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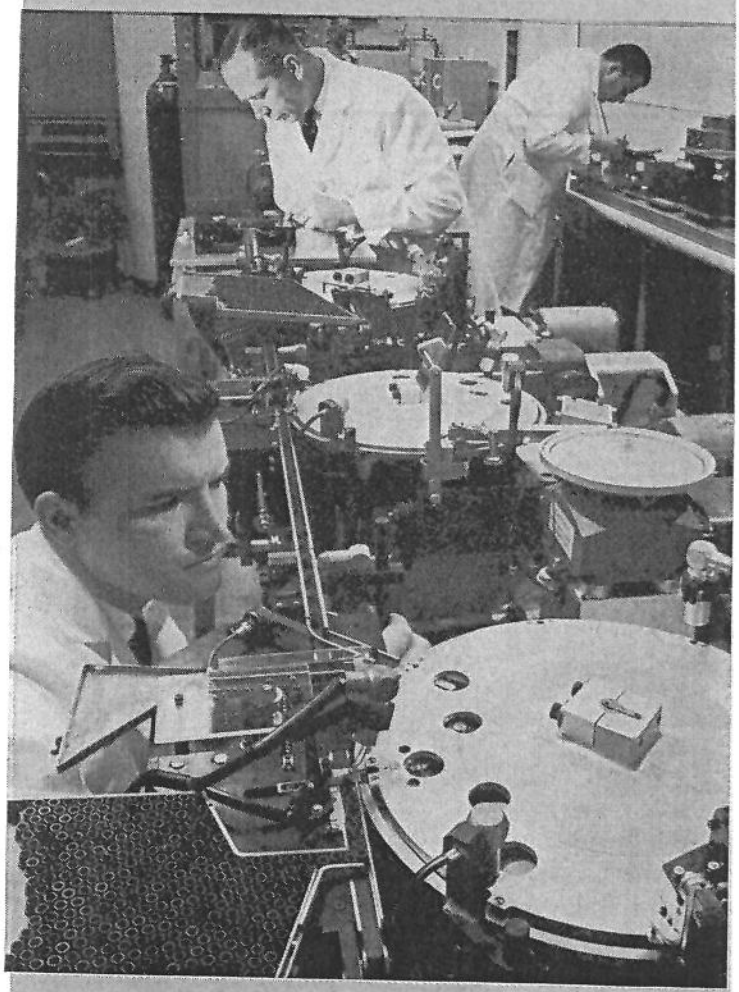
Automated Assembly of Alloy-Junction Transistors

Transistors of high uniformity and high quality are obtained with this fully automatic electromechanical assembler. Step-by-step inspection insures output of perfect units

By THOMAS J. LEACH, Special Equip. Eng. Manager, Component Eng. Dept., I.B.M., Poughkeepsie, N. Y.



Fully automated transistor assembler. Carbon boats convey transistor components to assembly stations

DESIGN OF THE automatic transistor assembler described in this article is based on the concept that each transistor be assembled and inspected individually, as opposed to the concept of batch manufacture. This approach offers many advantages.

Sequential individual assembly permits individual inspection at every step so that only perfect units are passed to the next step. Each vehicle, or boat, used to transport the transistor assembly through the machine is given off-line inspection; individual rejection of imperfect units is economical. If a boat is misloaded at any step, such misloading is corrected without interrupting the overall assembly process. Processing and quality control are facilitated by elimination of manipulation and judgment variables and by performance of each process step at one station only. Samples are pulled at each step and defects traced directly to the source.

The machine requires only one mechanism for each feed, unload, and inspection station. The high productivity of this single set of tools not only gives close process control but also low cost.

