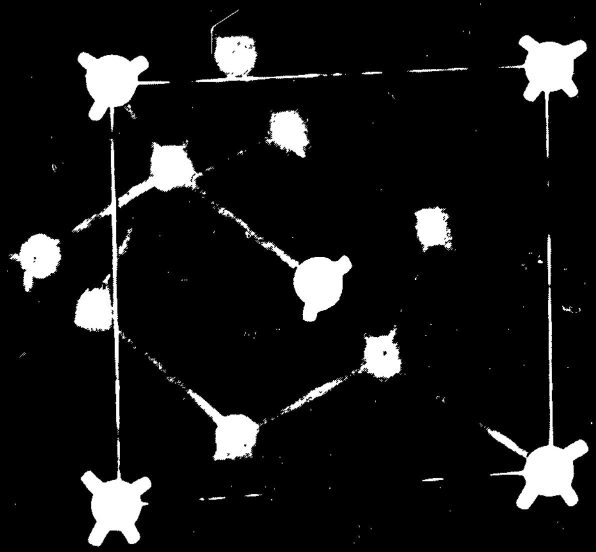

PRODUCTION ENGINEERING MEASURE

MECHANIZATION OF SEMICONDUCTOR DEVICES

2N559 - 2N1094

QUARTERLY PROGRESS REPORT NO. 22
FOR THE PERIOD
APRIL 1, 1963 TO JUNE 30, 1963

CONTRACT NO. DA-36-039-SC-72729
ORDER NO. 53888-PP-56-81-81

PLACED BY

U.S. ARMY ELECTRONICS MATERIEL AGENCY
PHILADELPHIA, PENNSYLVANIA

Western Electric Company
INCORPORATED
LAURELDALE, PENNSYLVANIA

Copy No. 66

PRODUCTION ENGINEERING MEASURE

MECHANIZATION OF SEMICONDUCTOR DEVICES

2N559 - 2N1094

QUARTERLY PROGRESS REPORT NO. 22

FOR THE PERIOD

APRIL 1, 1963 TO JUNE 30, 1963

OBJECT:

Design And Provide High-Volume Production Equipment For Use In The Manufacture Of Semiconductor Devices.

CONTRACT NO. DA-36-039-SC-72729

ORDER NO. 53888-PP-56-81-81

Prepared by: M. N. REPPERT

Approved by: R. E. MOORE

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SECTION I

ABSTRACT

This progress report reviews the activity on PEM Contract No. DA-36-039-SC-72729 during the twenty-third quarter, April 1, 1963 to June 30, 1963.

Phase 1 activity terminated in June with the submission of the Phase 1 Final Report. With the exception of the final report, the U. S. Army Electronics Materiel Agency has accepted all Phase 1 Contract Items. Phase 2 modification of transistor processing and production equipment continued throughout the report period as indicated in the following paragraphs. The Western Electric Company has, however, initiated preparation of a proposal to redirect the Phase 2 contract effort to support Nike X development at the request of the U. S. Army Electronics Materiel Agency.

Major effort on Refinement of Phase 1 Machines was concentrated on five machines - Piece Part Cleaning, Header Assembling, Header Continuous Rack Plating, Can Getter Assembling and Closure Welding. The second Piece Part Cleaning Machine was modified to process ferrous glassed parts, and a new loading station was developed that will enable the two machines to handle a number of dipping baskets without jamming or tilting. Design of a platform-lead loading station for the Header Assembling Machine was completed and construction started, and modifications to the lead feeder improved lead feeding. Two refinements to the Header Continuous Rack Plating Machine were in progress during the quarter and will be completed next quarter. A corrosion problem within the control console is being studied. The corrosive atmosphere of the plating area causes this problem.

On the Can Getter Assembling Machine, an examination of the can loading station indicated that several modifications are needed to improve it and simplify maintenance. Early in the quarter the crystal size of the barium hydroxide getter was changed to screen out fine particles which remained on the can flange after getter loading. Tests aimed at optimizing the crystal size followed. The practicability of purchasing crystals meeting the optimum is being investigated. An evaluation of a modified electrode holder on the Closure Welding Machine indicated that this holder eliminated an arcing problem and facilitated changing electrodes. During the next quarter, efforts will be made to increase electrode life by redesigning the lower electrodes.

Preliminary development of the three Phase 2 Machines has continued. Modifications to an ultrasonic generator have increased the uniformity of wire bonds while determining the feasibility of using ultrasonic energy for wire bonding on an advanced design machine. A suitable wire feeding system is being sought. Difficulties are being encountered with the two systems tested thus far. A soldering technique capable of meeting Tinning Transistor Lead requirements and suited for mechanization is still being sought. In the meantime, plans have been made to increase the output of the present glass-seal-masking operation next quarter. Handling Tray Loading Machine development is still dependent on the results of evaluations of a new header handling system developed during the report period.

Engineering effort continued on the six process refinements and associated studies reported previously. A survey of Slice Surface Preparation has terminated effort in this area. since no specific improvements are needed. Another survey related to Stripe Evaporation and Alloying has produced a program for evaluating equipment and processes, but the evaluations have not started. Extensive data was collected for the Pneumatic Components study through personal contact, literature surveys and tests. The tests will continue next quarter in order to provide additional performance data of various pneumatic components and combinations thereof.

The header handling system, developed as a result of the Material Handling study started last quarter, is being evaluated. The study is directed toward improving material handling, especially between emitter etching and closure welding. Sample trays, retorts, plastic carriers and stainless steel channels for the carriers are being evaluated to determine their feasibility and develop design requirements.

Further evaluation of Wire Welding equipment has not produced the desired results. Equipment modifications will now be made in an effort to overcome difficulties which cause erratic performance.

The Thermal Shock study of last quarter was expanded into a Header Thermal Capability study this quarter to evaluate additional factors which may introduce strain and cracks in the glass seal. Experiments performed to date are inconclusive; results have, however, indicated that an uncontrolled variable was probably introduced at the can welding operation. Experiments will be performed next quarter which control the variables at can welding completely. Three additional process refinements were initiated during this report period. Orders have been placed for equipment needed to refine the Diffusion operation. The aim of this study is to evaluate variations in sheet resistivity from slice to slice in a given diffusion run and to find means of precisely controlling the diffusion variables.

Data collected to evaluate the Silicon Dioxide Coating operation has led to the choice of a process - application of a clear coating prior to in-process aging. Experiments will be conducted next quarter to determine the repeatability of this process.

To improve Header Internal Lead Trimming, several modifications were made to a turret-type lead trimmer. The modified trimmer will be evaluated next quarter to determine if the trimmed lead length is held within the tightened heighth tolerance.

SECTION II

PURPOSE

The mechanization program for 2N559 and 2N1094 transistors is divided into three phases. During Phase 1 it was directed toward establishing a limited production line capable of producing at least 24,000 transistors conforming to applicable specifications per two (2) shift, eight (8) hour, five (5) day week. Machines are to be provided for mechanizing the following operations:

Cleaning Header Lead Wire*
Piece Part Cleaning*
Piece Part Gold Plating*
Platform Lead Welding
Header Assembling
Header Glassing*
Header Lead Trimming
Strip Perforating and Welding*
Header Continuous Rack Plating*
Can Getter Assembling
Slice Scribing*
Wafer Breaking, Screening & Loading
Wafer Bonding
Wire Bonding*
Final Cleaning
Closure Welding
Card Loading
Testing and Date Stamping - 2N559
Data Handling*
Card Packaging

*These machines are also to be capable of processing 2N560, 2N1051, and 2N1195 transistors.

In Phase 2, the Phase 1 2N559-2N1094 transistor production line is to be expanded to a capacity of 60,000 transistors conforming to applicable specifications per two shift, eight hour, five day week. In addition, the transistor processing and production equipment is to be modified to increase the Phase 1 device assembly production yield by six percentage points with refinement in the following areas:

Phase 1 Machines
Wire Bonding
Handling Tray Loading
Tinning Transistor Leads
Slice Surface Preparation
Stripe Evaporation
Stripe Alloying
Wafer Evaluation
Emitter Etching
Protective Coatings

In Phase 3, the Phase 1 and 2 transistor processing and production equipment is to be further refined to increase the Phase 2 device assembly production yield by four percentage points.

SECTION III

ENGINEERING NARRATIVE

This section reviews the final Phase 1 efforts and progress made on Phase 2 Contract Items during the twenty-third quarter of the Contract. For this report period, effort was directed toward final completion and acceptance of the last four Phase 1 items and toward continuing or initiating Phase 2 modifications to transistor processing and production equipment.

1. ACCEPTANCE OF PHASE 1 CONTRACT ITEMS

During this report period limited engineering effort was directed to complete three incomplete Phase 1 technical requirements of the Contract. Test data accumulated on nine thousand 2N559 transistors and 250 each of transistor type 2N560, 2N1051, 2N1094 and 2N1195 was submitted during April. Supporting data verifying production rates and yields of various items of mechanized equipment was also submitted early in the quarter. A representative of the U. S. Army Electronics Materiel Agency reviewed the detailed drawings of production equipment provided during Phase 1. USAEMA has indicated that the foregoing Contract Items as well as the correlation samples and accompanying data, submitted last quarter, are acceptable. Thus, all Phase 1 technical requirements are completed.

The major portion of the Phase 1 effort for the reporting period was centered on final preparation and printing of the Phase 1 Final Report. This effort terminated during the second week of June after the final report was distributed. This report covers all 2N559-2N1094 mechanization developments from April 30, 1959 to December 31, 1962. All Phase 1 Contract Items will be completed as soon as the Phase 1 Final Report is accepted by USAEMA.

