allows additional usable area within the substrate for larger components not previously usable because of space limitations of the substrate itself.

Another essential attribute of glass-bonded mica is its machineability. This allowed RCA to contour machine or drill holes in existing parts as desired. Conventional ceramic materials are machined with great difficulty in comparison to glass-bonded mica. Its machineability also allowed Molecular Dielectrics to vary the configuration with the substrate for suppliers of module components, without having to build special molds for each part. Parts were molded by using an existing mold which had the required notches, and were then machined to the component supplier's internal configuration and height. In this vein, a round hole is very easy to machine, partly because this material is brittle, similar to ceramic. A square hole must be molded using dowel, or mold pins in the mold.

Another recent development which, if successful, will increase the use of this material for substrates depends on our ability to metallize it such that metal component leads can be resistance welded to it. With the aid of RCA, Molecular Dielectrics has resistance-welded some leads successfully.

The substrate manufacturing process consists of injection molding the substrate to the required configuration, If desired, a machining operation can then be performed on the part. The next step is to metallize the land and lead areas. This is accomplished by an electroless plating technique developed by Molecular Dielectrics, which does not require firing; thus, all the flatnesses and parallelisms previously built into the part are kept throughout the operation and no distortion takes place within the substrate. Metals, such as copper, gold, rhodium, silver, nickel and others can be plated to this material. Techniques other than plating have been used to metallize glass-bonded mica, such as fired-on silver, vacuum deposition, and application of metals using cements. After metallizing, the parts are solder-coated in conformance with the micromodule substrate specification requirements, and are ready for use.

RCA uses our micro-module wafer as an element housing for transistors and for variable and fixed inductors.

In conclusion, the properties of glass-bonded mica which make it so useful for future substrates should be emphasized: (1) it meets the extremely close tolerances required, and (2) metals can be molded into it, providing a metal part as an integral part of the substrate without the use of metalizing. In order to bond a metal terminal to ceramic material, you have to metallize it, fire it, and then put the metal to it. With the molding operation you eliminate quite a few steps. As stated previously, glass-bonded mica is well suited to this program because a larger cavity can be made in the thick substrates without problems of distortion.

CALCULATIONS PREDICTING PHYSICAL AND ELECTRICAL CHARACTERISTICS OF MOLYBDENUM FILMS ON MICROELEMENT WAFERS

SANDFORD S. COLE, JR. & BAYNARD A. SMITH
MITRONICS

This paper is divided into two sections, the first a brief examination of how Mitronics manufactures micromodule wafers, and the second a careful examination of the coatings thus produced.

Figure VII-12 shows the pressing operation where the alumina powders are compacted to the wafer form. The wafer is then fired, as shown in Figure VII-13, in a wet hydrogen atmosphere. Figure VII-14 shows the lapping of the micromodule wafer to insure perfect flatness. Next, the wafer is silk screen coated, as shown in Figure VII-15 to produce the lead and land areas. The coating is refired in hydrogen and barrel plated as shown in Figure VII-16. Figure VII-17 shows the tin dip operation. Finally, the coatings are inspected as shown in Figure VII-18.

It will be our objective to examine the exact nature of refractory metal coatings on micromodule wafers and to predict their electrical and mechanical characteristics. In order to do this, let us examine a coating in considerable detail.

The starting point is, of course, a mixture of molybdenum powder and from two to thirty percent of an accessory metal or metal oxide such as manganese, titanium, silica or iron. Particle size is normally in the range of three microns or below. The powders are suspended in organic liquids such as combinations of amylacetate, nitrocellulose, acetone, toluene or xylene which serve as vehicle in the fluid state and as a binder when the vehicle has evaporated after application. Exact binder combinations depend on method of application and personal preference. Binder and metal combinations are milled to further reduce particle size. Application to the ceramic is carried out on micromodule wafers by silk screening and by spraying.

The coating at this point consists of about 60% to 70% by volume of metal, the balance being binder-vehicle. As the coating starts the sintering process the binder-vehicle is driven off as gas leaving a loose porous metal structure having a porosity of 30% to 40%.

As sintering temperature is increased, two important things start to take place.[1] Accessory metals, titanium, manganese, and nearly all others, start to oxidize. This occurs despite the fact that the furnace atmosphere is hydrogen and is the result of the water vapor which is introduced by bubbling the furnace gas through water. In addition, the molybdenum metal starts to sinter. The sintering is accomplished by a solid state reaction having time, temperature and particle size as its major variables.[2] The degree of sintering varies approximately as a function of the cube of temperature and the one third power of time, and inversely as a function of particle size.