SEQUENCE OF ASSEMBLY—The machine fabricates the transistors from preformed components—emitter and collector dots, the germanium disk, the base washer, the whisker wires, and the mounting base. The machine first assembles the dots with the

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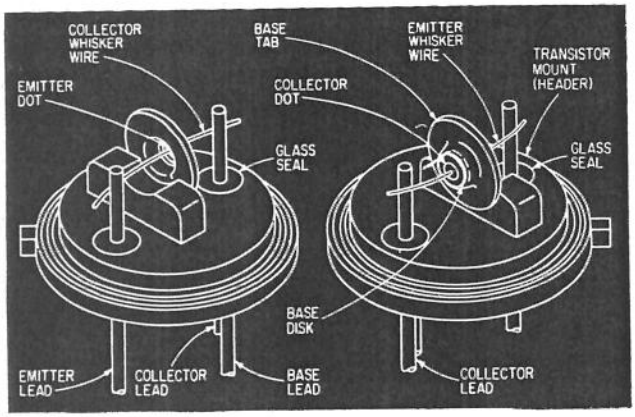


FIG. 1—Alloy-junction npn transistors are assembled from preformed components

germanium disk and alloys them. The machine then assemblies the base washer and the emitter lead and bonds them to the transistor. Next, it bonds the collector lead. Finally, the machine welds the base washer to the transistor mounting base and welds the emitter and collector wires to the mounting base posts. Figure 1 shows the assembled structure.

Each function is performed on an internally driven and controlled turntable. The turntables are interconnected by belt transports, but each is independent, operating only when boats are supplied to it and when there is demand for its output. Ninety minutes are required to complete the assembly of each transistor. Production is at the rate of one transistor every two seconds.

Figure 2 presents a flow diagram of the complete assembly process. The unit type boats—actually machined carbon jigs—are used in the assembly process to confine and position the components of the transistor during the alloying operation. The first component inserted into the boat is the collector dot, accomplished on turntable 1. The boats are fed onto a conveyor belt by a linear vibrating tray. From the conveyor they are injected into pockets of the indexing table.

At the first index of the table, station 2, a photoelectric detector checks for the presence of the boat. The check at this point permits the automatic inhibiting of the dot loading operation if the boat is not present. At the next station the collector dot is inserted into the cavity of the boat. Before leaving the turntable, the boat is again photoelectrically checked to insure proper positioning of the dot. If the dot