2. PHASE 2 CONTRACT ITEMS - MODIFICATION OF TRANSISTOR PROCESSING AND PRODUCTION EQUIPMENT

Transistor processing and production equipment provided during Phase 1 of the subject PEM Contract will be modified in accordance with the latest semiconductor technology. This task will be directed toward increasing the Phase 1 device assembly production yield by six percentage points.

The specified yield increase will be accomplished by, but not limited to, work in the following areas:

- Phase 1 Machine Refinement
- Machine Design, Fabrication and Refinement
- Process Refinement
- Tooling Design, Fabrication and Refinement

Engineering effort continued on all process and machine refinements undertaken in the first quarter. In addition, refinements in the following areas of transistor processing were undertaken - Diffusion, Silicon Dioxide Coating and Header Internal Lead Trimming. Effort applied during this reporting period, the second quarter of Phase 2, is reviewed in the following subsections:

2.1 REFINEMENT OF PHASE 1 MACHINES

GENERAL

Refinement of the 22 machines provided for high volume production of transistors during Phase 1 of the Contract, continued during the second quarter of Phase 2 as reported in this section. Progress reports on the three machines following are deleted since they were outmoded by process and header design changes:

Cleaning Header Lead Wire
Piece Part Gold Plating
Header Lead Trimming

Progress reports on refinements for the other 17 mechanized operations follow. These reports also indicate the objectives and direction of future effort on each machine. Appendix A contains a description of each machine completed during Phase 1.

PIECE PART CLEANING - J. H. Blewett

During the past quarter both machines have been idle. This time was utilized to drain the machines and replace the packings in the pumps. The machines are also scheduled for complete repainting in the near future.

The conversion of the second machine to handle ferrous glassed parts and the replacement of "Hastelloy" heating coils by tantalum coils has also been completed.

Preliminary development of an improved loading mechanism has been made and will be designed and constructed during the next quarter. This mechanism will permit loading of four or five dipping baskets on the loading rack and maintain a fixed distance between each basket so as to prevent jamming and tilting. After a basket is removed from this station and enters the machine, this loading mechanism will move another basket to the pickup point.

PLATFORM LEAD WELDING - F. J. Reinhard

Modification of the Platform Lead Welding Machine is pending. Improved component positioning nests designed for nail-head leads were built last quarter. Their installation has been delayed until similar nests on the Collector Lead to Platform Welding Machine, PEM Contract No. DA-36-039-SC-81294, were thoroughly tested and evaluated this quarter. Results of trial runs on this machine indicated that lead location and pull strength improved. On the basis of this evaluation, the nests provided for the Platform Lead Welding Machine will be installed during the next quarter.

HEADER ASSEMBLING - J. H. Blewett

During the past quarter several phases of machine improvement were started. The most significant of these is a station for automatically loading the platform-lead subassemblies into the ceramic glassing molds. The design of this station has been completed and the detailing of parts nearly finished. Construction has been started and all purchased items are scheduled for delivery early next quarter.

The selector gauge, which sorts out the platform-lead subassemblies having improperly positioned collector leads, is performing satisfactorily and has decreased the number of rejects due to poor welding. The investigation of culling defective glass rings and glass slugs from those fed into the machine is being continued.

The lead feeder has been modified by providing flexible side plates on the magazine and a new spring loaded detent on the feeder drive. Initial results of test runs have indicated improvement in the feeding of leads without jamming. Development in this area will continue by investigating various combinations of detent spring pressures, flexible plate thickness and the addition of an electrical vibrator to better align the leads in the magazine.

HEADER GLASSING - L. R. Sell

Ambient conditions within the Header Glassing Machine were analyzed during the first and second quarters of Phase 2. For this analysis the machine was essentially divided into two sections - the oxidizing and the glassing sections. The glassing section was analyzed for moisture, oxygen and hydrocarbons. The oxidizing section was analyzed for moisture and hydrocarbons only.

The analysis showed that no hydrocarbons were detectable in either zone.

The oxidizing zone shows a very low level of moisture at the beginning of a run. This value goes up to 100 - 200 parts per million during a run depending on external conditions. At the end of the run this value again diminishes. This is shown on Figure 3-1.

The glassing zone had a large increase of both moisture and oxygen at the beginning of a run while dummy boots were introduced. This leveled off to a constant value and diminished for both factors at the end of the run. This is shown on Figure 3-2. The constant value of oxygen and moisture during a run is 20 parts per million in the glassing zone.

STRIP PERFORATING AND WELDING - R. P. Loeper

The Strip Perforating and Welding Machines have been operating satisfactorily during the quarter. An investigation led to ordering changes in the punch and die during the quarter to allow individual alignment of the strip perforating punch and the locating pin. This change should ease maintenance and increase die life. An order was also issued for an automatic parts feeder to feed headers from a bulk supply into the individual slots of the locating blocks which position the headers for welding.

Hand feeding of the steel strip to perforate an initial length presents a problem in that it is very easy to index the strip improperly. To eliminate this difficulty, a butt welder will be provided. With this welder it will be possible to weld a pre-punched section of strip to the end of an unpunched coil of strip prior to feeding it into either of the two machines, thus eliminating the manual index while starting a new coil.

Design, construction and procurement of parts for all three modifications will be started during the next quarter. All modifications are scheduled for completion in the fourth quarter.

<u>HEADER CONTINUOUS RACK PLATING</u> - R. P. Loeper

The new pump for the acid cleaning station was constructed during the last quarter. Installation and prove-in will follow early in the third quarter. No problems have been encountered so far.

Redesign of the header staggering rollers so they can be transferred from the Strip Perforating and Welding Machine to the Header Continuous Rack Plating Machine is completed. Construction and alteration of parts for the modified station has started and is scheduled to be completed early in the third quarter. The redesigned station will provide jam-free operation.

A device for measuring plating thickness is presently being evaluated. If found satisfactory, it will be used as a process control. This evaluation will not be completed until the end of the third quarter.

In May a corrosion problem within the control console became evident. Relays and other electrical components are being damaged by the corrosive atmosphere in the plating area. The problem is being studied. At the present time, consideration is being given to sealing the control console and supplying an acid-free ambient within the console.

<u>CAN GETTER ASSEMBLING</u> - R. W. Ingham
The Can Loading Section of the Can Getter Assembling Machine was in operation most of the report period. About mid-June this section was taken out of service because the problems connected with the feeding and loading of cans could not be resolved. Efforts were made to relate our problems to cleaning methods, but the results were not conclusive enough to form a basis for action. The can loading mechanism was removed from the machine and examined for wear and telltale marks that might indicate reasons for malfunction.

As a result of the investigation several modifications were decided upon. The track between the vibratory feeder and can loader will be modified to prevent occasional misoriented cans from entering the track to the can loader. A special tandem air-hydraulic cylinder will replace the mechanical indexing system originally installed. The modifications planned for the index mechanism are expected to simplify maintenance through improved adjustments and also provide better control of the indexing motion.

When the machine was originally placed in operation, the maximum size of the barium hydroxide crystals was controlled by screening with a U. S. Sieve No. 25. No minimum was specified. In order to reduce the possibility of getting barium hydroxide on flanges of the cans, maximum and minimum sieve sizes were specified as follows early in the quarter: Crystals shall pass through a U. S. Sieve No. 20 and not through a U. S. Sieve No. 40.

This change brought the presence of barium hydroxide on the flanges under control. A deterioration in moisture getting ability was then noted. This was due to the higher bulk to weight ratio of the sized barium hydroxide crystals. Tests were then conducted to determine the optimum size of the cavities in the measuring plates and the optimum crystal size. The tests indicated a relation between crystal size, uniformity and moisture getting ability and that the optimum size fell within the upper half of the specified limits. On the strength of these findings, the supplier of the barium hydroxide getter will be contacted to determine the economics and practical limits of the particle size requirements.

An air-powered reciprocating-type vibrator was installed on the shake-out station. This has improved the station by increasing the strength of the vibrating force. The vacuum system, mentioned in the previous quarterly report, has also been installed on this station and is operating satisfactorily.

SLICE SCRIBING - J. F. Anderson

The Slice Scribing Machine has continued in active use during the report period. Meanwhile, a study of the mechanized operation was completed. Part of this study involved finding an alternate indexing method to improve indexing the slice for scribing. Another concern of this study was to develop a means of varying the scribing speed. Recent studies have shown that variable speed scribing will increase breaking yields and permit scribing slices that could not be previously scribed.

The recommendations of this study have led to the modification of a Wafering Machine under PEM Contract No. DA-36-039-SC-81294. This machine is very similar to the Slice Scribing Machine. An electronic counter and stepping motor has improved slice indexing and a variable speed d-c motor provides a range of scribing speeds. The machine has been completed and returned to the shop for production trial. It is anticipated that the output of the machine may be increased as much as 25 percent as a result of these modifications and studies being conducted to improve setup techniques. The Slice Scribing Machine will be modified in like manner during the latter part of September.

WAFER BREAKING, SCREENING AND LOADING - J. F. Anderson
The status of the Wafer Breaking, Screening and Loading Machine remains the same as last quarter; it is being used for limited production runs. Initial results of the general Wafer Separation studies, being conducted under PEM Contract No. DA-36-039-SC-81294, have indicated chat a newly developed system of closed circuit television when combined with a special optical system is far superior to the comparator used on this machine. The improved viewing system will enable more rapid, versatile and efficient wafer screening. At this time, consideration is being given to adapting the present wafer screening equipment for this system. Final plans for refining or updating this machine will be completed next quarter.