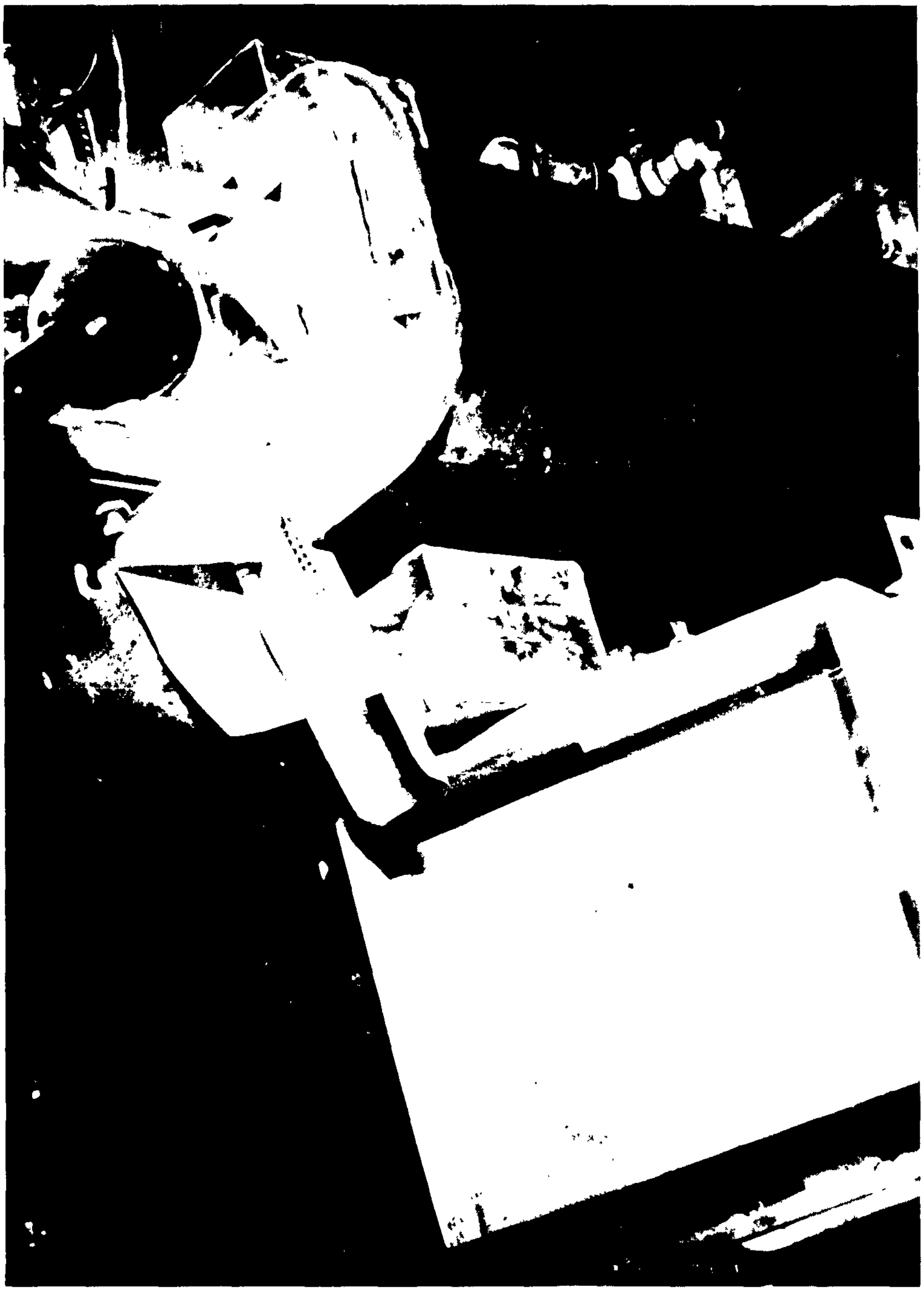


Figure VII-12. Wafer Pressing Operation

Figure VII-13. Firing of Wafers

Figure VII-14. Wafer Lapping to Insure Flatness

Figure VII-15. Coating of Wafers Using Silk Screen

Figure VII-16. Barrel Plating Facilities

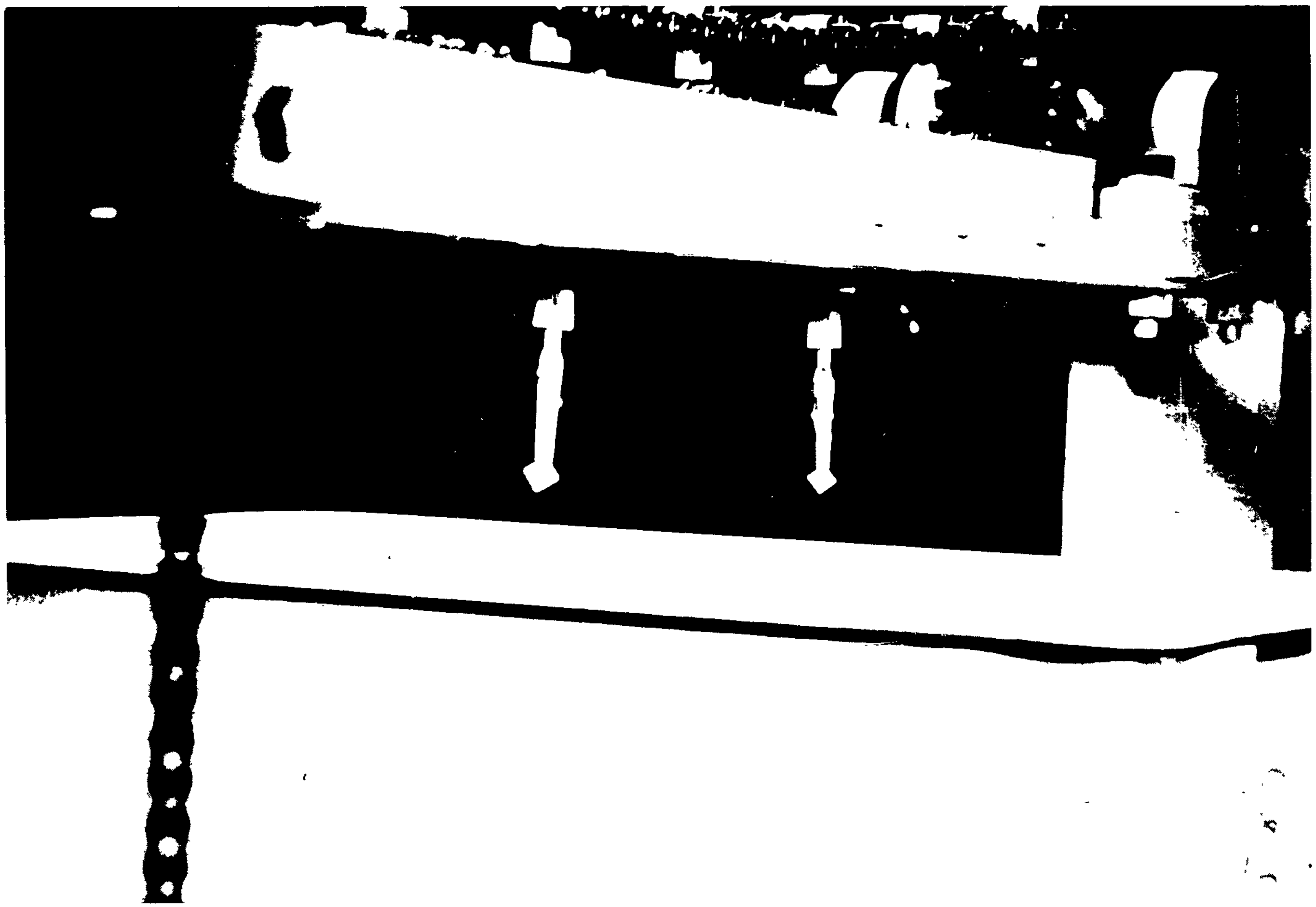


Figure VII-17. Tin-Dip Operation

Figure VII-18. Inspection of Wafer Coating

As temperature is increased to the range of 1200° to 1300°C the oxides of the accessory metals begin to play a major role in the nature of the resulting metal film. Only two of these are well understood, those being manganese and titanium. In the manganese system[3] a manganese aluminate compound forms at about 1200°C. It tends to form a mechanical lock of the alumina ceramic to the porous molybdenum coating with only minor penetration of the manganese aluminate into the molybdenum structure. At 1500°C, the manganese aluminate phase is found to disappear by metallographic examination and apparently unites with the glass phase in the ceramic which in turn enters the molybdenum matrix.

In the titanium system,[4] no intermediate compound is formed. The titanium dioxide enters the glassy phase of the ceramic and lowers glass viscosity so that flow may start and advance into the porous molybdenum structure.

The highly magnified cross section of such a coating is shown in Figure VII-19.

The important point to note is that the resulting film is not pure molybdenum. It is actually an impregnated molybdenum consisting of 30% to 40% pores which are filled with glass.

Before examining this coating in more detail, let us make some observations concerning any resulting discoloration or "penetration" of metal coatings into the micromodule wafer. All of the common accessory metals become oxides. As such they are capable of entering the glass phase to promote glass migration as we have seen. Some of these oxides, particularly titanium dioxide, are strong colorants and have the ability of coloring glasses black. Other oxides, such as manganese, impart a very mild

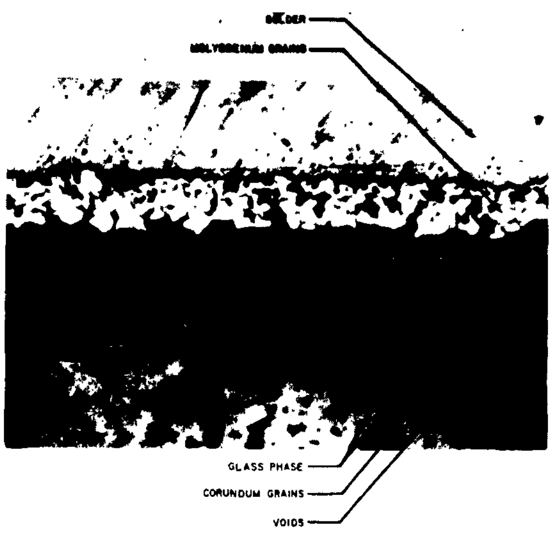


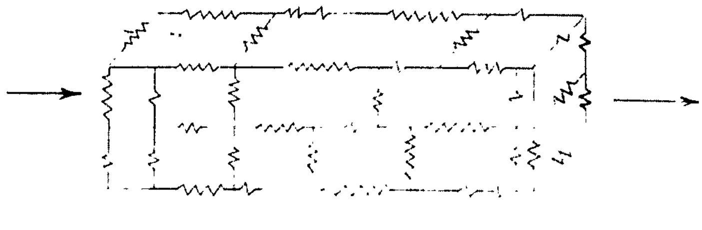
Figure VII-19. Cross-Section of Molybdenum Film on a Substrate

coloring effect and therefore they are not visually obvious. The final result is one additional oxide in an already complex oxide system. It is important to understand that the color of the micromodule wafer beneath the molybdenum film does not indicate the amount of penetration. It simply indicates the nature of the accessory metals. The amount of penetration depends on the amount of the starting accessory metal. There is probably far more penetration in a wafer coated with a 20% manganese, 80% molybdenum mixture than one coated with a 5% titanium-95% molybdenum mix. The penetration in the titanium base coating will be far more obvious, however. Finally, there is probably no significant difference in the electrical characteristics of either wafer because of the fact that an additional oxide in minor quantities has been added to the system.

The most important aspect of the metal film on a micromodule wafer ceramic, however, is probably the electrical characteristics which result. Considering the film as an infinite network of random resistances, one could represent the resulting circuit in three dimensions as shown in Figure VII-20(Part A).

Now this could be a pretty rough circuit to deal with as the magnitude and position of each resistance is unknown.

The circuit can be simplified, remembering that it is infinite and random. Each resistance perpendicular to the direction of current flow will carry small amounts of current from one series circuit to the next, sometimes in one direction, sometimes in the other. The net result will be a zero current flow between series resistances and the parallel resistances drop out. The network can be reduced to independent series resistances Figure VII-20(Part B). The large resistances represent narrow necks and the small ones represent large continuous molybdenum grains. A typical random unit cell



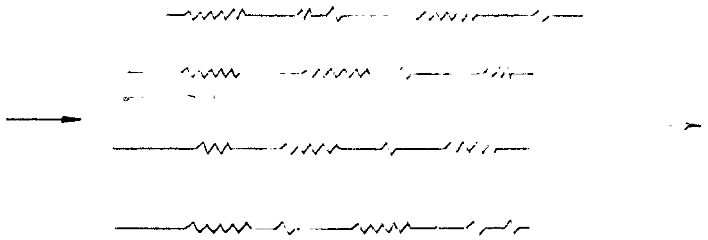


Figure VII-20. Electrical Characteristics (Random Resistance Network) of Metal Film on Ceramic Wafer

can thus be estimated (Figure VII-21, Part A) which can serve to allow calculations of resistivity on the total molybdenum coating.