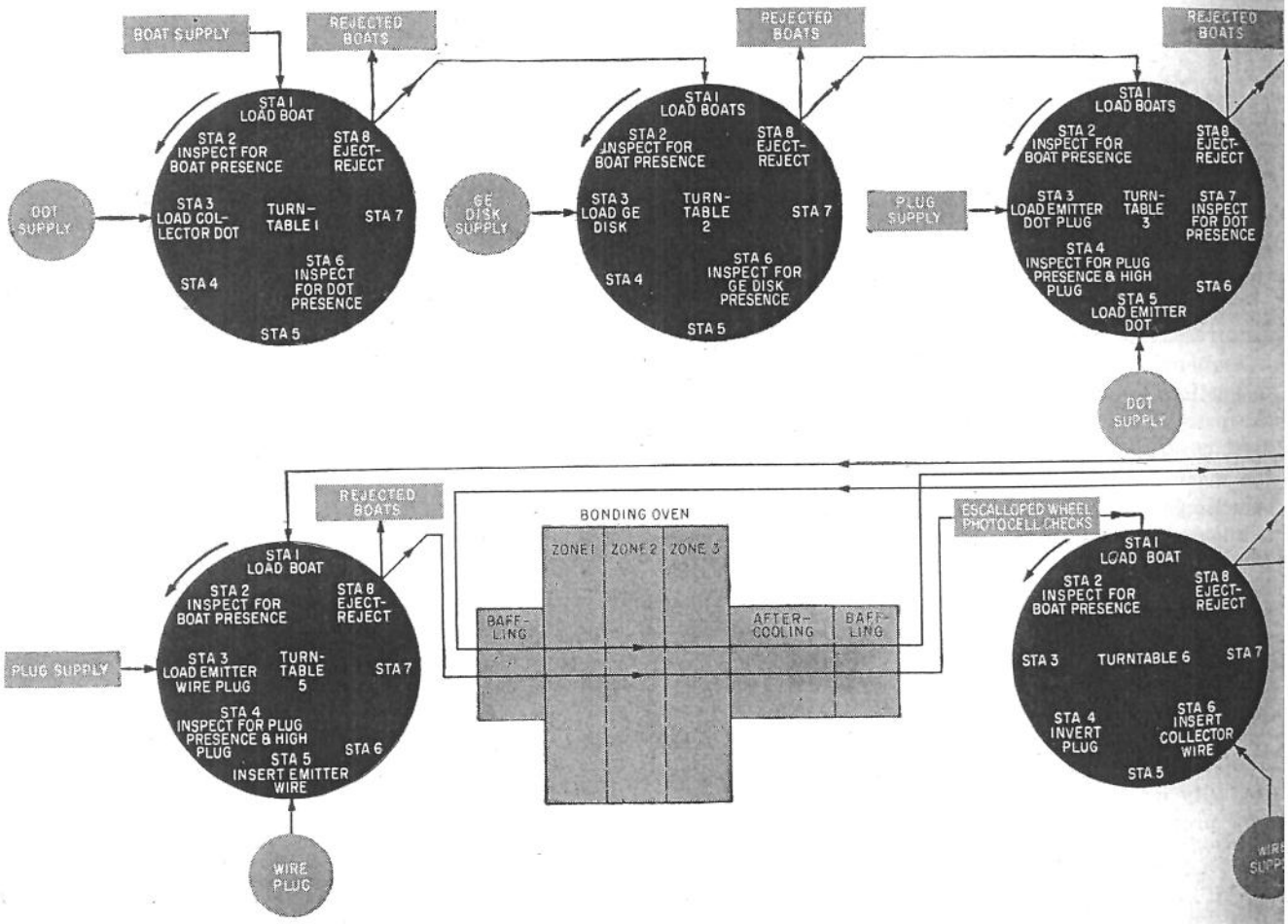


FIG. 2—Flow diagram for the complete assembly process. Machine first assembles collector and emitter dots with the germanium disk and alloys them; it then assembles the base tab and the emitter leads and bonds them to the transistor; next, it bonds the collector

is absent or improperly positioned, the boat is rejected at the output station of the Unit. Accepted boats are placed on a conveyor for transport to turntable 2.