WAFER BONDING - Q. L. Schmick
Comparative evaluations of the quick-heat wafer bonding process for this machine and the ultrasonic wafer bonding process developed under PEM Contract No. DA-36-039-SC-81294 were completed during the quarter. These evaluations demonstrated that the Wafer Bonding Machine produces as originally conceived. Development of the ultrasonic bonding process has, however, outdated the quick-heat process. Ultrasonic bonding enhances the electrical parameters of the transistors being assembled by providing tighter distributions which are closer to the optimum measurements. A decision was made not to refine or update the machine since the Wafer to Header Bonding Machines, Contract No. DA-36-039-SC-81294, provide adequate production capability for both PEM Contracts. Therefore, future quarterly reports will delete progress reports on Wafer Bonding Machine refinement.

WIRE BONDING - M. K. Avedissian

Three refinements are planned for the bonding station as indicated in the previous report. These refinements will be made as scheduled; however, they were not scheduled as the quarter ended.

FINAL CLEANING - J. H. Blewett

The Final Cleaning Machine was in operating condition throughout the quarter although the machine has not been utilized. No changes have been made to the machine or the etching process, and no definite action has been taken on Phase 2 work. This work consists of installation of a method of mixing hot water and hydrogen peroxide as it is being used, thus eliminating the need to mix large amounts in advance, and the relocating of the bubblers in the etching and rinsing stations to accept the header handling trays currently used.

CLOSURE WELDING - R. W. Ingham

The Closure Welding Machine has been in daily operation during the past quarter. A lower electrode holder has been modified to eliminate the arcing problem and thus facilitate electrode replacement. The modified holder was evaluated and a decision made to modify a complete set of electrode holders. This work will be done during the next quarter.

An access door was installed on the dry box to facilitate machine maintenance and dry box cleaning. A frame was fastened to the dry box and the door mounted on the frame so that a good seal could be obtained. Dry box cleaning will improve additionally next quarter by adding a vacuum cleaning system and modifying a platform within the dry box. This platform is to be cut into three parts and, as such, will be removable to facilitate cleaning the work area.

Increasing electrode life is now the most critical refinement remaining. Several modifications to the lower electrodes are planned for the next quarter that we expect will increase the number of welds made before redressing is necessary. An evaluation of the modifications will also be made during the next quarter.

CARD LOADING - C. R. Fegley

No physical changes were made to the Card Loading Machine during the reporting period. The modifications outlined in the previous report, which will increase the output and performance, will be started next quarter.

TESTING AND DATE STAMPING - 2N559 - D. H. Lockart

The 2N559 Testing and Date Stamping Machine was evaluated during the reporting period as to its ability to meet Phase 2 production requirements. It was determined after reviewing pilot run results that these requirements could be met by increasing the operating speed of the index table. As a result it will not be necessary to provide additional modules to completely tool up both test lines.

In order to increase the speed of the test set index table, modifications to the Card Loading Machine which feeds the test set will be required. Operating cams will be redesigned to provide smoother operation. Loading of card-mounted transistors onto the test holders will be made more accurate and clamping of the cards to the test holders after loading will be made more positive. No other changes to either machine will be necessary.

Test modules presently provided on the machine are adequate for testing 2N559 transistors. No related codes are being manufactured in sufficient quantity to warrant the addition of new modules at this time. However, space for additional modules is available, so they can be added as required.

Definite orders for performing the work described above will be written early in the next quarter, and work will start during the last half of the quarter.

DATA HANDLING - D. H. Lockart

During the reporting period, the Data Handling System was evaluated for possible Phase 2 updating. The "TACT" test set was examined to determine what improvements should be made. It was decided that only those improvements which would increase the test set reliability would be made at this time. Definite orders to perform this work will be written early in the next quarter.

The switching time generating and recording portion of the system has also been evaluated. Certain improvements in operation between the generating and recording components will be made; however, no major changes are contemplated.

The Monrobot Mark XI Computer rented during development of the Data Handling System has been returned to the supplier. All programs developed, which proved feasible for production control, have been re-written for the plant computer, an IBM 1401. The Monrobot performed a very useful function during development, but since time is available on the 1401, continued rental of excess computer capacity could not be justified.

All updating effort will be covered by definite orders during the next quarter. Work will be started during August according to present plan.

Evaluation of certain electrical parameters not presently included in the various test specifications was started during the quarter. The purpose of this evaluation is to provide data which will indicate normal behavior and distribution of values for these parameters. An additional objective is to provide an explanation for departures from these norms, so that processing problems may be correlated with variations from the norms.

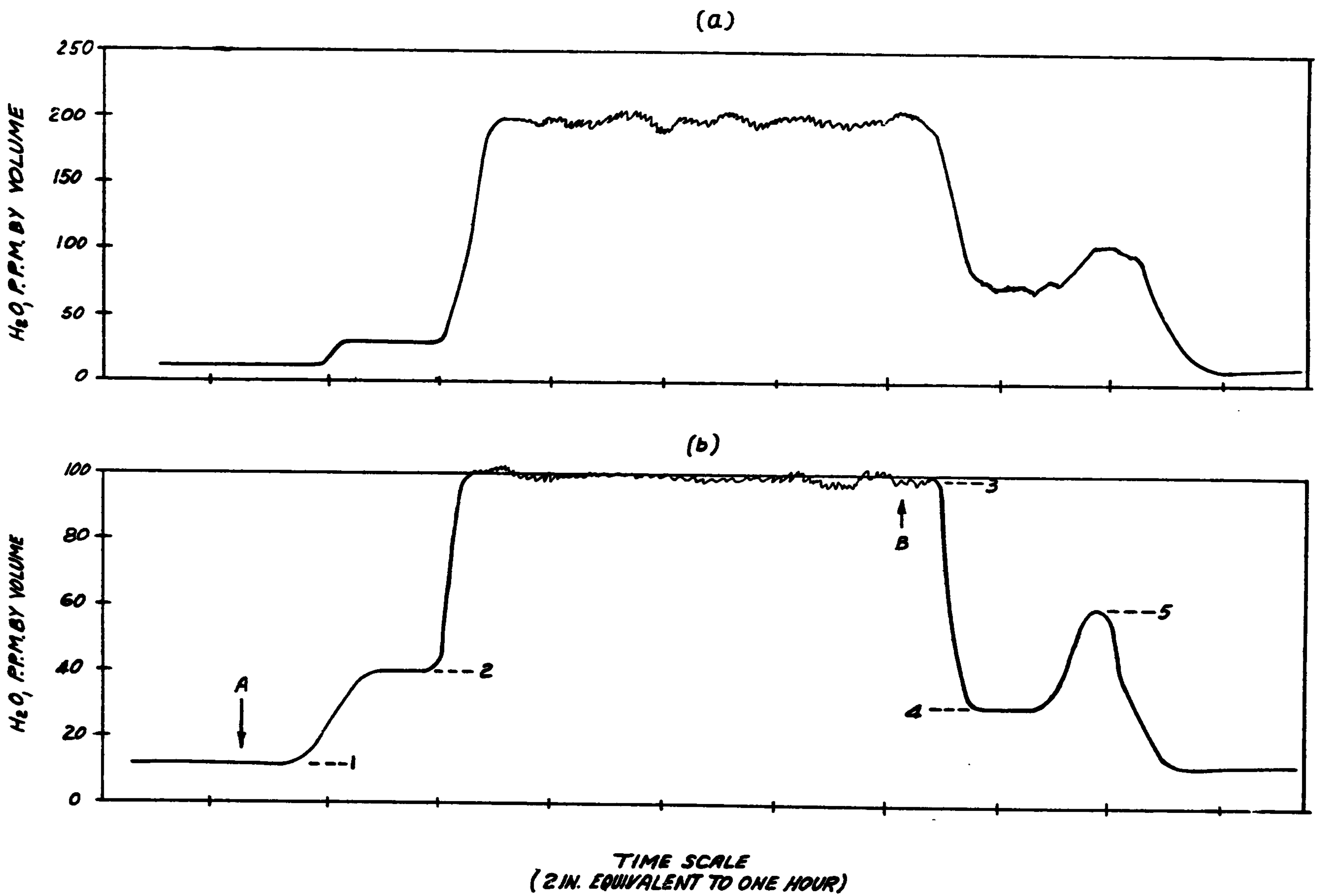
As an example, forward voltage drops across the emitter and collector junctions of 2N559 transistors are being measured at a variety of currents. It is expected that these measurements will give evidence of variations in the electrical resistance of the bonds between wires and stripes formed during the wire bonding process and variations in alloying of the stripes during evaporation.

Further information on the quality of stripe evaporation and alloying will come from measurement of gain versus current, where the effective area of the emitter is related to the current at which the gain shows a peak value. Also, reproducibility of the surface conditions of various devices can be determined from measurement of low-current gain.