The magnitude of the resistance in the resulting cells will be proportional to the size and frequency of the narrow necks. At this point it becomes necessary to estimate the frequency and magnitude of the necks so that some sort of addition can be made. This is of necessity a qualitative problem. After studying a reasonably large number of molybdenum coatings, made by using moly-manganese and moly-titanium, it appears that in both systems a neck in the range of 50 to 100 microinches in thickness occurs about every 0.0005 to 0.0010" for each 0.0005" of coating thickness. The length of the necks seems to run from 0.0001 to 0.0005". There is no tendency for the necks to grow in a plate-like form so that a sponge-like structure is formed. For the sake of calculations we will assume uniformity for a depth of 0.0001". Using a DC resistivity of 5.7×10^{-6} ohm - cm [5] for solid molybdenum the resulting resistivity of the porous structure would be in the range of 20×10^{-6} ohm - cm. The resistivity was calculated by computing the resistance of the typical unit cell and computing resistivity using the standard resistance-resistivity function. This would be in effect an addition of an infinite number of unit cells. We note, therefore, that the 30% to 40% porosity in the molybdenum coating gives rise to a three fold increase in DC resistivity.

If the metal film is to carry alternating current, the same analogy of an infinite and random series of resistances, and in addition, of capacitance can be made. The circuit can be simplified to establish a typical random cell as represented in Part B of Figure VII-21.

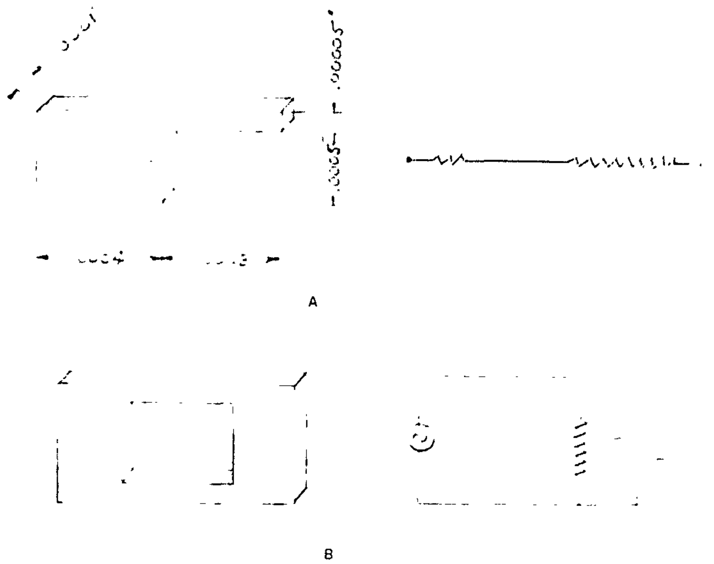


Figure VII-21. Typical Unit Cells of Molybdenum and their Electrical Analogies

Using the same cell dimensions as in the DC case, the impedance of the resulting RC circuit can be estimated. As it turns out, the capacitances involved, the glass having a dielectric constant of 5, are extremely small. They are in the range of 10^{-4} micro-micro farads. The net result, of course, is that the inductance of the coating tends to have very nearly the same value as is the DC resistance. Even at microwave frequencies the difference actually occurs beyond fifth or sixth significant place. It is possible, however, that a minor phase shift could be encountered.

This, of course, is the possible electrical state of the molybdenum coat. The coating is usually hump-back in cross section with a maximum thickness of 0.001 inches. Over it is a 0.0001 to 0.0002" coating of nickel and a 0.001 to 0.002 of lead tin solder. Both follow the same hump-back contour of the moly coating. With the lower resistivities of these metals the final result is a good conductor over a small resistor over an insulator. It is difficult for the manufacturers such as Mitronics to know whether the details of these coatings are of electrical significance or not. We feel that it should be pointed out and that the electrical designer should be aware of the nature of the coatings.

The second major area which we would like to discuss is the mechanical result of the coatings as they effect camber of a micromodule wafer. The question comes up rather frequently concerning the stress effect of coatings and braze materials in general on the strength of a ceramic seal. No work has been reported in this area but there are some interesting calculations that can be made. They become significant if there is an indication that coatings alone could be some of the causes of micromodule camber or of physical failure.

The origin of any stress which would develop is the combined existence of differing Young's modulae and differing thermal expansions of the materials involved. Of the two materials involved, molybdenum metal and tin, only the molybdenum is of interest. The nickel of course is not a factor since it is applied at room temperature. Due to the high ductility of tin any forces which it tries to exert will be quickly dissipated by yielding.

The stress state and resulting camber, if any, can be approached through the means of the formulae which have been derived for eccentric loaded columns.[6] The derivation is achieved by considering the stress created by the molybdenum film and then applying this as an eccentric load. The expression has the form of the familiar secant formula and for the special case at hand the camber in inches per inch is:

$$C = \frac{1}{2} t_1 \left[\sec\left(\frac{3 (\alpha_1 - \alpha_2) (E_1 - E_2) t_2 T}{E_1 t_1^3} \right) -1 \right]$$

Where: "t" refers to physical thicknesses; the subscript "1" to the physical properties of the ceramic and the subscript "2" to the physical properties of the molybdenum; α to the coefficient of expansion; E to Young's Modulus; "T" to the sintering temperature.

As it turns out, in sample calculations, the ceramic and the coating must approach the same order of magnitude in thickness before any significant camber occurs as the result of the molybdenum coating alone. In sample calculation the thermal expansion and Young's modulus of the glass were assumed to be the same as that of the molybdenum. The further assumption is made that Young's modulus was not exceeded in cooling. These assumptions would lead only to too high a value for camber. Because camber does occur, we must look elsewhere for its origin in micromodule wafers. The formula can be of value, however, in considering camber in metal members, butt-brazed to ceramics. Again, it should be noted that the formula assumes that members behave according to Hooke's law and that indiscreet application of it, without regard to high temperature elastic properties, particularly yield point, will lead to unrealistically high values.

Thus far we have discussed the predictable nature of coatings on alumina substrates. To do this it is necessary to know a reasonable amount of detail regarding adherence mechanism. Of considerable interest would be the same examination of coatings on the high thermal conductivity ceramic - beryllia. At the present time it is possible only to guess at the adherence mechanism for beryllia. From working with metallizing formulations for beryllia, however, it is apparent that the general microscopic appearance of the coatings is the same. One can speculate, at least, that the same conditions will prevail. The significant characteristic which a theoretical study of this type reveals is the loss of DC conductivity and it is very likely that the same loss will occur in beryllia coatings.

The authors regret that we are unable to present any experimental data to corroborate our predictions. It has been our objective to acquaint users with the exact nature of the coatings involved and to point out that the state-of-the-art has advanced to a point where calculations of some meaning can be made. We would welcome indications from electrical design engineers regarding the exact significance of these properties. If interest exists we are considering undertaking more advanced studies.

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METALLIZING WAFERS

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COORS

This paper describes the process steps involved in the coating, handling, metallizing and inspection of finished wafers as developed by Coors.

The metallizing coating station functions by coating the wafer completely, drying it, and placing it on a belt that transports it to the boat loading area. The wafer is picked up and deposited on firing boats; the boats are loaded under single level conditions, that is with no overlapping of the wafers; and the wafer follows a track or conveyer to the metallizing furnace. This is continuous and automatic, as the wafers are processed through the furnace to the unloading station, where the parts are unloaded from the boats. Proceeding to the next station, the parts are again coated over the entire surface, this time with the photo-resist material. This coating is dried and the parts are transported to the orienting and exposure station. The exposure station has two prime parts; one for orienting the wafer, and the second, for exposing the photo-resist material. The orienting is done on all wafers. If a wafer is upside down, the equipment will turn it over and orient it properly by using three termination notches and the index notch, and present it to the exposure position in a precise, uniform manner every time. The photo-resist material is then exposed and the wafer is transported to the developing and etch-stripping station. Here, the photo-resist material is developed, using the required pattern, and the undeveloped portion is removed. Next, the wafer is transported through the etch bath where the unwanted metallization is removed. The wafer proceeds to the stripping station, which removes the exposed resist material, and through a batch process where it is nickel plated using standard barrel-plating processes. The capability of this line is one wafer every two seconds or approximately 290,000 parts per month on a one-shift basis. On a two-shift operation with an 80% yield, it can produce 460,000 per month. This is sufficient to supply the estimated needs for the industry through 1963.