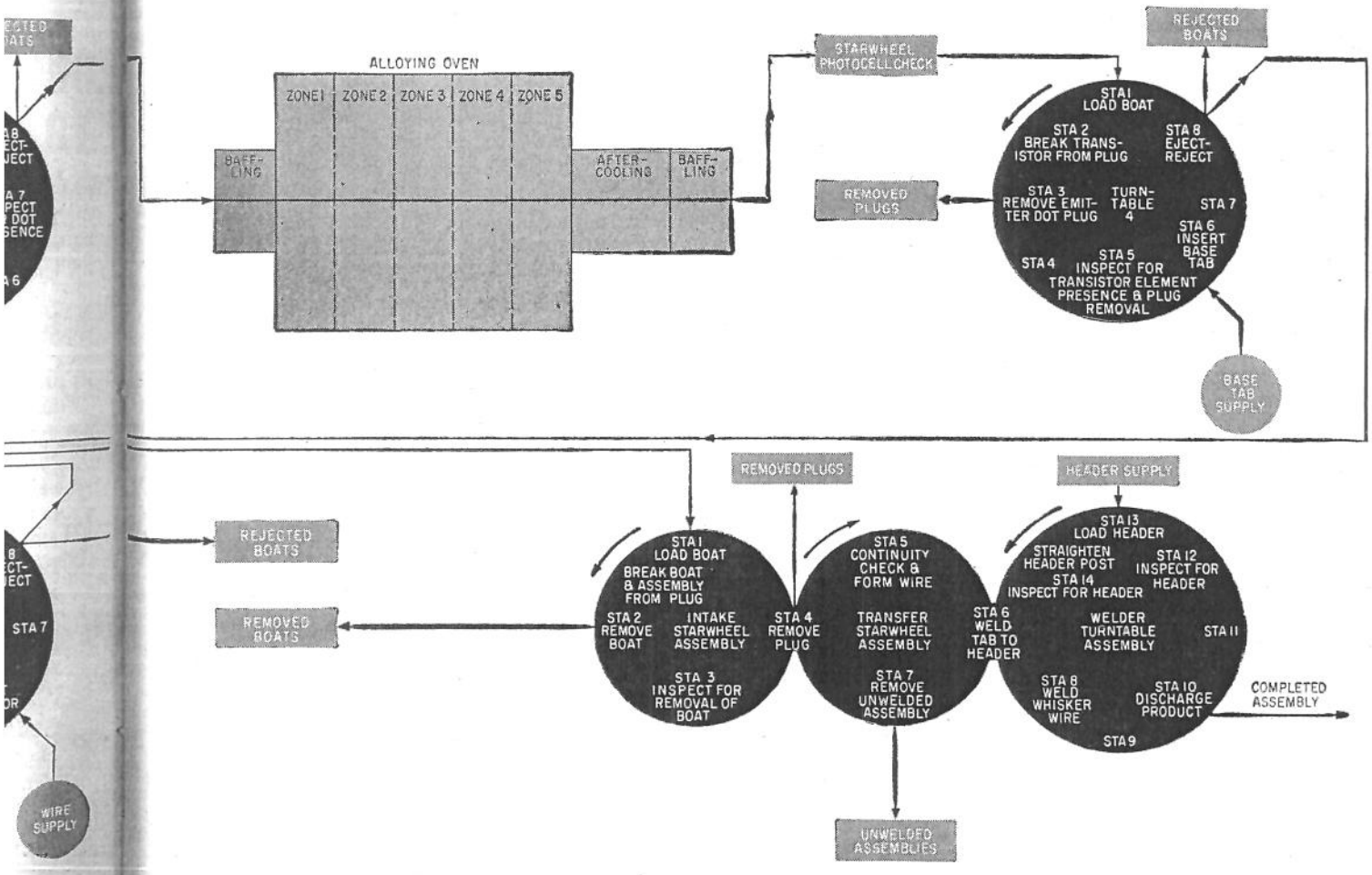
A built-in float or overload between all units in the machine permits a predetermined number of boats to arrive at the input of each unit. An oversupply will automatically restrict the output of the preceding unit.

At turntable 2 the boats are loaded with the germanium disks and checked. The disks are fed into and oriented in a rotary Syntron feeder which will remove chips or broken disks. Accepted disks are then fed into a linear feeder track for delivery to a pickup station. During their trip down the track, the disks pass below two control points called bridges, which prevent out-of-tolerance, dirty, or double disks from reaching the assembly point. At the end of track, accepted disks are picked up by a vacuum probe, carried over, and dropped into the orifice of a cone, which guides them to their proper position in the boat. Another photoelectric check determines the presence and proper position of the disk in the boat. Accepted boats are transported along the conveyor; rejects are removed from the assembly process.

At turntable 3 an emitter dot plug is automatically placed in the boat on top of the germanium disk. Its function is to position accurately the emitter dot in the center of the disk. This plug-loading operation is also controlled through a detector device. If no boat is present in the preceding station, the plug-loading cycle is inhibited. With the plug in proper place, the emitter dot is inserted, and the boat is checked for its presence.

Now, loaded with its cargo of collector dot, germanium disk, and emitter dot, all correctly positioned, the boat is set for the alloying operation. It is loaded onto the oven conveyor belt by a cam-operated pusher. Still on the belt, it is conveyed through the tunnel furnace, where the units are alloyed.

