



## Inexpensive Quality

FROM the beginning, -hp- instruments have been characterized by high quality at moderate cost. The wide acceptance of -hp- instruments by industry has been largely due to this high quality-moderate cost feature.

In many -hp- instruments, high quality at moderate cost has been achieved through novel basic designs. For example, the first -hp- RC oscillator was equal or superior to comparable existing bfo oscillators in performance; but in price the RC oscillator offered a saving of more than 50%. More recently, the new waveguide instruments have also been characterized by high quality at moderate cost through design ingenuity.

A number of contributions to inexpensive quality have been described in past issues of the *Journal*. These issues have been mainly concerned with the work of the electrical design group. However, the work of the -hp- production and mechanical engineering groups has also contributed substantially to

the realization of inexpensive quality in production instruments. Some of these contributions are described in the following article.

Most of the newer -hp- instruments have been designed with resistors and capacitors mounted on a resistor card. This type of construction is widely used in more expensive electronic equipment, where common practice has been to construct the resistor card by riveting lugs into drilled phenolic boards. However, a cost analysis of such a resistor card showed that it was an expensive method for mounting small components: the cost of the mounting arrangement often exceeded the cost of the components themselves. Further, the lug arrangement was not without disadvantages. To provide a good mechanical connection between the resistor and lug, it was necessary to wrap the resistor lead a complete turn around the lug. This often placed additional strain on the resistor element and made servicing difficult.

Some of the equipment and processes described herein are subject to existing and pending patents.



*Street view of -hp- factory. New building described in article appears at left.*



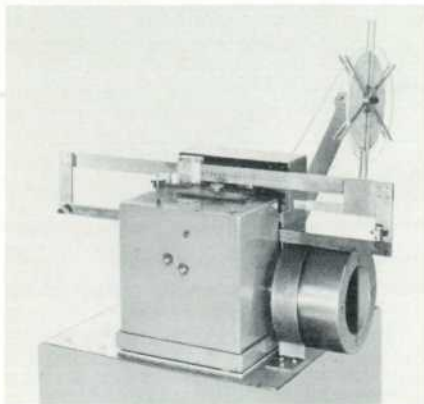


Figure 1. High-speed resistor-card fabricating machine.

The project of designing a less expensive type of resistor card was assigned the mechanical design group, which designed a new type of card as well as a machine that fabricates the card automatically. This machine, familiarly called the "Kingman machine" after its designer R. M. Kingman, eliminates screw machine, drill press and riveting operations to achieve a tenfold reduction in fabrication time.

The resistor-card machine performs three basic operations. It stamps a flat lug out of silver-plated brass ribbon, punches a hole in a phenolic board, and mounts the lug in the hole. The machine can also punch a number of large holes that can be used to mount the resistor card in an instrument.

The silver-plated brass ribbon mounts on a spool at the back of the machine and is fed between a punch and die that forms lugs like that shown in Figure 2. A phenolic board or card previously cut to desired size is manually inserted into a traveling carriage at the top of the machine. This carriage carries the phenolic board past a punch and die in a stepping or indexing motion similar to that of a typewriter carriage. As the board moves through the machine, the punch stamps out small round holes along the edge of the board. Into each hole the ribbon feed mechanism inserts a stamped lug, leaving

the shank of the lug protruding from the back side of the board. A crimping punch crimps the shank which is then "set" by a small automatic hammer, thus mounting the lug securely to the card. The machine continues this operation along one complete side of the card, after which the card is manually inverted and the process continued along the opposite edge. A separate punch and die are included in the machine so that mounting holes for the card itself can be punched at desired points along the card. A disabling cam prevents the insertion of lugs in these mounting holes.

The operation of the machine is rapid and lugs are mounted at a rate in excess of 130 per minute. A typical resistor card having 10 pairs of lugs can be completely fabricated in about 15 seconds. Costwise, the machine-made resistor card amounts to

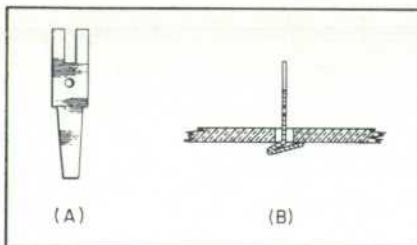


Figure 2. (a) Lug formed by resistor-card machine; (b) lug secured in resistor card.

only 1/7 to 1/10 the cost of conventional cards and at the same time frees valuable machine shop facilities.