Although it is in the early stages, this line has produced wafers which indicate that the pattern specification can be met. In other words, there will be no problems in pattern location or line definition. The moly-manganese coating is working very satisfactorily as regards both strength and thickness. In addition, this metallized material is suitable for brazing or welding; brazing has been performed using nickel gold alloy, at temperatures as high as 1100°C. Many problems have occurred with this line, the biggest, or at least the most frustrating, having been with the orienter-exposure station. The triggering signal was quite complex, making it very difficult to get everything properly timed and adjusted. However, in the present stage of debugging, this station is very satisfactory.

Quality Control will be maintained in three different stages: raw materials, in-process checks, and final inspection.

The raw materials will be checked for such things as proper formulation, contaminance, viscosity, density, ph values of etching acids, etc. Plain ceramic wafers are inspected completely prior to this operation, just as they would be if they were being supplied to the customer.

The first in-process check will take place immediately after metallizing is performed in the coating station; here the wafer is checked for completeness and uniformity of the coating. After processing through the metallizing furnace, it is checked to verify that the firing was of proper nature, and that there was no burn off because of too thin a coating on the ceramic. The next check takes place directly after the etch station where the wafer is checked for proper pattern. It wouldn't do any good to check between the metallizing furnace and the etching station because of the nature of the material; it is very difficult to discern by eye, or by other than a destructive test, whether any deficiencies have occurred.

The third phase of inspection is the final inspection where the parts are checked prior to shipment. They are inspected in accordance with MIL-STD-105, by lots, so that they are consistent with the general industry inspection requirements.

The product capability and versatility is the second step in discussion. Wafer thickness up to 0.020 inch can be accommodated. Future investigation will include exposure of all six surfaces either simultaneously or in sequence, thus accommodating all the lengths that may be used in the Micro-Module Program. Once the 0.020 inch length is exceeded the notch area is not fully exposed, because of the equipment conditions at this time; this precludes good line definition down the edge of the part. In this case, a separate operation is required using different equipment of the same nature. Pattern capability is as versatile as any camera type operation. We use a film, a positive condition of the film, so that we can do anything, we might say, that can be done with a silk screen process.

We believe that the photo etch process has superior line and edge definition and better control because, in the sintered condition, the manganese material will not flow or change location after it is applied. One of the problems involved in this process is camber. If the camber of a wafer is 0.001 inch or more, light is diffused around the pattern where it is not in close contact with the substrate. The original desire to hold camber to a maximum of 0.001 inch has been maintained, even though the latest specifications will allow camber up to 0.004 inch. For our purposes and the general purposes of the industry, it is desirable to keep camber as small as possible.

The accuracy of location is directly dependent on the ceramic outline dimensions; that is, the 0.310 inch nominal dimensions ±.004. Selected lots of material that generally run within 0.002 inch from part to part for a particular lot will be used. Although a few will exceed the 0.002 tolerance, all parts in a given lot will meet the 0.004 requirement. So by using a fixture with two-fixed sides, the pattern location can be maintained for all wafers that don't exceed 0.002 and, by adjusting the fixture dimensions, the same holds true for wafers whose tolerances go up to 0.004 inch.

VIII

MOUNTING COMPONENTS ON WAFERS

B. V. VONDERSCHMITT *RCA*

VIII

MOUNTING COMPONENTS ON WAFERS

B. V. VONDERSCHMITT
RCA

SUMMARY

The Introduction describes some of the various problems which have been encountered in the mounting of microelements in the past. Particular emphasis will be placed on problems encountered in the module manufacturing process. There will also be a brief discussion of the importance of cost, since the mounting of a microelement on a wafer is an additional cost not normally incurred when using conventional components inserted in printed-circuit boards. Since effective series connections are required, that is, connection of the microelement to the wafer and connection of the pad on the microelement to the riser wire, reliability will be stressed as an extremely important consideration.

Following the introduction will be a review of the various types of active and passive components which must be mounted in some fashion, that is, those components which are not manufactured directly onto a carrier, such as the cermet resistors and ceramic capacitors.

Under the topic of mounting requirements will be reviewed the cost objectives relative to the total component cost. These costs, of course, will include the carrier or wafer, the labor required to preform and mount, and any special reworking of the component that may be required. The detail requirements considering module processing and particularly any degradation that the act of mounting of a component will have upon the electrical performance of a component will be reviewed.

Examples of mounted components which have been developed will be shown, and comments will be made on problems and advantages that various types of component mounting have from a module assembly standpoint.

Conclusions and Summary will cover a final review of the importance of the compatibility of a mounting method with processing, again stressing the importance of reliable connections and cost.

INTRODUCTION

The purpose of this discussion is to provide guide lines and to indicate tests necessary to determine the adequacy of a selected method of mounting microminiature components on a carrier or wafer compatible with the micro-module form factor. It is not the intent of this discussion to indicate the best or most acceptable method existing at the present time to perform this function. It is merely the purpose to guide any manufacturer of components to insure that the total problem of mounting components is considered. In broad terms, these basic problems are as follows:

1. The reliability of the connection between the basic element and the carrier is of paramount importance since, prior to insertion in an operating equipment, at least two additional connections are required, namely connection between the substrate or carrier and the riser wire, and connection of the completed micro-module to the printed board. (Series connections increase reliability demands.)

2. The mounted microelement must retain a reliable connection, and this connection must in no way degrade during the total module manufacturing process.

3. Since the cost of mounting this element on a carrier and the cost of the carrier or wafer itself are partially in excess of conventional components inserted into a printed circuit board or integrated components made by semiconductor manufacturing techniques, it is important that the total cost of mounting a component not exceed 5 to 10% of the basic component cost.

DISCUSSION

Passive Components

Figure VIII-1 is a partial collection of the various passive microelements which have been mounted previously during the course of the micro-module program. Included in this list are toroidal transformers and inductors, cup type (magnetic core) i-f transformers, tantalum capacitors, cylindrical resistors, single layer capacitors, and thermistors.

Active Components

Figure VIII-2 shows some of the various types of transistors and diodes which have to be mounted. Included among these are the T046 and T051 transistor package, the U-8 transistor package, germanium diodes and various types of silicon diodes.

Examples of Mounted Components (Brief Discussions of Advantages and Disadvantages of Method Used) are discussed in the following paragraphs.

MOUNTED PASSIVE COMPONENTS

Two examples of mounting toroidal inductor and transformer elements are shown in Figure VIII-3. Method (not shown) consists of mounting the inductor on a metallized ceramic substrate or a ceramic capacitor. The disadvantage of this method of mounting lies in the fact that, during the mounting operation, the transformer conductors are either placed in the wafer notch, thereby later interfering with assembly, or are soldered in the land area of the metallized wafer. The latter method invites potential lifting during the assembly soldering operation. Another example of a mounted inductor is the one showing a deep recessed wafer (Part A of Figure VIII-3) on which one plane of the wafer provides a means of connecting the transformer conductors without interfering with the notch area. Through the use of high temperature solder (plastic temperature 50 - 100°C higher than soft solder such as 60-37-3) for the component

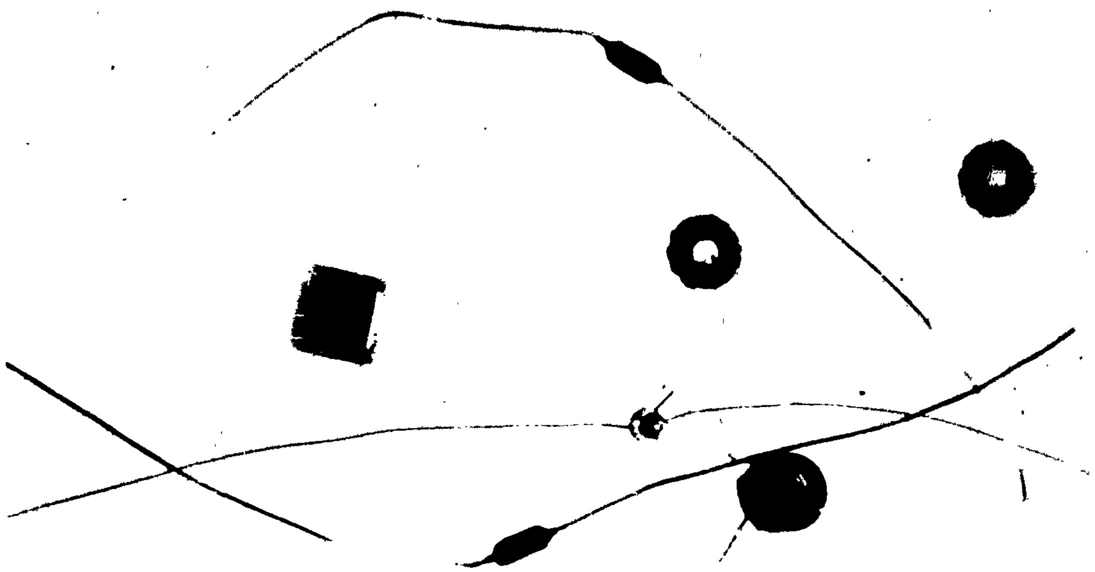


Figure VIII-1. Typical Passive Microelements (Unmounted)