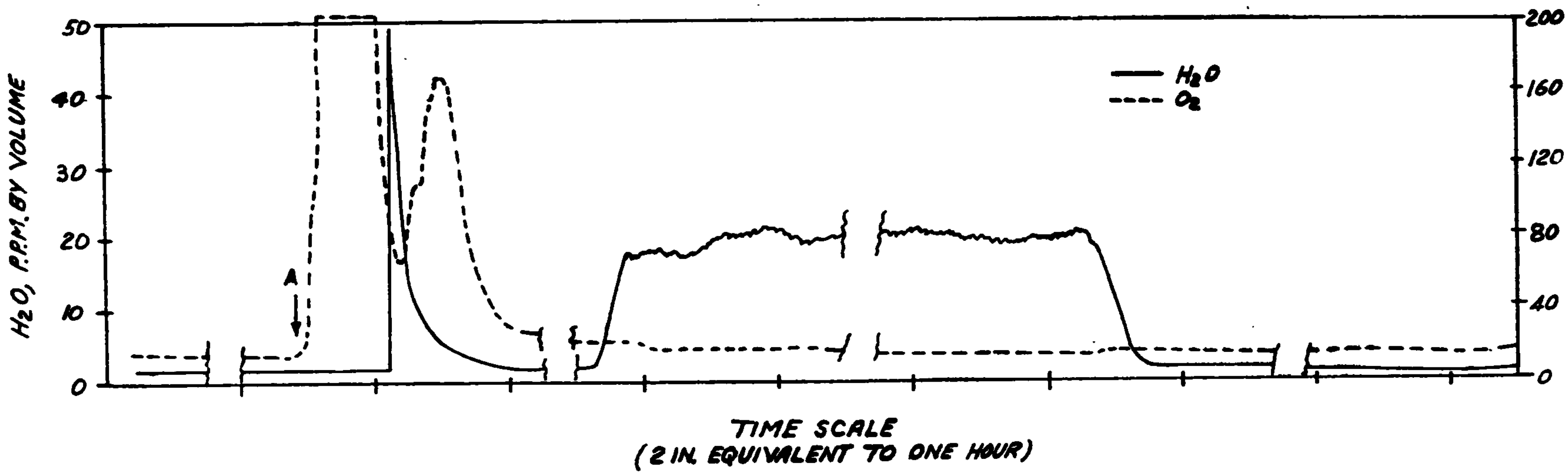
If this evaluation indicates that measurements such as those mentioned above can be used for production control purposes, the Data Handling System will be used for collecting and processing the electrical test results. One of the system's major functions is that of production control through electrical evaluation of small numbers of semiconductor devices.

CARD PACKAGING - C. R. Fegley

In the last quarterly report, several modifications were outlined which would improve the Card Packaging Machine. These refinements are not necessary at this time, and therefore, will be postponed indefinitely. The machine operates satisfactorily at the production rate presently required for Nike Zeus.



CHANGES IN H_2O CONCENTRATION
IN OXIDIZING ZONE OF HEADER GLASSING FURNACE
FIGURE 3-1



CHANGES IN H_2O AND O_2 CONCENTRATIONS
IN GLASSING ZONE

FIGURE 3-2

2.2 WIRE BONDING - C. A. Karnish

GENERAL

An advanced design wire bonding machine is being planned to be compatible with advanced transistor technology. This machine will bond connecting wires to the transistor wafer and to the internal posts.

ENGINEERING STATUS

The development study to determine the feasibility of using ultrasonic energy for wire bonding is being continued. Large numbers of samples have been bonded for mechanical evaluation and several groups of units have been tested for electrical continuity. No bond deterioration from ultrasonics was detected. An investigation of mechanical bonding strengths indicated a lack of bond strength uniformity. Part of the lack of uniformity was traced back to the commercial timer in the ultrasonic generator, which had a time pulse variation of as much as 50 percent. A replacement timer was designed and installed to replace the original timer. Time pulse variation is now minimal and a considerable improvement was noticed in uniformity of bonding. To facilitate feeding of the wire under the bonding wedge, two approaches were investigated; an external feed, distinct from the bonding needle, and a hollow needle to permit feeding of the wire through the needle. Difficulties have been encountered with both methods.

The external feeding device consisted of a mounted spool of wire, a locating tube and a positioner. The major difficulty with the external feeder was its inability to properly place the wire so the groove in the bonding needle could be aligned over it. This misalignment is caused by the clearance required in the feeding tube, the stress in the wire and the difficulty in manipulating wires in the .001-inch range.

In initial trials, the hollow bonding needles exhibited good feeding characteristics but would not transmit sufficient ultrasonic energy to produce good bonds. Solid needles of the same external configuration and size transmit the ultrasonic pulse and give good bonding results. Since the solid and hollow needles had comparable natural frequencies well above the system frequency, the large hollow center appears to be causing the difficulty in transmission. To determine whether this can be overcome, a needle with a smaller center hole is being prepared.

CONCLUSIONS

The investigation to determine whether ultrasonics will be used to provide the energy to make wire bonds is being continued. Wire feed methods and associated problems are being studied to determine the most practical feeding system. The design of the bonding machine will be delayed until the preliminary studies are complete.

OBJECTIVES FOR NEXT QUARTER

The ultrasonic bonding development study will be continued. Bonding needles and wire feed system investigations will be undertaken to develop a system compatible with ultrasonic bonding.

2.3 HANDLING TRAY LOADING

GENERAL

Phase 2 of the PEM Contract requires that a machine be designed, fabricated and refined to perform the Handling Tray Loading operation. The method of operation of this machine would, of course, be determined to a large extent by the type of handling tray used. For this reason, the development of the machine is intimately tied to the development of material handling systems.

No separate status report on this machine is provided. For information on Material Handling see Section 2.9 on Page 36.

2.4 TINNING TRANSISTOR LEADS - R. W. Ingham

GENERAL

The purpose of Tinning Transistor Leads is twofold: First, tinned leads provide a prepared surface in those applications where units are to be heat soldered into place. Second, and probably most important, tinned leads provide a protective surface that will resist corrosion and at the same time be ductile enough to permit mechanical methods of attachment, such as wire wrapping.

Presently, Tinning Transistor Leads is being examined and investigated in an effort to assemble the necessary operations in an effective manner and propose tooling that will allow production of acceptable devices.

ENGINEERING STATUS

The existing equipment has been inspected, observed and evaluated during the past quarter. During this period the process and equipment have remained virtually unchanged. Both the operations and material handling are being performed manually. Bubbling or splattering sometimes causes solder to be deposited on the glass seal when the leads are lowered into the molten solder. These deposits are objectionable and detract from both the appearance and performance of transistors. To overcome this condition a protective paper shield is used to cover the glass and, at the same time, expose the leads.

Originally, an individual shield 1/2 inch square was placed on each unit using a bench fixture at a rate of approximately 120 transistors per hour. This operation was replaced by a bench fixture that accommodates a continuous strip of 1/2-inch-wide paper. Using the improved bench fixture, the operator can install masks on approximately 250 to 300 transistors per hour. During the next quarter the fixture will be modified in order to power it with a foot-operated air cylinder. This will free both hands for loading and increase the output of the operator to about 600 per hour.

Several types of tinning devices have been examined in an effort to eliminate the necessity of masking each transistor. The advantages claimed by the various manufacturers are based, at least in part, on producing printed circuit boards. All of the soldering pots examined were quite successful in providing an area free of dross; however, none of them produced acceptable transistors without masking the glass seal. Faced with these facts, it seemed advisable to concentrate our efforts, at least for the immediate future, on increasing the capacity of the masking operation.

CONCLUSIONS

During the past quarter our investigative efforts have not uncovered any new equipment that would appreciably improve the quality or appearance of the tinned leads. The investigation did reveal, however, the importance of adequate cleaning and proper fluxing prior to the dipping of the leads into the molten solder. At least for the present, masking is necessary if the glassed area is to be kept free of solder.

OBJECTIVES FOR NEXT QUARTER

1. Suggest modifications to increase operator productivity.
2. Complete investigation of solder dipping equipment.

2.5 **SLICE SURFACE PREPARATION** - K. C. Whitefield

GENERAL

A preliminary survey of present industry and Western Electric practices in Slice Surface Preparation was started in the first quarter of Phase 2. Developments being considered involved improvement in diffusion and surface smoothness of semiconductor materials.

ENGINEERING STATUS

The survey of present Western Electric practices on polishing and chemical cleaning of semiconductor material prior to diffusion has disclosed that the practices are quite suitable for the PEM mesa-type devices. No specific improvements are needed.

A study of diffusion quality and uniformity is already in progress on this PEM Contract and Contract No. DA-36-039-SC-81294. The subsections titled "Diffusion" review the progress made in this area.

CONCLUSIONS

This improvement study will be discontinued in view of the foregoing status and no further reports will follow.

2.6 **STRIPE EVAPORATION AND ALLOYING** - K. C. Whitefield

GENERAL

Effort this quarter has been directed to a study of available means of improving: (1) slice cleanliness prior to evaporation, (2) adherence, composition and surface condition of evaporated stripes, and (3) emitter stripe alloying of germanium devices.

ENGINEERING STATUS

A preliminary survey of equipment and processes has been completed, and a program for testing their feasibility has been submitted for approval.

A study of electrical and physical parameters not called for in the test specifications has also been undertaken during the quarter. Initial effort has centered on parameters related to stripe evaporation and alloying. Data is being collected to determine the normal behavior and distribution of various parameters. The aim of this study is to provide explanations for departures from the norms so that processing difficulties may be pinpointed, and, hopefully, brought under better control.

Following are the test parameters that are being studied:

(1) Forward Voltage Drop - This parameter is expected to indicate variations in electrical resistance of the wire-to-stripe and the stripe-to-slice bonds.

(2) Gummel Measurement - This measurement gives a measure of the total number of dopant atoms and an indication of the emitter alloying depth.