The machine-made resistor card also has a number of advantages that improve the equipment in which it is used. The lugs are thin in the direction of resistor strain so that danger of damage to resistors during and after wiring is minimized. Also, it is not necessary to wrap the resistor lead around the lug. The lead simply drops into the slot at the top of the lug (Figure 2). After the resistor is soldered into place, the excess lead is cut off and no strain of any sort has occurred in the resistor. Leads connecting to the resistor card

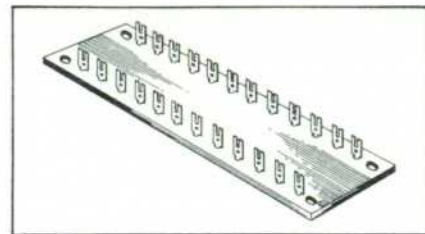


Figure 3. Typical card fabricated by resistor-card machine. Mounting holes at ends of card are punched during card fabrication.

are inserted through the round hole at the bottom of the lug and soldered without wrapping. The mechanical joint formed by soldering is good and completely fabricated resistor cards with components mounted thereon do not show weakness when subjected to military type vibration and shock tests in finished equipment. The simplicity of wiring also reduces labor costs required for wiring in components.

Since neither the resistor lead nor connecting wire is wrapped around the lug, an otherwise difficult servicing problem becomes easy. Any component can be disconnected by heating the terminal and lifting the lead out of the slot. Connecting wires can be removed by pulling the wire out of the round hole after the lug has been heated.

#### SIMPLIFIED UHF CONTACTS

Another interesting example of inexpensive quality through design ingenuity is found in UHF shorts. Contacting type shorts have been used in many -hp- instruments that operate at high frequencies. From careful investigations we have found the contacting type shorts to be superior to the choke types in general use, especially in broadband equipment. The contacting short can be designed to be effective with a high VSWR and no resonances over wide frequency ranges. Further, life tests of 100,000 cycles show no significant wear. In contrast, the choke type plunger must often be designed with very close tolerances, and when used



with extruded waveguide sections these tolerances usually become meaningless.

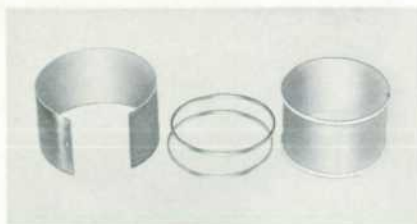
In making contacting shorts, it has been customary to "hog" the contact out of a solid slug of beryllium copper. This procedure resulted in a satisfactory short, but fabrication cost was high and life expectancy was not.

The first problem was to improve the life of the contacts. A satisfactory solution to this problem was to bond a solid silver overlay to the ends of the contact fingers. This solution gave long life and excellent performance, but still resulted in high fabrication costs.

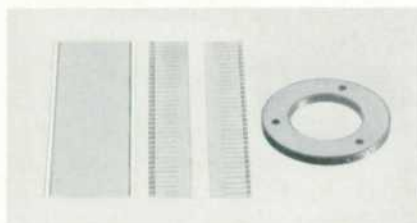
After considerable study, a completely different fabrication process was worked out. In the new process a strip of beryllium copper sheet of suitable size is rolled into a cylinder and a silver ring slipped on each end. The ring is then brazed to the sheet in a furnace. After brazing, the rings are cut at the joint in the cylinder and opened into a flat strip as shown in Figure 4. Each strip is cut longitudinally, providing two basic pieces that can be made into any of a variety of sizes of contacts.

Fingers are formed from the strips by grouping a large number of strips in a packing fixture and slotting the whole pack with a saw attachment rigged on a horizontal mill. Afterward, each strip is put through a special roller that gives the necessary "set" to the fingers to insure good contact.

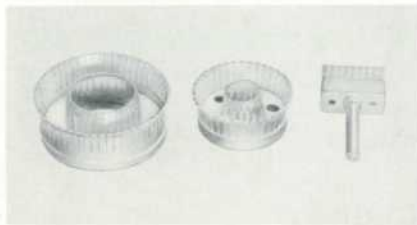
The short itself is now formed by assembling each strip into a simple brass ring. This assembly is placed in a furnace to harden the fingers for proper spring action. A soldering operation is then used to bond the strip to the brass ring, after which the contact is honed to achieve proper surface contour for the silver overlay contacts. A simple cleaning and plating operation readies the short for use.



(a) Beryllium copper strip and silver rings are brazed together to form assembly at right.



(b) Opened strips are cut, slotted, and assembled into brass ring.



(c) Various types of contacts made from basic strips.