After the alloying, the boats are conveyed to the next operation on a wide belt. This belt also provides overnight or temporary storage for all boats in the oven. On turntable 4, to which the boat is now directed, a probing operation releases the alloyed parts from the emitter dot plug and removes the plug. With the plug removed, the gold-plated base washer is loaded into the boat. These washers are Syntron-fed to a fixed position on the bowl. Here they are picked up by a vacuum probe and placed into the



lead; finally, it welds the base tab to the transistor mounting base and welds the emitter and collector wires to the mounting base posts. During these operations, machine performs 50 individual checking functions

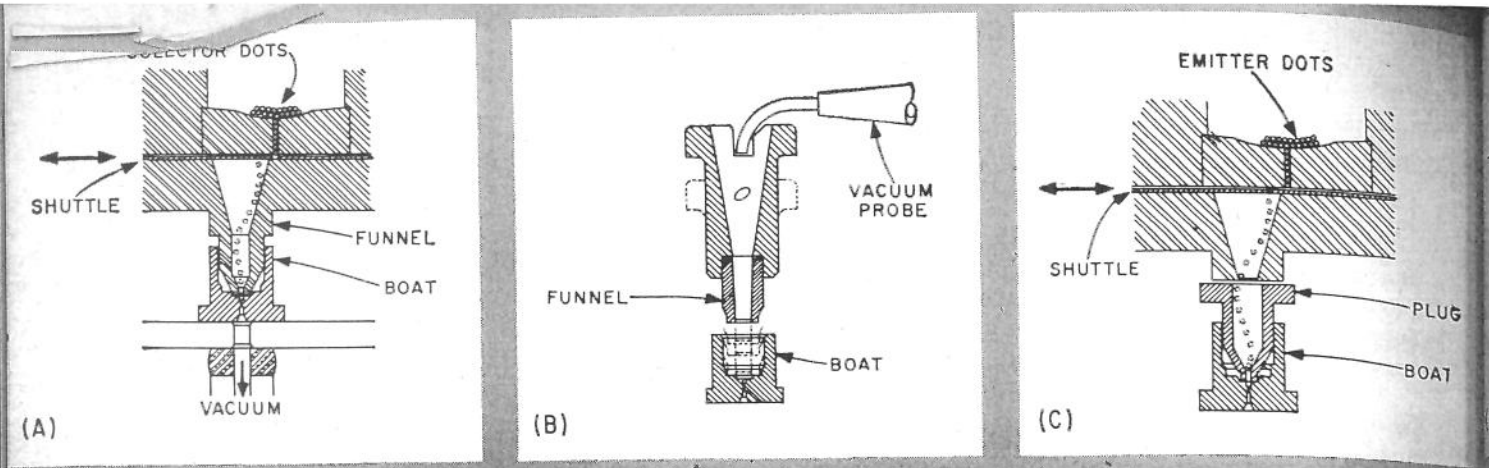


FIG. 3—Transistor assembling operations: collector dot loading at station 3 of turntable 1 (A); germanium base disk loading at station wire insertion at station 5 of turntable 5 (E)

boat on top of the alloyed unit. Accepted boats are then transported to the wire-insertion operation.

An emitter wire locating plug is loaded into the boat on top of the base washer, its function being to position the emitter wire relative to the emitter dot during the bonding operation. After the wire is inserted, the units are moved to the bonding oven over a series of conveyor tracks.

On the first pass through the oven, the base washer is bonded to the germanium disk and the emitter wire to the emitter dot. The bonded output, emerges from the oven and moves to the collector wire unit. Here the complete boat, still containing the emitter wire plug and the assembly device, is inverted to permit the loading of the collector wire through a tiny hole in the new topside of the boat. The boat is then transported back to the bonding oven.

After the second pass through the oven, the output contains the alloyed and bonded assembly of collector dot, germanium disk, emitter dot, base washer, and emitter and collector wires. At this point the assembly is prepared for attachment to the transistor mounting base. Mounting bases (headers) are manually loaded into magazines for placement on the machine, which, in turn, automatically inserts the mounting bases into their holders.

The completed assemblies in their boats are fed into position on the welder unit. As each boat travels to a boat removal station, it is gently lifted and agitated by a cam and sawtooth mechanism. This operation frees the transistor assembly from its nest in the boat. The transistor assembly is then carried by the plug to a station where it is removed from the plug by a tweezer-type gripper. Held by this gripper, the assembly is checked for electrical continuity between the base washer and the emitter and collector wires. During this operation, the emitter and collector wires are formed, providing additional shock resistance to the assembly.