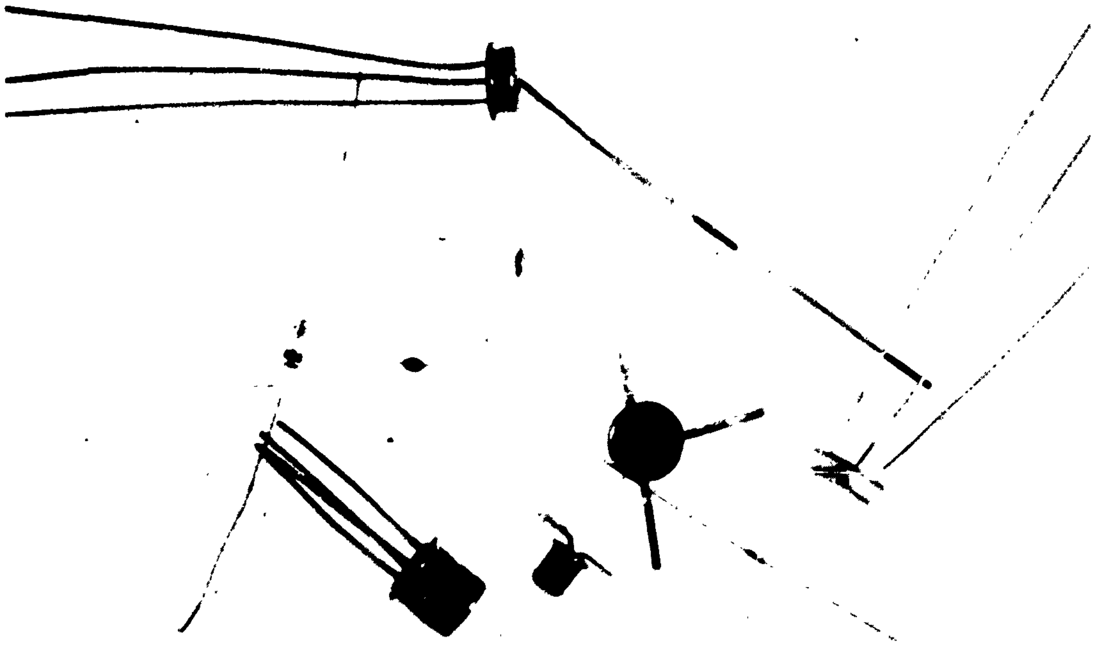


Figure VIII-2. Typical Active Microelements (Unmounted)

A

B

Figure VIII-3. Inductor Assemblies

soldering operation, the possibility of solder lifting becomes remote. Another variation of this same mounting (Part B) permits welding of nickel strips (in spider form) to this same plane of the wafer which subsequently can be used as a lug to connect the transformer conductors using high temperature solder. In this case, many problems, e.g., leaching of the metallization, common with the use of high temperature solders are avoided, and the soldered joint is sufficiently remote from the riser wire area to alleviate any problems of solder lifting during module assembly. As will be developed later in the discussion, this is considered an ideal carrier and component mounting method. Other examples include the mounted rod resistors shown in Figure VIII-4.

Figure VIII-4. Soldered Resistor Assembly

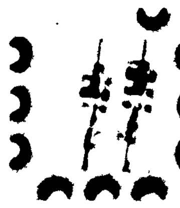
MOUNTED ACTIVE COMPONENTS

Figure VIII-5 shows mounted examples of the T046, T051, germanium diode, and silicon microdiodes.

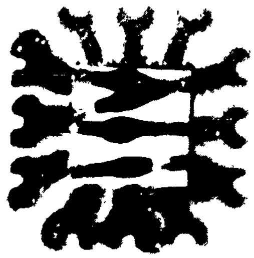
Not noted specifically in discussing the previous examples is the very important consideration of selecting a mounting process such that the act of mounting the unit does not degrade the reliability or the electrical performance parameters of the mounted component. Of significant interest are any excess strain on component leads and any excess temperature of temperature sensitive components, particularly small area germanium semiconductors. It is important, when a process is initially established, that measurements be made prior to and after mounting on a substantial quantity of components to determine the degree of change in characteristics; for example, in the mounting of semiconductors, particularly germanium units, it would be highly recommended to make a performance check of transistor parameters such as I_{ebo} and

TO-46 Transistor

TO-51 Transistor



Germanium Diode



Silicon Microdiode

Figure VIII-5. Examples of Mounted Active Components

"Beta", and reverse current on diodes so as to effectively evaluate any degradation due to excess temperature or mechanical stresses encountered during the mounting operation. It is also extremely important that hermeticity checks - for example, joy bomb tests - be made on a continuing basis even after the process has been established. This obviously leads to making limited parameter checks prior to mounting and detailed checks subsequent to mounting.

It is also very important, having selected the mounting method, that a substantial quantity of microelement subassemblies be processed and assembled into modules (not necessarily an operating module) and then checked in accordance with the thermal shock requirements. Measurements of the components should be made at the temperature extremes to insure that the mounting methods selected do not cause - during the thermal expansion resulting from the temperature excursions - failure or degradation of the components. This is probably the singular important source of difficulty which will arise in any newly developed mounting method. Since the coefficient of expansion of the carrier and mounted unit may not necessarily be compatible, proper precautions must be taken to prevent (1) severe strain on the component during the thermal shock and (2) failure of the connection means between the component and carrier.

MICROELEMENT MOUNTING AND MODULE MANUFACTURING PROCESSES

The following items must be considered from a module assembly standpoint:

1. Interference of mounted components in notch area.

2. Excessive temperature environment during module assembly (e.g., soldering).

3. Microelement subassembly form factor.

Since at least two of the present module manufacturers would find assembly difficult by any mechanical interference of a component in the notch area, it is important that the completed microelement assembly meet with the gauge requirements discussed previously by Mr. Oates. Reference has already been made to the importance of Item 2; that is, the component to carrier connection being capable of withstanding all manufacturing processes, particularly soldering. The third item noted indicates that it is desirable to have both the top and bottom of the microelement assembly as uniform as possible to prevent non-parallelism between wafers in the completed assembly.

It is desirable for all module manufacturers to have components which do not have a single high projection point, so that when the element rests on a spacer or a tape transport during the stacking process, the carrier will be kept parallel with either the spacer or the tape transport.

COST CONSIDERATIONS

There are three major items of cost: the material cost of the carrier or wafer, the cost of labor, and the cost involved in special handling of the component. The total of these costs should not exceed a maximum of 5 to 10% of the basic component cost. There are obviously exceptions to this rule of thumb, but in normal cases, a 10% cost increase would be the maximum that could be tolerated to stay cost competitive with other packaging systems.

SUMMARY

In conclusion, we can restate in order of importance, though not necessarily separable, the three most important considerations. They are:

a. Compatibility with processing.

b. Reliability both from the standpoint of long life, degradation of component and ability to withstand thermal shock requirements in the module.

c. The cost of the mounting method must be a small percentage of the intrinsic cost.

IX

PLANS FOR USING MICROMODULES IN ARMY EQUIPMENT

MR. T. KYNE *USAEMA*

IX

PLANS FOR USING MICROMODULES IN ARMY EQUIPMENT

MR. T. KYNE
USAEMA

Most large and many small industrial firms have market planning organizations which try to predict the type and quantity of their products required in future years and the share of the market their company will have, and which also recommend the action to be taken to assure profitable future business. You will not find market planning organizations in any Government, but our Industrial Preparedness Activity has the same type of work among its functions. The Production Development Division is responsible for satisfying the predicted Army demands for future electronic equipment by developing the necessary production capabilities in those cases where industry cannot develop its own facilities in time to meet the Army's planned schedules.

Most of you here from industry represent companies that have already invested heavily in micro-module production facilities. Your managements are vitally concerned as to whether they will eventually have a profitable micro-module business. Decisions must be made on additional investments in facilities, engineering, and marketing promotions. We cannot tell you how to run your business, but we are interested in having a healthy micro-module industry which will make a reasonable profit and therefore remain in business. I'm going to use the best and most up-to-date information we have, to give you our ideas on future micro-module business possibilities. These predictions are not based on vague generalities and arbitrary percentages. They are the results of studies and definite plans to convert particular Army type-numbered equipments completely or partially to micro-modules.