(3) Gain vs. Current - In this measurement, the effective area of the emitter is related to the current at which the gain shows a peak value.

CONCLUSIONS

Application of presently available processes, equipment and proper controls should produce the major Phase 2 improvements desired for these operations.

OBJECTIVES FOR NEXT QUARTER

1. Plan program for feasibility experiments of the following:
    a. Clean-bench processing
    b. Getter and ionizing evacuation
    c. Automatic temperature and vacuum control during evaporation
    d. Temperature control during stripe alloying
2. Develop program for the fourth quarter of Phase 2 from results obtained above.

2.7 HEADER THERMAL CAPABILITY - H. J. Huber

GENERAL

During the second quarter of Phase 2, the header thermal shock development study, which had been initiated during the first quarter, was expanded into a header thermal capability study. Encapsulation of the headers, which had been resistance heated for the original thermal shock evaluation, produced inconclusive experimental data for evaluating the effects of other variables on the header at can welding but indicated a problem area in either the experimental procedures or the variables being investigated.

Other investigations developed methods for applying parallel step stress techniques to the header heating experiments and evaluated the effects of residual glass stress, chemical attack on the glass, and resistance heating clamping forces on the header.

The results of an experiment for evaluating the effects produced on the header at can welding by the header glassing techniques, hydrofluoric glass etching and header resistance heating indicated that the welding operation was probably introducing an uncontrolled variable into these experiments.

ENGINEERING STATUS

During the second quarter, the header thermal shock development study for evaluating the effects of the header resistance heating at wafer bonding on the glass seal was expanded into a header thermal capability study for evaluating other factors which give rise to strains and cracks in the glass seal. This expanded study is to investigate the interrelated effects of the header fabrication processes, the resistance heating of the header at wafer bonding and can to header closure welding.

In view of the increased scope of this study, the 9 header subgroups of 75 headers each, which were used for the first thermal shock experiment reported in the previous quarterly report, were encapsulated at the can welding operation. This experiment was extended to evaluate the effects on the header of the alternate header manufacturing processes, variations in the glass seal quality and resistance heating of the header at the can welding operation. The results of this experiment, as evaluated by glass defects, indicated some incompatibility between the header and the header resistance heating and welding operations. These results, however, were inconclusive as an exrerıment of this scope would require a much greater number of headers and experimental controls than those used in the original experiment in order to provide reliable data, that is, data not influenced by variables which are not being investigated and are not controlled. Qualitatively, the results of this experiment did show that a problem area existed, either in the experimental procedures or in the variables being investigated.

In addition to the preceding experiment, other investigations were conducted to develop experimental methods for obtaining reliable test data without using large numbers of headers. In these investigations, parallel step stress techniques were applied to header heating experiments for both header temperatures and header heating rates. While the lack of statistical data at this time imposes some limitation on the use of the parallel step stress technique, consistent test data was obtained from these experiments which showed a header thermal capability in excess of the temperature conditions experienced during header resistance heating at wafer bonding.

The effects of the residual glass stress, of chemical attack on the glass and of the header resistance heating clamping force, ranging from 1-1/2 to 7 pounds on the TO-5 headers were also investigated. Within the normal production range and the wider experimental range of these variables, no significant effects on the header capability could be determined that would cause a degradation of the header.

Another major experiment, covering header fabrication through the encapsulation can weld, was then conducted having the header glassing, the hydrofluoric glass etch and the header resistance heating as the variables. The factorial combinations of these variables resulted in eight separate header groups of 25 units each at the can welding operation. Specifically, the variables were:

1. Header glassing
   - 1.1 Separate oxidizing and glassing furnaces
   - 1.2 Combined oxidizing and glassing furnace
2. Hydrofluoric glass etching
   - 2.1 Harsh HF (maximum specification)
   - 2.2 Average HF (normal production range)
3. Header heating
   - 3.1 Resistance heating of header to wafer bonding temperature
   - 3.2 No heating of header

Prior to can welding, there were no visible glass defects in any of the header groups. After can welding, the glass defects for the eight groups ranged from 8 to 68 percent but due to the small lot sizes with this range of percentage defects, no statistical differences between the variables of this experiment could be established. Another factor associated with the glass defects was that the percentage defects showed a sharp increase between the header lots that were can welded first and those welded at the end of the experiment. As the header groups had been randomly can welded, this sharp increase in glass defects indicated that the welding operation had probably introduced a fourth and uncontrolled variable into the experiment.

CONCLUSIONS

The header thermal capability study has demonstrated that parallel step stress techniques can be applied to header heating experiments. For a reliable evaluation of the overall header thermal capability, all experiments must maintain complete control of the can welding operation.

OBJECTIVES FOR NEXT QUARTER

1. Perform experiments for a complete evaluation of the effects of the can welding operation on the header glass seal.

2.8 WIRE WELDING - M. K. Avedissian

GENERAL

A method other than thermocompression bonding is being investigated for the internal lead attaching operation. This method, known as "Wire Welding" or "Microwelding", heats a section of wire being attached by employing the principle of resistance heating. The welding electrode on the tool consists of two halves separated by a dielectric.

The objective of wire welding is to eliminate the necessity of heating the transistor as required by the widely used thermocompression bonding process. Another objective is to reduce the effect of stripe surface conditions on the quality of lead attachment.

ENGINEERING STATUS

Experimental work was done with 0.0005- and 0.001-inch-diameter gold wire. The results are still not satisfactory. Either fusion or incomplete bonding occurs between the wire and the semiconductor material as in previous tests. Fusion cannot be tolerated because it destroys the junction. The fusion occurs only in the area immediately underneath the dielectric of the electrode. Therefore, it is suspected that the fusion is due to differences in heat dissipation of the electrode and semiconductor material.

Good bonds were made to the gold plated headers and posts, and no melting was noted. The reason appears to be the high melting point of gold compared to the relative low temperatures required for formation of the gold-germanium and gold-silicon alloys.

CONCLUSIONS

Although the terms "Microwelding" and "Microwelder" are used in the literature describing the equipment used in this study, at this time it appears doubtful that making a true weld, i.e. heating the parts to be bonded to a molten state, is the real objective of microwelding. Whenever an acceptable bond was observed, there was no evidence of molten metal. The bonds appeared to be similar to thermocompression bonds. It is possible that the primary difference between micro-welding and thermocompression bonding is the difference in approach to heating the parts to be bonded.

OBJECTIVES FOR NEXT QUARTER

1. Improve electrode.
2. Build a better mechanical system which will permit a capability study of microwelding.

2.9 MATERIAL HANDLING - K. C. Whitefield

GENERAL

Phase 2 refinement of transistor material handling has been expanded to include silicon dioxide coating, baking and closure welding. This refinement program has been targetted toward a substantial increase in device yield through reduced damage while handling the devices during these assembly and process operations.

The wafer handling tray development was completed during the quarter. Major effort was assigned to the development of improved header handling trays.

ENGINEERING STATUS

Wafer Handling

The epoxy plastic wafer trays reinforced with glass fiber have now been thoroughly proven; therefore, they were released to product engineering with the recommendation that oil-hardened-steel replaceable inserts be used in the molds and adequate amounts of silicone parting agent be used during each mold cycle. During the first two quarters of Phase 2, the wafer trays have been proven satisfactory. No scuff rejects developed, and only a few trays developed an excessive lengthwise curvature after repeated solvent washes.

Header Handling

During the second quarter, the evaluation of the many header handling systems under previous consideration resulted in the development of a new transistor handling system for the entire mechanized assembly line from wafer bonding to closure welding. In the new system; in-line, one-piece, stainless steel header trays will be used for all machines and processes except mechanized emitter etching. The trays are designed to allow headers to slide into and out of each machine under gravity with vibration added if necessary.

Lead clearance slots in the trays will be provided in two widths. The wider slot will be wide enough to orient TO-5 headers utilizing the three leads; the narrow lead clearance slots will orient TO-18 headers in like manner. All trays will have a common cross section below the lead clearance slot, and will be deep enough to accept tip welded leads as trimmed following the Header Continuous Rack Plating operation.

For identification, the trays will be made in two lengths. The longer trays will hold twenty TO-5 or thirty TO-18 assemblies and will be used for operations preceding emitter etching. Twenty of these (holding 400 TO-5 or 600 TO-18 assemblies) will be carried in and supplied from a magazine which facilitates tray handling and provides protection and covered storage for the assemblies. The shorter tray will be used for post emitter etch operations; 13 of these (holding 280 TO-5 or 400 TO-18 assemblies) will be carried in covered stainless steel retorts to facilitate controlled atmosphere bakes as well as covered storage.

At the entrance to the Emitter Etching Machine, headers will slide from the in-line trays into a pickup position for mechanical insertion into single-position, acid-resistant plastic carriers. These carriers support the headers by a friction grip on the leads, and nest so that 20 will fit in a stainless steel channel only a little over 8 inches long. These channels also serve as a holder when inverted to immerse the header platforms only in a sequence of troughs which contain etchant and cleaning solutions for cleaning and rinsing the semiconductor junctions. At the exit from the Emitter Etching Machine, the headers will be stripped from the plastic carriers and returned to the shorter post-etch, in-line trays.

Two sample retorts complete with post-etch trays, and 250 sample plastic carriers with the required channels have been made and are being evaluated. Tests now in process will aid in the development of a suitable sequence for mechanized emitter etching and for the oven baking and silicon dioxide coating processes which follow etch cleaning.