The units accepted by the continuity checker are brought together with the mounting bases, to which the base washers are welded. For those units that are not accepted, the base washer welding operation is inhibited, and the units are ejected. Unwelded mounting bases are recycled without additional handling. After the base washers are welded to the mounting bases, the transistor assembly is rotated 90 degrees, permitting simultaneous welding of both wires to the mounting base parts. This welding completes the machine operation. The alloyed, bonded, and mounted units are discharged and placed on carriers for manual removal. After assembly, the units are etched, tested, capped, and categorized for use.

MECHANICAL DESIGN—Because transistor components are so small and fragile, it was decided initially to feed, assemble, and inspect each component assembly on individual turntables. The nine major operating units (six turntables, two ovens and the welding unit), integrated by the series of conveyors, evolved from this unit concept.

Although the major portion of the units required custom designing, the use of standards reduced design and delivery time and permitted a minimum inventory of spare parts. As a result of the mechanical standardization, it was possible to a large extent to standardize the electrical controls.

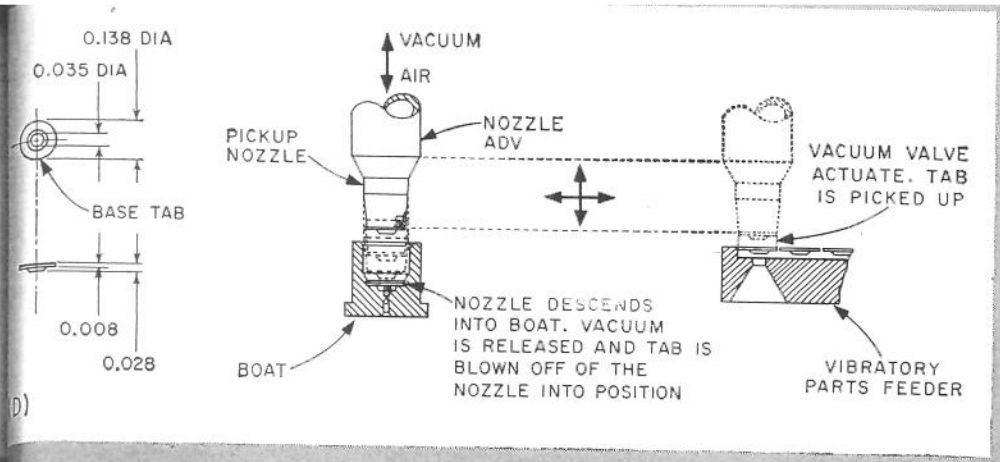
The radial indexing drive units, using Ferguson drive cams, were custom designed and built to provide four switch-controlled output speeds, ranging from 1.4 to 4.1 seconds per cycle. The units provide eight-position indexing, which covers the known requirements and also permits the addition of unplanned operations at a future date without major alteration.

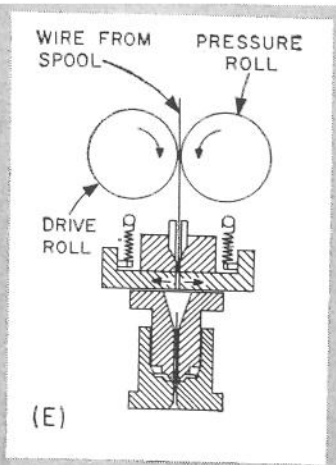
INSPECTION DEVICES—Three basic types of inspection devices are used in the machine.

Mechanical limit switches determine the height of the boats passing through the process. These switches provide protection against damage to the boats and the mechanism from parts too high to pass under the loading station. The switches also give an indication of components improperly assembled.

In the base washer loading unit a vacuum probe lifts the base washer from a vibratory feeder and deposits it in the boat. Since the vacuum achieved in the probe is determined by the presence or absence of the base washer, a vacuum switch checks the operation at this point.