Let's start with the orders already placed. You all know about the 13 AN/PRC-51 Helmet Radio Sets and the AN/TYK-9 MicroPac Computer on the RCA micro-module contract. RCA also has orders for 350 AN/PRC-25 Walky-Talky sets using over 40 modules each and 2 Informer Computers using over 10,000 modules in each. Mallory has a small order for 400 AM-427/U I-F Amplifiers used in the AN/PRC-8, 9, and 10 series of Handy-Talky sets; but this is just the beginning. This i-f amplifier is used in the Army by the thousands and plans are eventually to replace all or most of the present tube-type units with the micro-module version. In Fiscal Year 1962 just concluded, the Army obligated about 4 million dollars on micro-modulized equipment.

Plans are being formulated for converting tactical radio communications equipment to micro-modules. These sets are scheduled to start in production in FY-1963 and continue at least through FY-1967. Tentative plans have also been made to apply micro-modules to Army aircraft electronic equipment. These include the AN/ARC-51 and AN/ARC-54 Radio Communications Sets, the AN/ARR-49 Receiver, and the C1611/AIC-12 Interphone Amplifier. Deliveries of these, however, will not start until FY-1964. Other items in the FY-64 and FY-65 plans are the AN/GRC-106 and AN/GRC-108 Single Sideband Radio Sets and Ground Radio Set AN/GRC-66.

The production equipments are listed below; as you may know, they are already transistorized. They use modular construction. There are a great many used and procurement is scheduled in 63 and 64.

AN/PRC-25	AN/ARR-49
AN/VRC-12	AN/AIC-12
AN/ARC-51	Ground Single Sideband
AN/ARC-54	AN/GRC-66

Now we'll summarize equipments in the R&D stage where complete micromodulization is more likely at the start of production, but where we have no definite production quantities yet. In this category, we have the seven equipments listed below, which are the result of the R&D Program:

a. Airborne HF SSB Radio

b. Tactical Digital Communications System.

c. Electronic Teletypewriter.

d. MicroPac Digital Field Computer.

e. Secure Forward Area PCM Communications Set.

f. Lightweight surveillance radar AN/PPS-6.

g. Flash Ranging Set AN/GAS-1.

Micro-modules for these seven sets, except for a handful of engineering samples, will start to build up slowly during FY-1965, and reach about one million per year by FY-1969. Out total Army Signal Corps requirements based on a conservative percentage of planned equipment conversion to micro-modules are represented by the curve of Figure IX-1. You notice we have the best of current production sets on which we have an overlay of the sets as they come into production fromR&D, and it builds up to a fairly impressive figure. It adds up to a total of about 400,000 wafers a month, but if we build up even to the 2 million mark, we will not have any excess capacity.

I should emphasize that these figures are based on planned conversion where the greater reliability, small size and weight, the standardization and logistics advantages justify paying a higher initial cost to get the service life advantages of the micro-module.

Meanwhile, what will happen to micro-module costs as quantities increase is shown in Figure IX-2. This curve has been worked on for a number of years. The competitive advantages, of course, increase as the quantities increase so that we get to a price competitive with the conventional printed board. Now, as you may notice from the symbol, this is a slide that was computed by the RCA people and it might be criticized as over-optimistic. It may be in predicting the years for certain production levels but, from the trends we have already seen and the expected competition, the price reductions might even be a little conservative. Obviously, where costs are a

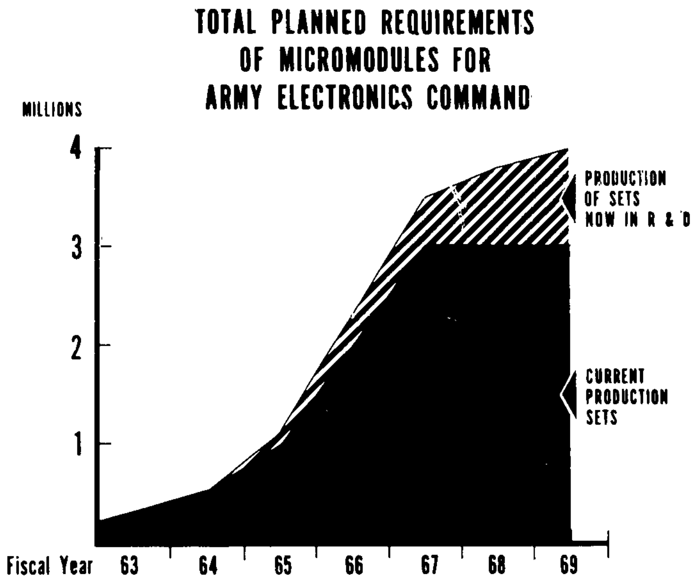


Figure IX-1. Total Planned Requirements of Micro-Modules for Army Electronics

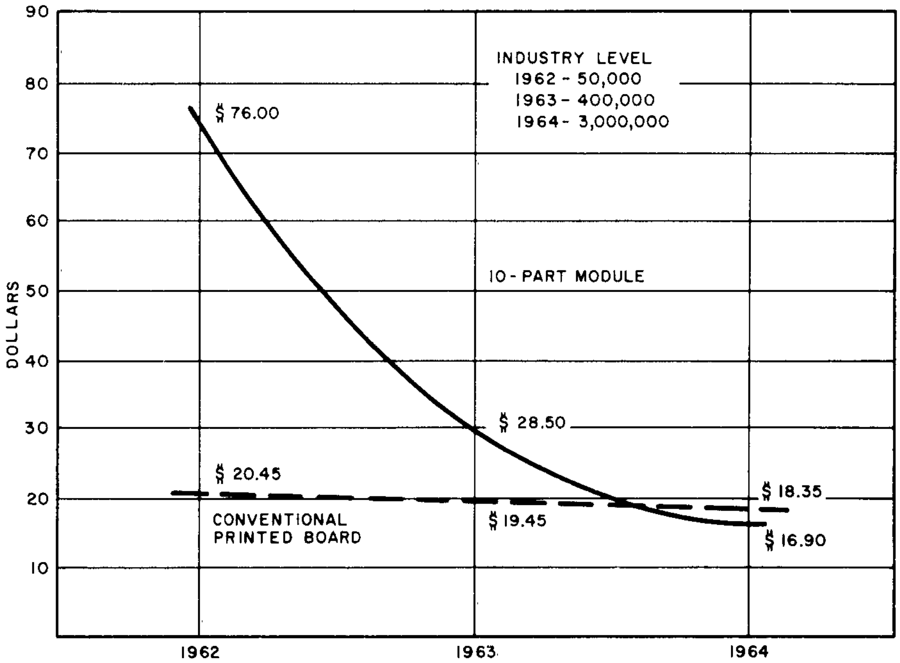


Figure IX-2. Price Projection for Average Micro-Module greater factor for initial procurement, lower micro-module prices will encourage greater applications. However, I will ignore this trend in my estimates and simply assume that it will make my figures more conservative.

So far I have talked about just the Army Electronics Command. What about the rest of the Department of Defense? All 3 services are currently using the so-called "cord-wood" modules in some of their production equipments. These are larger than micro-modules and consist of standard miniature components stacked like cord-wood with connections either welded or soldered and the entire assembly encapsulated. The Air Force, Navy, and Army are also sponsoring advanced research and development work in integrated circuits, thin films, and molecular electronics. We in the military services who have sponsored various approaches to electronic assemblies naturally would like to see our own system used for production equipment, but we actually have very little control over the assembly methods chosen by military electronics equipment designers. The choice is usually determined by proven ability to meet performance, by availability, and cost. This is true regardless of who developed the system and who the customer is. For this reason, we expect to see hybrid combinations of several systems in Army, Navy, and Air Force equipment, where each represents the most economical method of achieving the desired performance.

Our most recent figures indicate that the Signal Corps bought about 1/3 of the electronics parts and equipment procured by the Army. Army purchases in turn represent about 1/6 that of the total spent by Department of Defense on electronic supplies. We expect to encounter approximately the same ratio of circuits capable of conversion to micromodules in Navy and Air Force equipment as we have found in Army applications. However, we do not expect as rapid nor as complete conversion in other services as we plan in the Army. For these reasons, we assume a maximum conversion factor of 28% for 1969. In other words, only 28% of the Department of Defense equipment which could use micromodules actually will use them 6 years from now. Accordingly, our estimate for Department of Defense micromodule requirements during the next 6 years is shown in Figure IX-3. As you may notice, the Army Electronics Command is not the biggest but we are there first and the figures build up to a very impressive amount.

In order to avoid any misunderstanding, I must emphasize that these figures have not been officially approved by the Department of Defense, the Army, or my own Agency. The estimates were developed in my division using the best available information on future plans and past experience with the introduction of similar new items in electronics production. The management of companies planning additional investments in micromodule production facilities should have as much information as possible regarding our future plans. I hope the unofficial estimates I have given you today will be of some use in your own company's planning.