Figure 4. Steps in fabricating UHF contacting shorts.

In spite of the fact that this process appears involved, it is actually much faster than older methods. Fabrication time with the new process is only about 20% of that formerly required. In addition, the basic strips resulting from this method can be used to form a variety of sizes and types of shorts. Three different shorts made from the basic strip are shown in Figure 4.

#### SHORT-RUN PLASTIC MOLDING

It is generally held that plastic moldings are economical only in large runs. However, in a number of instances it has been possible to lower costs in -hp- instruments and maintain high quality through the use of short-run plastic moldings. To accomplish this, it has been necessary to keep die costs low and to achieve flexibility in molding operations.

Die costs have been minimized by confining die designs to simple fig-

ures of revolution wherever possible, so that dies can be machined in a few hours from ordinary steel bar stock. Although such dies are only single or dual cavity types, they are entirely adequate for runs of a few hundred pieces. Simple dies such as these are frequently less than 3% the cost of ejection-type multiple dies designed in accordance with established molding-die practice.

Pieces molded from these dies generally have a shorter fabrication time than the corresponding time on a turret lathe. Even more important, however, is the fact that the dimensions in small molded pieces are uniform to a degree difficult to obtain in production lathe operations.

A typical example of the use of inexpensive moldings in -hp- instruments is found in the new waveguide equipment. One of these equipments required a piece consisting of a metal contact pin pressed in a close-tolerance polystyrene support insulator (Figure 5). It is readily apparent that the fabrication of such a piece by conventional shop methods is relatively expensive and somewhat difficult. The need for pressing the center contact into the insulating material leads to breakage, while close-tolerance machining slows production.

A simple die was made for molding the insulating material around the machined center contact. This die, shown in Figure 6, consists of three easily-made steel pieces that were fabricated at a total cost of less than \$25. In this case breakage and rework were negligible while die costs were extremely modest. In other applications dies have been made at a cost of less than \$15.

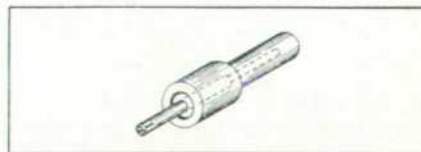


Figure 5. Piece consisting of metal contact molded in polystyrene insulator.



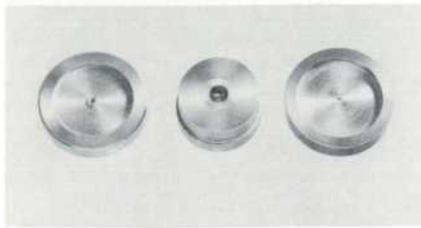


Figure 6. Simple die for molding piece shown in Figure 5.

In some cases plastic moldings have proved economical in the long run even where die costs have been higher. In the Model 460 140-mega-cycle bandwidth amplifiers, artificial transmission lines with lumped inductances are used. To insure uniformity among instruments, it is necessary that the characteristics of these inductances be controlled closely. This was achieved by molding a number of coil forms on a common mounting bracket. Although the dies for this piece cost considerable more than the dies described above, a substantial reduction in

fabrication and final testing time for the amplifiers resulted.

These examples are typical of the type of work being done by the production and mechanical engineering groups to maintain the quality of -hp- instruments. In spite of rising labor and material costs, this sort of work has allowed the price of -hp- instruments to be held constant with a continual improvement in quality.

#### NEW FACILITIES

Along with improvements in quality, we have been making every effort to better the delivery of -hp- instruments. To further this effort a new building has been added to the plant and is expected to be ready for occupancy within thirty days. This building brings -hp- facilities to approximately 60,000 square feet of floor space with some 400 employees.

Emphasis in the new building, as in the older buildings, is on light,

**I.R.E. 7th REGION  
CONFERENCE**

The Seattle Section of the I.R.E. has announced the program for the 7th Region Conference to be held in Seattle June 20-22. Included in the program are three days of interesting papers and field trips. I.R.E. President Ivan S. Coggshall will be a guest at the convention banquet on June 21.

ventilation, and a high degree of flexibility. The new building is radiant-heated and walls are almost completely glass above the three-foot level. Power, air, water, and telephones are supplied through covered channels in the floor. Color schemes are professionally designed for pleasant working conditions and minimum worker fatigue.

With the new building in operation, we hope to shorten the delivery cycle on -hp- instruments, although material shortages continue to be a major problem.

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-hp- technical field representatives are located at the following places. Whenever you desire first-hand information regarding -hp- instruments, contact the nearest representative.

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