CONCLUSIONS

The plastic wafer trays are now proven-in as wafer handling equipment and, as a result, will not be discussed in this report in the future.

The new header handling system selected this quarter is feasible for the mechanized transistor assembly operations prior to welding; both the yield and reliability of transistors processed with the sample equipment provided this quarter are being checked to determine the potential of this equipment.

OBJECTIVES FOR NEXT QUARTER

1. Process and test enough devices made with the sample equipment to demonstrate feasibility and develop design requirements.
2. Initiate design and construction of new material handling equipment and adaptation of associated machines.

2.10 **PNEUMATIC COMPONENTS** - R. S. Greenberg

GENERAL

In the design of special machinery for the manufacture of transistors and diodes, it is often desirable to incorporate air-operated machine elements instead of mechanical gears, cams and linkages. However, pneumatic components are available in a multiplicity of makes and types, and are not all of equal suitability. The purpose of the study is to investigate some of these various types and to thereby develop guide lines to assist the machine development engineer in making his selection.

ENGINEERING STATUS

An extensive literature survey was made of the great variety of pneumatic components. Discussions were held with maintenance people, Machine Development Engineers, and suppliers' representatives to get the benefit of their suggestions. Present machines at Laureldale using air-operated components were studied to determine the major performance characteristics that are needed.

Some performance data for specific items could be determined from specifications given in suppliers' catalogues, but other performance data must be obtained by suitable experimental tests.

Index tables, of varied types, were tested for smoothness of motion. It is important that the work is not jarred out of position when the table indexes. The effect on the work was simulated by a flat plate with a number of depressions of varying depth. A ball bearing rested in each depression. Index speed was measured using a Brush recorder and limit switches.

An extensive series of tests were made on speed control valves of varying types; using cylinders of different sizes; at various supply pressures; at varied speed settings; at various spacings between cylinder, speed control valve and directional valve; and when located to control input air and exhaust air. Stroke speed of the air cylinder was measured by a Brush recorder and limit switches.

CONCLUSIONS

Extensive data has been collected, but additional tests are needed.

OBJECTIVES FOR NEXT QUARTER

1. Continue investigation and testing of index tables, speed control valves, needle valves, air line lubricators for use at small flow rates, cylinders and valves for operation with non-lubricated air, combination air-hydraulic cylinders, combination cylinder-speed control-solenoid valve units, tubing and fittings, tubing length and size limitations, and piped-exhaust.

2.11 DIFFUSION - M. K. Brumbach

GENERAL

The process of diffusing an "N" skin into the basic "P" type material to be used in fabricating PNP germanium transistors consists of placing a number of germanium slices in a carbon boat and subjecting them to conditions of time, temperature and gaseous ambient in a diffusion furnace. The purpose of this study is to evaluate variations in sheet resistivity and diffusion layer depth from slice to slice in a given diffusion run and to find means of precisely controlling diffusion variables with particular emphasis on time, temperature and ambient. A companion study to this one is being performed under associated PEM Contract DA-36-039-SC-81294. The companion study will evaluate the formation of oxide layers and the problems concerned with making all required diffusions into silicon slices. Since this latter study will be the more comprehensive, the germanium study will be essentially limited to problems peculiar to diffusion into germanium material.

The portion of this study connected with evaluation of variations in sheet resistivity and diffusion layer depth within a diffusion boat started during this reporting period.

ENGINEERING STATUS

Slice to slice variation within a diffusion boat using the end points of sheet resistivity and diffusion layer depth as evaluation criteria is being studied. Changes will be made to the boat geometry to provide most uniform results throughout a diffusion run if found to be feasible. When this phase of the study has been completed, a sound basis will have been provided for proceeding with the study of the major diffusion variables.

It is intended to study the use of multi-point temperature recorders to continuously monitor diffusion furnace temperatures and in this manner detect any variations which may cause unpredictable results. Automatic furnace boat programmers will be studied as a replacement for manual diffusion run timing and boat location. The reduction or elimination of trace amounts of moisture and oxygen contamination in the gaseous ambient will also be studied to determine its effect on diffusion control.

Orders have been placed for a multi-point temperature recorder, for automatic furnace boat programming equipment and for gas purification equipment. This equipment will be used for both this study and the SC-81294 Contract study.

CONCLUSIONS

Since this study has just been started, only limited conclusions can be drawn. Analysis of slice variation between boat positions indicates that careful study should be given to this problem. The only data presently available is on silicon slices and is presented in the SC-81294 report.

OBJECTIVES FOR NEXT QUARTER

1. Complete the study of variations between slices in a diffusion run.
2. Start evaluating the effects of such variables as temperature, time and gaseous ambient on the diffusion process.

2.12 SILICON DIOXIDE COATING - L. A. Gagnon

GENERAL

The purpose of the Silicon Dioxide Coating study is to develop a facility for application of protective coatings on silicon and germanium diffused base transistors. The equipment originally used for this purpose had a limited production rate and caused many delays due to frequent breakdown of heating elements. The equipment was modified to eliminate the frequent breakdowns and provide higher production rates.

ENGINEERING STATUS

During this report period, data was gathered to evaluate the type of coating that is most desirable, (i.e. clear, hazy, low temperature, high temperature) and the most effective point during transistor assembly at which the coating should be applied.

CONCLUSIONS

Preliminary evaluation indicates that the coating can be varied within limits and not have detrimental effects on yield or reliability. Further testing along these same lines is necessary to evaluate repeatability of the proposed process (clear coating applied prior to in-process aging).

OBJECTIVES FOR NEXT QUARTER

1. Continue experiments to evaluate repeatability of proposed process and definitely establish ultimate process for application of these coatings.
2. Submit facility concept to design and complete design.

2.13 HEADER INTERNAL LEAD TRIMMING - R. P. Loeper

GENERAL

With the mechanization of the transistor assembly operations, especially wire plucking, the problem of internal lead trimming becomes more critical. The height of these leads must be held to a tighter tolerance. This study is directed toward narrowing the tolerance to ±0.002 inch.

Support equipment called a "Turret Trimmer" is used for this trimming operation. This trimmer has a small continuously rotating turret. Headers are manually loaded into slots in the periphery of the turret. As the turret rotates the headers are clamped, moved past a cutoff wheel, and then ejected by opening the clamps. The turret is mounted on a small cross-slide that permits positioning of the turret in relation to the wheel. The cutoff wheel is mounted on a standard "Dumore" tool post grinder.

ENGINEERING STATUS

Three areas were found where variations in lead lengths could occur. The first was runout of the locating turret. The locating face of this turret was ground in place thus eliminating the runout.

Another source of variation was caused by slight differences in length of the five clamping mechanisms. As they passed over the clamping cam, the longer clamps exerted enough force on the locating plate to bend it out of position. This was remedied by mounting the clamping cam on an elastic base. Now the cam gives when the longer clamps move into position.

It is also felt that trimming wheel flutter could vary the length of internal leads. In an effort to reduce this flutter special support collars were made to hold the wheel with the fibers on one side of the wheel in compression while those on the other side are in tension.

CONCLUSIONS

Completion of the refinements coincided with the end of the report period; therefore, evaluation of the modified turret trimmer was not completed.

OBJECTIVES FOR NEXT QUARTER

1. Study effects of the refinements on trimmed headers.

SECTION IV

CONTRACT MODIFICATION - H. J. Huber

On June 20, 1963 a meeting was held by representatives of the Army Missile Command, the U. S. Army Electronics Materiel Agency, the U. S. Army Electronics Research and Development Laboratory, the Bell Telephone Laboratories and the Western Electric Company to review the status of PEM Contract DA-36-039-SC-72729 and associated Government contracts being performed at the Laureldale Plant of the Western Electric Company. The purpose of this meeting was to ascertain whether these contracts should be redirected at this time to meet the needs of Nike X development. While it was agreed that Phase 2 effort of PEM Contract DA-36-039-SC-72729 would continue without change, the Western Electric Company is concentrating on efforts that apply to Nike X as well as Nike Zeus.

As a further result of this meeting, the Western Electric Company is to review each contract item to determine its applicability in the support of the Nike X program and is to submit to the U. S. Army Electronics Materiel Agency, by August 26, 1963 of the next quarter, a proposal outlining an intended modification for redirecting the Contract to support Nike X.

SECTION V

IDENTIFICATION OF PERSONNEL

1. PERSONNEL CHANGES

The following personnel changes were effected during the report period:

Added to the Contract

C. G. Brittain - W.E.
M. K. Brumbach - W.E.
D. D. DeMuzio - W.E.
L. A. Gagnon - W.E.
W. B. Myers - W.E.
A. A. Orchowski - W.E.
K. C. Whitefield - W.E.

Deleted from the Contract

None

2. ENGINEERING TIME

Western Electric Personnel spent approximately 6,450 engineering hours on the Contract between April 1, 1963 and June 30, 1963. Bell Telephone Laboratories Personnel spent approximately 150 hours during the same period.

3. PERSONNEL BIOGRAPHIES

C. G. Brittain

C. G. Brittain, a native of Hickory, North Carolina, graduated from Clemson College in 1955 with a Bachelor of Engineering Degree in Ceramic Engineering. He was employed by the Norton Company, Worcester, Massachusetts, from 1955 to 1960 in research and development of refractor and nuclear materials. From January 1960 to November 1960 he was employed by the Nuclear Materials Division of Davison Chemical Company, Erwin, Tennessee, in the production of ceramic type fuels for nuclear reactors. In December 1960, he joined the Western Electric

Company and is presently engaged in the manufacture of glass-to-metal seals for semiconductor devices.