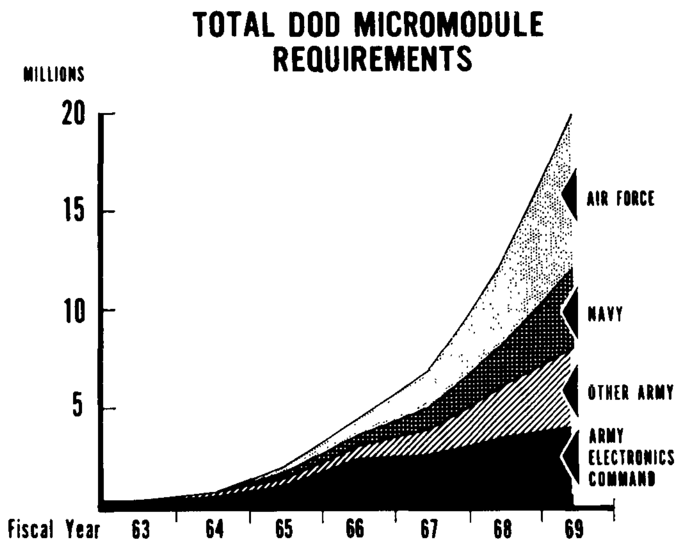


Figure IX-3. Total Department of Defense Requirements

X

STATUS AND PLANS FOR SPECIFICATION, QUALIFICATION APPROVAL AND STANDARDIZATION

D. S. ELDERS — *USAERDL*

MISS SARAH ROSEN — *USAEMSA*

X

SPECIFICATIONS - PRESENT STATUS

D. ELDERS
USAERDL

The documents that I am going to speak about this afternoon are the ones that have been issued by the Army Electronics Research and Development Laboratory at Ft. Monmouth and are, essentially, for the use of our equipment development engineers to guide them in any applications they may have for micromodules in their equipments.

Between February and July of this year, the laboratories have issued ten specifications or, as we call them, Signal Corps Technical Requirements. These documents, which are listed below, are referenced in all of our equipment R&D specifications, and the seven R&D equipments that Mr. Kyne mentioned previously included a requirement for these documents.

(1)	SCL-7700	Technical Requirements for Micromodules
(2)	SCL-7701	Capacitors, Fixed, Ceramic Dielectric, General Purpose, Microelement
(3)	SCL-7702	Capacitors, Fixed, Ceramic Dielectric, Temperature Compensating and Precision, Microelement
(4)	SCL-7703	Capacitors, Solid Electrolyte, Tantalum, Microelement
(5)	SCL-7704	Capacitors, Variable, Ceramic Dielectric, Microelement
(6)	SCL-7705	Resistors, Fixed Film, High Stability, Microelement
(7)	SCL-7706	Inductors and Transformers, Microelement
(8)	SCL-7707	Crystals, Quartz, Microelement
(9)	SCL-7708	Transistors, Microelement
(10)	SCL-7709	Diodes, Microelement

Most of these documents are quite comprehensive and quite voluminous. To give a brief idea of what these documents include, let us briefly summarize the table of contents on the module specification. SCL-7700 includes requirements for electronic performance of modules; and for environmental requirements; reliability requirements; manufacturing information; assembly process information; requirements for the individual microelements as they relate to the micromodule; and the individual specification sheets, which include such information as the micromodule outline and termination dimensions, marking, coding, encapsulation, terminations, and so forth.

Some of the specifications, particularly the transistor and the diode specifications include individual specification sheets on specific types of items.

As new items become available, particularly solid circuits or thin-film circuits, and as they reach a state of maturity where they are consistent with our micromodule requirements, specification sheets will be written to include these items in our module specifications.

I would like to mention that these Signal Corps technical requirements have been forwarded to our Electronics Materiel Agency to be processed into Signal Corps procurement specifications. I would also like to mention that the complete list of Signal Corps technical requirements given above can be obtained by writing to the Laboratory at Fort Monmouth.

STANDARDIZATION IN MICROMODULES

S. ROSEN
USAEMSA

The technical requirement documents discussed previously are based on data resulting from the research and development phase of the Micromodule Program with RCA and are not in standard procurement format; consequently, our agency, the U.S. Army Electronics Materiel Support Agency, is presently preparing 10 limited coordination Signal Corps Department of Army procurement documents which, in addition to incorporating R&D Data from the SC Technical Requirements, are also including data developed from the Production Engineering Measure Phase of the RCA contract.

These ten documents will consist of a basic micro-module specification assigned as MIL-M-55183(SigC) and entitled, "Micro-Modules, Design, Construction and Application of, (For Army Signal Equipment)." Each of the nine microelement specifications is a general type specification and will detail all requirements for the procurement of four types of capacitors, and one type of resistor, diode, transistor, crystal, and inductor. Individual specification sheets attached as appendixes to the general specification will contain specific requirements for each type of microelement being procured. Tentative specification numbers have been assigned to each of these microelement specifications.

Our micromodule specification will contain specific requirements for a complete micromodule, since each micromodule being procured is presently considered a "custom" procurement; in addition to this micromodule specification, three additional complementary documents will be required as part of each procurement. These documents will consist of:

a. Manufacturer's micromodule drawing

b. Manufacturer's test specification

c. Microelement manufacturer's drawing or microelement specification sheet.

These combined documents will provide the schematic circuit diagram, precise electrical requirements, configuration of each wafer, metalizing information and module testing apparatus, test jigs, etc.

The micro-module specification will also contain the collective requirements applicable and common to the microelements covered by their respective documents. Each microelement specification will directly reference the micromodule specification for such basic standardized requirements as:

Substrate material

Solder and flux

Mounting information

Wafer Dimensions and form factor

Wafer Marking - hole locations, etc.

Metalizing areas

Permissible terminal areas

Useable area

Riser wire requirements

Cleaning

Coating

Encapsulating material

In addition, standard environmental testing to be performed in accordance with MIL-STD-202 will be referenced, such as:

Vibration tests

Shock tests

Shock and Spin

Moisture Resistance

Barometric Pressure (altitude)

Temperature Cycling, etc.

Each microelement specification will detail specific electrical and physical parameters required for each microelement which will be checked before and after subjection to these environmental conditions.

Regarding the quality assurance provisions for these documents, all ten specifications will have consistent quality assurance requirements. Each will provide for:

a. Component Materials Inspection, which will be verification of solder, solder flux, riser wire, substrate material, shells, printed wiring boards, desiccants, etc.

b. Preproduction Testing, which will require all tests in the applicable specification to be performed on an established number of micromodules and microelements.

c. Acceptance Inspection, which shall be in accordance with MIL-STD-105 and will contain "A", "B", and "C" inspection requirements. Major and minor defects will be defined in each of the specifications. Information gathered from results of the preproduction testing will be maintained by the production engineering personnel of our Agency to aid them in selecting reliable sources of supply for additional procurements.

Because of the urgent need for these procurement documents, coordination with interested Department of the Army activities is being made on an accelerated basis - such as informal conferences. RCA, the contractor-leader for this Micro-Module Program, has commented on the initial drafts of these documents. We expect to have all the documents approved and printed by December, 1962.

Although standardization of circuits is not included in this current specification effort, it is recognized that efforts in this direction would be fruitful. The equipment standardization personnel in our agency have initiated an internal project to study possible standardization of modular circuits which would be in consonance with the specific requirements of the micromodule and microelement documents described above.

In conclusion, as new microelements, material, and processes become available as a result of either military research and development or Production Engineering programs, or as a result of commercial developments, these procurement specifications will be modified wherever necessary.

XI

A REVIEW OF THE MICROMODULE PROGRAM

COL. D. O. TOFT *USAEMA*

XI

A REVIEW OF THE MICROMODULE PROGRAM

COLONEL D. O. TOFT
USAEMA

As most of you know, those of us here, either from Industry or the Government, are specialists in our own particular fields. Since we are aware of the problems concerning our own interest in the field and of our individual problems in the production of micromodules, our natural tendency is to read carefully only those parts of the micromodule reports which cover our own areas and to skim through or completely ignore the remainder.

One important purpose of this conference is for us to look at the entire micromodule program and see what a vital part each of our individual efforts play. So let us briefly review the reasons for starting the program, our accomplishments to date, and our plans for the future.

In looking back at the early history of "radio parts" we remember that the size and shape of capacitors, resistors, and transformers were not a major problem for the radio designer or manufacturer because the vacuum tubes were so bulky that a lot of space was needed to dissipate the heat. Small components were easily mounted by their leads between the tube socket terminals on the underside of the chassis and, if there were larger components, they were fastened to the top of the chassis adjacent to the tubes.