The third and primary inspection device, which is used throughout the assembly process, is a photocell





3 of turntable 2 (B); emitter dot loading at station 5 of turntable 3 (C); base tab insertion at station 6 of turntable 4 (D); and emitter

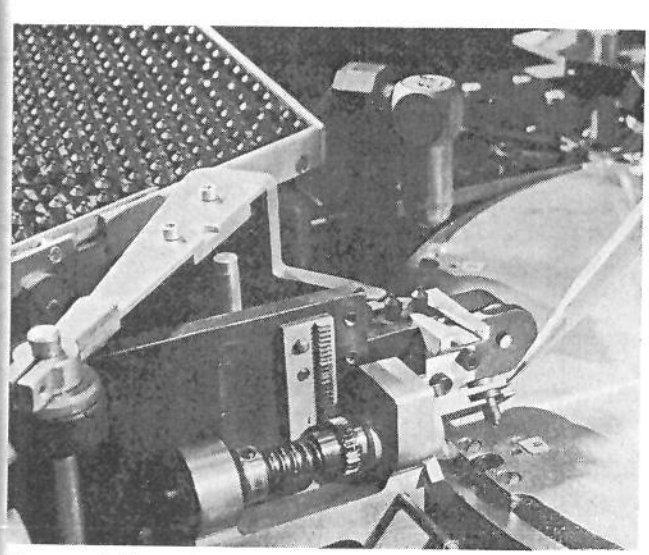
detection circuit. This circuit consists of a Number 12 lamp and a Clairex CL-3 photocell whose resistance decreases with an increase in the intensity of light falling on its surface. The photocell, a current-limiting resistor, and a sensitive relay are in series across the rectified 117 v a-c used as a power source.

This circuit, along with its power supply, is contained in a small plug-in unit. The device is operated when the part being sensed reduces the light intensity and, in turn, the resistance of the photocell increases to the point where insufficient current flows to hold the relay energized. Modifications of current-limiting resistance and relay sensitivity are necessary in several instances, particularly in detecting the presence of germanium disks and emitter dots whose bright surfaces reflect the light. Exclusive of oven temperature and gas flow controls, the machine performs 50 individual checking functions.

LOGIC—With the exception of wire loading, each assembly turntable includes a final checking device that determines whether the boats should continue in the process or be rejected. Provision is made automatically to stop any operation after a preset number of consecutive rejects. Information concerning the disposition of the transistor being assembled—accept or reject—is carried in a relay shift register, in which the information is transferred progressively to relays corresponding to the cycle in which the machine unit is operating.

The final relay of the register establishes a circuit from a cam-operated circuit breaker to the desired solenoid, accept or reject. Current to all solenoids is made or broken by cam-operated circuit breakers; relays are used only to establish the circuit. The repeating reject circuit consists of an elapsed-time meter, which resets whenever an assembly is accepted. The time cycle is adjusted for a maximum number of consecutive rejects, and if no assembly is accepted during this time, the machine stops.

Each turntable is equipped with a conveyor overload detector which stops the table when its output conveyor is full. This detector consists of a photocell unit mounted across the track. A boat interrupting the light beam causes the photocell relay to drop out. A relay logic circuit is then energized to determine whether the boat is to move to the succeeding machine cycle; if the boat should not move, the machine unit will stop until the light beam is reestablished.



Closeup of plug and boat being fitted together. Boats and plugs have tolerances as close as 0.0005 inch for precise positioning of transistor parts during alloying, bonding and welding

WELDING UNIT—In the welding unit a check is performed on the complete assembly operation. The assembled unit—consisting of the base washer, the germanium disk, collector and emitter dots and wires—is checked for continuity before being welded to the mounting base. In this check, current passes through two relays in series with the two transistor leads (emitter and collector), the base washer being grounded. An indication of a correctly assembled transistor is obtained when both relays are energized. Only transistors that pass the continuity check are welded to the mounting base.

Mounting bases to which no transistors have been welded are recirculated while the welding operation and the loading of new mounting bases in the welding and loading indexes of the unit are suppressed. The output of the unit, therefore, consists entirely of mounting bases to which correctly assembled transistors have been welded.