M. K. Brumbach

M. K. Brumbach, a native of Reading, Pennsylvania, was graduated from Pennsylvania State University in June 1957, with a B.S. Degree in Mechanical Engineering. He immediately joined the Western Electric Company where, except for a leave of absence in 1959 for service in the United States Army (Corps of Engineers), he has been engaged in the manufacture of semiconductor devices including diodes and transistors. He has experience with both silicon and germanium devices from material preparation through to final testing of the completed transistors.

D. D. DeMuzio

D. D. DeMuzio, a native of Medford, Massachusetts, attended Massachusetts Institute of Technology, graduating in 1951 with a B.S. Degree in Mechanical Engineering. Following graduation he was employed by the Electric Boat Company and the Hamilton Standard Division of United Aircraft. Prior to joining Western Electric he did graduate work in Electrical Engineering while he was a Research Assistant at the M.I.T. Dynamic Analysis and Control Laboratory. In February 1954, he joined the Western Electric Company at the Merrimack Valley Works and was associated with various product, machine development, and test set development engineering assignments. In January 1960, he was transferred to Laureldale and was assigned to be in charge of one of the groups responsible for mechanization engineering under associated PEM Contract No. DA-36-039-SC-81294.

L. A. Gagnon

L. A. Gagnon, a native of Maine, graduated from the University of Maine with a B.S. Degree in Mechanical Engineering in 1957. After graduation, he went to work for the Ingersoll Rand Company in New York. There he worked in the portable and small-stationary compressor engineering departments. He came from Ingersoll Rand Company to Western Electric Company in 1959, and has since worked in Magnetron and Semiconductor Engineering Departments at Laureldale.

W. B. Myers

W. B. Myers graduated from High School at State College, Pennsylvania, in 1947. Attended the Pennsylvania State University as a member of the NROTC program, majoring in Mechanical Engineering and graduated in 1951 with a Bachelor of Science Degree. Served as a commisioned officer in the U. S. Navy until 1957. Joined Western Electric Company in 1959 as an Engineer in the 2N559 Engineer of Manufacture Department. Subsequently, transferred to the Outside Sales Department. Now assigned to the Diffused Transistor Engineering Department.

A. A. Orchowski

A. A. Orchowski, a native of Reading, Pennsylvania, graduated from Lafayette College in 1952 with a B.S. Degree in Mechanical Engineering. From 1952 to 1956, he served in the United States Air Force. He joined the Western Electric Company at the Laureldale Plant in August 1956 and is engaged in the manufacture of semiconductor subassemblies.

K. C. Whitefield

K. C. Whitefield, a native of Madison, Wisconsin, attended the University of Wisconsin, graduating in 1932 with a B.S. Degree in Mechanical Engineering and obtaining an M.S. Degree in Mechanical Engineering in 1933. He was employed by Westinghouse Electric Corporation in 1933 and had various Product Design Engineering assignments in the Appliance Division Plant at Springfield, Massachusetts. He joined the Western Electric Company at the Laureldale Plant in December 1959, and was assigned directly to work on associated PEM Contract No. DA-36-039-SC-81294.

APPENDIX

PHASE 1 MACHINE DESCRIPTIONS

CLEANING HEADER LEAD WIRE

The Cleaning Header Lead Wire Machine is a continuous motion, 7-station machine that utilizes an electropolishing process to clean cut wire leads. A magazine automatically supplies the cut leads, one at a time, to a loading mechanism which moves them to a point tangent to a continuously moving turret. There a belt clamps and holds the leads against the turret in a vertical position until it leaves the turret at the unload station. Approximately 1/2 inch on the bottom end of each lead is cleaned by reverse electroplating with an electropolishing solution in the first station. In the next three stations the leads are thoroughly rinsed and dried. Then the leads pass through an oxidizing station. This station heats the leads with radio frequency energy and in the process oxidizes them for the subsequent glassing operation. At the last station, the belt releases the lead and drops them into a container without losing orientation.

PIECE PART CLEANING

The Piece Part Cleaning Machine contains four in-line modules having three stations each. Each module can be modified for special process conditions by adding or deleting 17 different attachments. The machine automatically transports dipping baskets of various configurations from the loading station, through degreasing, etching, pickling, rinsing and drying stations and then stores them on an unload station. The sequence, etchants, and cleaning periods of the processing stations can be varied as needed to clean ferrous parts prior to assembly operations or to clean glassed headers after the glassing operation. The drives and transport mechanisms are located to the side and below the cleaning tanks so the cleaning agents will not be contaminated by dirt from overhead transfer mechanisms. The four module machine occupies an area 3 feet wide by 20 feet long.

PLATFORM LEAD WELDING

The Platform Lead Welding Machine automatically butt welds a collector lead to a TO-18 header platform. It is a 4-station, semiautomatic machine that has identical die set type aligning fixtures at each station. Cams located on the stationary center column of the rotary index table actuate the fixtures as the table indexes from station to station. At the first station an operator loads a platform in the lower electrode; at the second station another operator positions a lead in the upper electrode; at the third station the lead and platform are automatically welded together; at the fourth station a third operator removes the welded assemblies.

PIECE PART GOLD PLATING

A modular, commercial barrel plating machine provides the capability to gold plate a variety of piece parts. Cleaning and plating cycles can be varied considerably, programmed automatically or modified through manual override controls. Eight self-contained modules make up the machine and have identical frames, elevators, and auxiliary mechanisms. The modules are couples to one another forming a closed continuous loop covering an area approximately 10 feet by 42 feet. The function of each module can be altered by varying the interconnecting electrical controls. A load and unload station and 14 processing stations (2 per module) are aligned along one side of the loop. An overhead monorail trackway conveys a free-wheeling carrier with the plating barrel attached through the machine. At each processing station elevators lower the plating barrel suspended from a section track and the free-wheeling carrier into the processing tanks. Fumes at each processing tank are exhausted into a common plenum chamber through side draft exhaust hoods and risers.

HEADER ASSEMBLING

The Header Assembling Machine is a 6-station, in-line, rectangular machine that assembles TO-18 headers prior to header glassing. It automatically indexes glassing molds containing platform-lead assemblies into and through the various work stations. Emitter and base leads are simultaneously added as each mold position is indexed to the lead load station. Glass rings and glass slugs are successively placed in the platform-lead assemblies as they are indexed past the respective stations. The last work station crimps and welds the three lead ends together to maintain lead straightness and facilitate header processing on succeeding machines.

HEADER GLASSING

The Header Glassing Machine or Seal-ox Furnace is a dual atmosphere furnace that oxidizes metal parts in one zone and fuses a glass-to-metal seal in a second zone. Boats filled with assembled headers in glassing molds are automatically pushed from a feed conveyor onto the furnace conveyor. A pair of photoelectric interlocks and a timer regulate the rate of boat feed and prevent jams. The furnace is zoned into four parts: the first or preheat zone raises the temperature of the header to 800°C in a nitorgen atmosphere. The second zone is the oxidizing zone (800°C) and contains dry air. The third zone is the glassing zone (1000°C) and contains nitrogen. The last or cooling zone contains nitrogen and anneals the glass seal while bringing the headers down to room temperature. Processed boats are deflected from the conveyor near the output end of the furnace.

HEADER LEAD TRIMMING

The Header Lead Trimming Machine trims the three isolated leads of TO-18 headers to a predetermined length and then bends and welds the collector lead to the header platform. The operator orients the headers while manually loading them in ceramic nests on the periphery of an 8-position index table. As this table rotates four operating stations process the header leads. At the first station a high speed grinder trims the three leads. At the next station another grinder prepares the collector lead for bending by notching it at a predetermined height. A motor driven bending arm then bends this lead 90 degrees; following which, the upper welding electrodes bends the lead against the platform before effecting a weld at the fourth operating station. An ejector unloads processed headers into a bin at the unload station. Sensing stations on either side of the load station stop the machine if the header is not oriented properly or the nest was not cleared during unloading.

STRIP PERFORATING AND WELDING

The Strip Perforating and Welding Machine prepares headers for the gold plating operation by welding the lead tips to a steel band. This band with headers attached is the input to the Header Continuous Rack Plating Machine. The base of the Strip Perforating and Welding Machine is approximately the same size and shape as a double pedestal desk. Five of six stations are mounted on the top; the sixth is mounted against the back. Plain steel tape is supplied from a rack and perforated with index holes as it passes between the punch and die of the first work station. Headers with lead ends welded together are manually loaded into locating blocks which align the headers. The extreme ends of the lead tips are welded to the strip as the headers are indexed to the weld station. Following welding the headers are alternately deflected to the right and left of the strip as they pass between a pair of meshed sprockets. The completed strip assembly and a plastic filler strip are then wound on a reel which is the input to the next machine.

HEADER CONTINUOUS RACK PLATING

The Header Continuous Rack Plating Machine cleans and applies a uniform gold plate on TO-5 and TO-13 headers while maintaining straight leads. The strip assembly prepared on the Strip Perforating and Welding Machine is fed through the machine from an unreeling station. Plated headers can be rereeled at the output end or cut off at a cutting station.

The machine is laid out in the shape of a "U" which covers an area 11 feet wide and 31 feet long. All 17 cleaning, plating, rinsing and drying stations are accessible from the aisle up the center of the "U". Guides, rollers and sprockets aid in guiding and pulling the strip assembly through the machine. At times the steel strip is turned into a horizontal position and completely immersed; for certain operations the strip is turned into a vertical position and only the headers are immersed. Two extra gold plating stations are available so that a heavier plate can be applied on the platform than on the leads.