As vacuum tube designers developed smaller tubes, equipment builders requested improvement to your components to keep pace with the size reductions during this period. In addition, increasingly severe environmental conditions, imposed by military applications, led to improvements in materials and protective coatings which gave better performance in smaller space. Shock and vibration considerations stimulated the development of ruggedized tubes and the mounting of components rigidly on terminal boards. This, in turn, evolved to the present use of printed wiring boards and dip soldering which, with today's conventional electronic construction, eliminates wiring errors, keeps soldered joints more uniform, and reduces the size still further. Most important, and that is for both military and commercial products, manufacturing costs have also been significantly reduced.

All the foregoing developments in electronic assembly were given a major revolution by the advent of transistors. We are no longer limited by the one or two-thousand-hour life of vacuum tubes, and we could permanently wire the transistor into the circuit. New lower voltages and power requirements enabled designers to use smaller power sources and thus much smaller components.

The Army, however, was still not satisfied that full advantage was being taken of the features made possible by the transistor. Most resistors were still tubular, capacitors were disc or rectangular in shape, and inductors had a prolific variety of shapes all their own. Most components were still suspended by their leads and had individual protective coatings which were marginal in many instances. We wanted a system that could, within a few years, be used for building military equipment that could give a 10-to-1 size and weight reduction, that could use familiar materials and techniques of proven reliability, that could cover at least 95% of the lower power digital and communications circuits, and still could compete with standard subminiature parts on production costs. As a bonus, we also wanted the capability of using integrated circuits, thin films, and other advanced techniques when they became reliable and economical enough for application in military equipment.

So, in 1958, all of the existing microminiature approaches were evaluated, and the micromodule proposed by RCA was chosen because it came closest to meeting all of our requirements. You are all familiar with the disciplined geometric shape of micromodule wafers and how they are assembled into a module; but what does this mean, related to our incremental size reduction of standard components over the years? It is a radical departure, mechanically, because we have eliminated the fragile leads, and the individual protective cases and coatings; have stacked uniformly shaped wafers into a cage of wires; and have encapsulated the entire structure to give it complete environmental protection. From a production cost standpoint, the uniform shapes enable us to standardize engineering layouts, facilitate hand assembly for small quantities and make possible a high degree of mechanization for larger quantities. Electrically, however, it represents very little change. For the most part, we have kept discrete components on separate wafers and used traditional materials and processes for which considerable test data and experience had already been accumulated. This approach was chosen to keep the development time to a minimum, give high production yields, and improve reliability. Thus, components can be handled in the traditional way with individual specifications, qualified suppliers, lot sampling, and all the other proven techniques established over the years between parts vendors and their customers.

By keeping our electrical changes to a minimum and by eliminating a major source of mechanical weaknesses of traditional components, we expected considerable improvement in reliability. Our test results indicated we have far exceeded our original goals. Reliability comparisons between micromodules and conventional components are difficult because test conditions are not usually the same. Using conservative conversion factors, the micromodule is apparently as reliable as Minuteman high-reliability components, which is a very costly operation, as you know. The micromodule data were taken on a completed assembly of 10 to 15 components and include the reliability of the soldered joints while the conventional component data were taken on individual components only. In addition, the micromodule data were taken on units manufactured many months ago and since then processing and assembly techniques have improved. Preliminary data on a smaller quantity of the latest improved micromodules show still better results.

We should now briefly review the status of our production capability for components and modules. Our production capability goal was 25,000 micromodules per month from three sources or otherwise a total of 75,000 per month on a one-shift basis.

Mass production facilities for some components were contracted for as early as March of 1961 and the last of the microelement pilot runs is scheduled to be finished in June of 1963. Resistor and capacitor production lines are further along than other components because this work was started earlier. The production tooling already in use for these two components is yielding gratifying results in improved quality and lower costs. Similar results are expected for other components.

Module production and test facilities are scheduled for completion at RCA by September of this year, and at two subcontractors in February, 1963. All module pilot production runs will be finished by August 1963.

The part and module manufacturers who are in the program now, augmented by some companies who have used their own funds exclusively, already have a production capability which, while limited, will satisfy requirements until the planned facilities are in operation.

The big question most of you are asking is -- where are we going to use all this production capability, present and future, and what are the Army's needs?

Thirteen models of the AN/PRC-51 helmet radio will be delivered within a few months and will be demonstrated to potential users in the military agencies. These sets are outstanding examples of the ruggedness, reliability, and size reduction possible by using micromodules in military communications equipment. Earlier demonstrations of this set have already resulted in two applications of micromodules in Army portable communications equipment. Of the new walkie-talkie AN/PRC-25 Radio Set, a small number, three hundred and fifty, will be delivered in which 60% of the components are in the micromodule form. This is an example of a hybrid combination of micromodules and standard components to optimize engineering, production, scheduling, and cost considerations. An order has already been placed by the Army for 400 i-f amplifiers for replacements in the standard Army AN/PRC-8, 9, and 10 Radio Sets.

The MicroPac computer was built to demonstrate the feasibility of using micromodules in digital applications. It is now undergoing final test and debugging but an earlier evaluation of this work by the Army Electronic Proving Ground at Fort Huachuca resulted in their order for two field computers, each of which uses about 10,000 micromodules. These represent the beginning of applications in Army production equipment.

Although the original cost of equipment in micromodule form is greater than equipment constructed with standard components at this time, the useful lifetime cost narrows this difference considerably. The micromodule is expected to have a longer shelf life because of its encapsulation. With better reliability, fewer spares will be required. The micromodule will be the smallest replacement unit so that one spare module will be equivalent to 10 or 15 conventional spare components. And I want to mention here that many of our troubles in the field occurred because of the inexperienced man with the soldering iron. It will take less test equipment, less time, and less skill to locate and replace a defective circuit than a defective part. Reduced size and weight will reduce shipping and storage costs. Preliminary studies indicate that the Army can pay a premium of up to 70% more for some equipments in micromodule form and still save in the over-all life time costs.

The Army has a broad program to carry the application of micromodules into as wide use as practical. New equipments in the R&D stage are being studied and, where practical, modules will either be specified or the reliability, size and weight limitations imposed will make their use mandatory.

In december of 1961, the Army Deputy Chief of Staff for Logistics issued a directive to the Chief of Ordnance, Chief of Engineers, and Chief Signal Officer to "Take prompt and positive action to incorporate the micromodule concept, as appropriate." To implement this order, the Signal Corps made presentations to a number of arsenals and agencies and acquainted their personnel with the advantages of using micromodules.

Efforts have not been limited to the Army, because the same advantages are valid for other military and civilian agency users. For example, the National Security Agency will soon receive over 1,000 micromodules made to their specifications for experimental use as building blocks for security equipment designs. The naval electronics research laboratory has ordered a portable computer test set which will use about 100 micromodules. Other military and industrial organizations have received small quantities of micromodules for their tests and evaluation.

Admittedly, these efforts to date have been far short of those necessary to bring the micromodule into wide industrial use in a short time. We were waiting until we were ready with the reliability, reasonable price, and production capability to meet the demands. Victor Hugo once said that there is nothing more powerful in all the world than an idea whose time has come. The time has now arrived for the micromodule and we plan to tell our story to the entire electronics industry. Two weeks ago, General Cook, the present Chief Signal Officer, held a press conference in New York to announce to the public that the micromodule is now ready for widespread use and I'm sure most of you have seen the newspaper reports. This announcement is expected to generate a large volume of requests for additional details on the sources and capabilities of micromodule parts and how to use them. A design manual is now being prepared for the Army, which will be a useful reference guide for equipment design engineers. It will contain information on how to design micromodule circuits and a components section listing sources, tolerances, ranges, and other performance data.

In looking at the future, let us bear in mind the R&D battle cry, "If it works, it's obsolete." The micromodule is working well and we want to take full advantage of this technique while it is available. The Research and Development Laboratories at Fort Monmouth have awarded a number of contracts for advanced studies in integrated circuits, thin films, welded connections and other techniques which will be used in future micromodule applications. Close liaison is maintained with other government and industry developments in similar fields. These new techniques may not be ready for quantity production for five or ten years and, even then we may still see hybrid combinations of present and advance type modules side by side in equipment for a long time. For most applications, economics will determine where each type is used.

In conclusion, we can say that the micromodule has come a long way in the last four years. The Army expects to see further reductions in price and improvements in quality before the present 18 million dollar contract is finished. However, as of now, the achievements are impressive enough for the Army to start using Micro-modules wherever practical and encourage the rest of the Army, Navy, Air Force, NASA, and Industry to do the same. Finally, we are planning to keep the micro-module in step with advancing techniques so that in future years we can use the best practical combination of methods for assembling military electronic equipment.