CAN GETTER ASSEMBLING

Fabrication of a moisture seeking non-tubulated can is accomplished on a straight line Can Getter Assembling Machine. It consists of two main sections - Can Loading and Powder Loading. A third component, Powder Leveling, is attached to a sintering furnace. Both the Can Loading and the Getter Loading Sections are built on the same type frame and utilize similar powder loading stations. All operations proceed automatically after a section is energized. The Can Loading section feeds TO-18 cans from a vibrating bowl and loads them into pallets. Following pallet loading measured amounts of finely ground nickel powder are simultaneously dropped into all cans in a pallet. Then the loaded pallet is stored in a magazine for transfer to the Powder Leveling component. This component levels the powder in each can by vibrating the pallets on a powder leveling station. Following this, the pallets are moved onto the moving hearth of a sintering furnace. Pallets leaving the sintering furnace are manually reloaded into magazines and then automatically processed through the Getter Loading section after the magazine is positioned in the load station. Following magazine unloading, on the Getter Loading section, the pallets enter a shake-out station. This station inverts the pallets and shakes out any sintered nickel not firmly attached. After loading measured amounts of barium hydroxide at the next station - getter loading - assembly is completed by heating the cans until the barium hydroxide melts and flows into the nickel sponge formed during sintering. The pallets are then stored in a magazine until the getter is activated in an activation furnace.

SLICE SCRIBING

The Slice Scribing Machine diamond scribes breakage lines on semiconductor slices. It is a single station machine capable of scribing on .020-, .030-, .040-, or .050-inch centers. A monocular microscope above the station is used to align the slice prior to scribing and view it during scribing. A rotatable vacuum chuck mounted on a precision cross-stage slide simplifies alignment and scribing in "X" and "Y" orientations. Slice indexing is accomplished through a solenoid controlled single revolution clutch, modified for half revolution indexing, driving a 50-pitch precision lead screw.

WAFER BREAKING, SCREENING AND LOADING

Segments of scribed 2N559 germanium slices are broken into wafers by the Wafer Breaking, Screening and Loading Machine. The wafers are then indexed to an inspection station. There an operator checks the wafers and stripes for defects before initiating accept or reject cycles. Depressing an "accept" button activates a transfer mechanism which places accepted wafers into multi-pocketed wafer trays. Defective wafers are vacuumed into a reject receptacle. The loaded wafer trays are the input to the Wafer Bonding Machine. The eight stations on the machine are mounted on a table attached to a floor model comparator. The comparator projects a wafer image magnified 300 times on a Fresnel viewing screen so that wafers can be inspected efficiently. The following mechanisms convert the slice segments to wafers and transfer the wafers and trays through the stations: (1) strip breaking, (2) strip indexing, (3) wafer breaking, (4) wafer indexing, (5) 4-position inspection table, and (6) tray indexing and locating mechanisms.

WAFER BONDING

Semiconductor wafers are gold-germanium eutectic bonded to TO-18 headers on the semiautomatic Wafer Bonding Machine. The operator manually orients the headers to carriers in a rectangular track. A 6-position turret transfers the wafers from wafer trays to the headers. When a wafer is poised above a header at the bonding station, electrode depressors push the electrodes into contact with the header immediately adjacent to the bonding area. A high amperage, low voltage current then heats this area for 5/6 second. At the same time, the wafer contacts the header and a mechanical agitator vibrates the wafer transfer needle. After three indexes, the wafer bonded header is picked up by a nylon sleeve on a 6-position unload turret, which transfers the header into a special tray. These trays are automatically indexed from a load magazine to an unload magazine.

WIRE BONDING

The Wire Bonding Machine attaches gold wire leads to the emitter and base stripes on semiconductor wafers and to the ends of the proper internal header leads. Gold wire, .0005 or .001 inch in diameter is continuously fed from a spool, through a hollow bonding needle and around a bonding tip. Precision scissors sever the wire and reposition the end under the bonding tip after each post bond. The machine has four main operating stations; tray load, preheat, bonding and tray unload. Trays containing 30 wafer-bonded headers are indexed through the machine on signal from the operator. At the bonding station a mechanism transfers headers into and out of the bonding nest. The operator feeds gold wire and aligns the bonding tips on the stripes and internal leads with an X-Y manipulator while viewing the work through a microscope. To effect each bond, the operator lowers a Z-lever. A temperature controller maintains the bonding nest at a preset temperature.

FINAL CLEANING

The Final Cleaning Machine is a 4-station, in-line machine that semiautomatically cleans wire bonded headers prior to baking and encapsulation. First, the operator manually aligns a batch of headers, 600 maximum, at an aligning station so that they barely clear the bubblers in the etching and rinsing stations. Then the operator manually transfers a magazine containing the lot of headers in handling trays from station to station. Cycle timers at the etching and rinsing stations control the flow of cleaning agents. Six hundred bubblers in these stations supply each transistor subassembly with fresh etchant or distilled deionized water. A cycle timer at a methanol drying station signals when the drying period is over. Two tanks behind the etching station are used to mix and heat the etchant. The rinse water recirculating and purifying system is located behind the rinsing and drying stations. The rinse water can be heated to 200^{o}F maximum. A still provides the make-up water needed to maintain the desired water level.

CLOSURE WELDING

The Closure Welding Machine is a semiautomatic machine which automatically assembles and welds gettered cans to wire-bonded and cleaned TO-18 headers. Two operators load the cans and headers into the electrodes and remove the welded assembly after welding. A rotary index table enclosed in a dry box contains 16 welding fixtures. Following electrode loading, the fixtures close but do not mate the can and header, thus forming a small enclosure inside the fixture. Dry gases continuously flush this enclosure until the weld is effected and the welding residue is exhausted. Just before the electrodes reach the welding station, the cans and headers are mated by closing the electrodes. Following welding the fixtures open automatically for unloading. Controlled atmosphere bake ovens are attached directly to the welding machine dry box so that baked headers are not exposed to uncontrolled ambient conditions prior to welding.

CARD LOADING

The Card Loading Machine completes the first step in 2N559 packaging. It prepares test holders containing completed 2N559 transistors by processing a cardboard belt, heat sealable tape and the transistors through the nine major stations. The machine is attached to and synchronized with the Testing and Date Stamping Machine. Transistors in handling trays are manually loaded on a track; all other materials are supplied automatically as the machine cycles. The machine prepares the cardboard belt by punching it with indexing holes and locating notches. Transistors are picked up in a chuck. A comb engages the leads and guides them into a lead spread and heat seal station. Spreading the leads simplifies contacting them during testing. At the end of the lead spreading operation the heat seal mechanism attaches heat sealable tape to the belt on either side of each lead. At the next station a wider tape is firmly attached near the center of the belt. Then the belt is fed to a cutting station where it is cut into 1-1/8-inch-wide cards each containing a transistor. A pusher feeds the card directly into a test holder of the Testing and Date Stamping Machine.

TESTING AND DATE STAMPING

The Testing and Date Stamping Machine performs all Group A electrical tests on 2N559 Transistors and stamps a 3-digit acceptance date on top of the transistor can. Tests are performed on a go-no-go basis with rejection following the first test failed. Test modules are located in a cabinet centered on top of a commercial straight line index table. Thirty-six test holders attached to the chain conveyor of the index table carry card-mounted transistors from station to station. An auxiliary cam shaft raises the transistors on the test holders into contact with three fixed test probes at each station. Timers in the test modules control the time bias is applied. After bias has been applied for the specified period, the test parameter measurements are made and compared to a standard by comparator circuitry within each module. Each side of the machine has 13 in-line index positions. A 2N559 test line has been installed on one side. It contains a test holder loading station, eight test stations and a date stamping station. A similar line can be added on the other side if the need arises. Unload stations for good transistors are located at both ends of the machine.

DATA HANDLING

The Data Handling System is used to generate electrical test data, to process the data and to convert it into forms useful for engineering evaluation. The system consists of eight interrelated items of commercial equipment. Test capability is provided by a Texas Instrument Transistor and Component Tester (TACT) and a Lumatron Automatic Switching Time Test Set. The former performs d-c and 1 kc "h" parameter measurements and the latter pulse response tests. Devices being tested are manually inserted in test sockets on both test sets. The TACT automatically performs the test programmed on punched cards. Test results are recorded on punched cards, punched tape or as typewritten data. Programming of the pulse response tests and digital readout of the test results is accomplished by a Delaware Products Digital Voltmeter. These tests are performed automatically after the operator initiates them. Output data is recorded on punched paper tape, on a typewritten sheet, or both simultaneously. A Monrobot Mark XI computer converts the data from the test sets into condensed form for evaluation. Output data of the computer is recorded on a punched tape or a typewritten sheet.

CARD PACKAGING

The Card Packaging Machine fabricates and assembles the special package required to automatically supply 2N559 transistors to the Transistor Insertion Machinery for the Nike Zeus A Package. It prepares a shipping belt by punching plain "Mylar" tape with tabs and notches, deflects the tabs so an operator can place card mounted transistors between them, and winds the loaded belt on a shipping reel. All operations except belt loading are performed automatically. The machine occupies a 6-foot long table; only the tape supply station is underneath the table top. Two index stations pull the belt through three work stations located along the front edge of the machine. A counter programs the machine either for intermittent or continuous belt loading.