Although the customer seldom sees a telephone's internal components, their design is as painstaking as the external styling of a new set. New materials and new devices are constantly being tested for smaller, lighter, and better performing components.

Designing Telephone Components

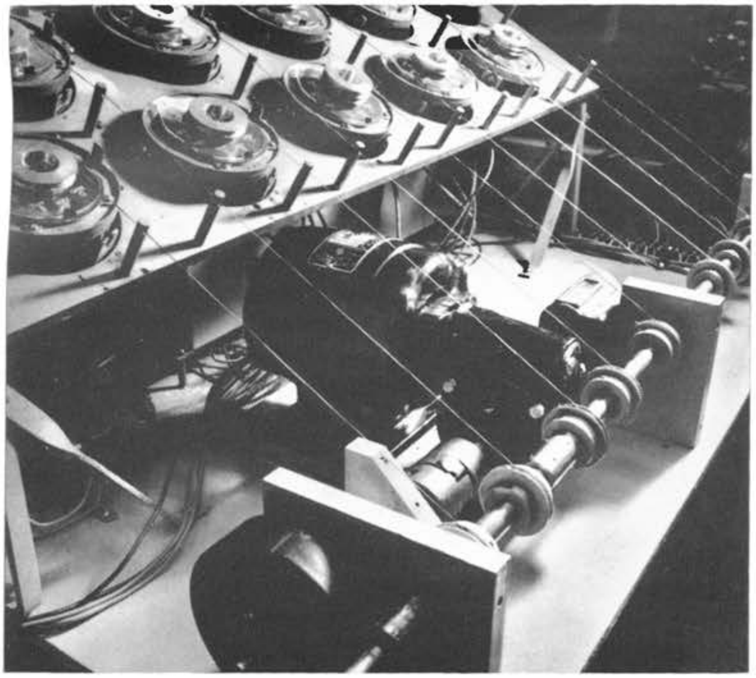
R. R. Stevens

BASIC TO THE DEVELOPMENT of new telephones is the design of the internal working components. The final design of these components determines the size and weight of the station set and strongly influences its external styling. For example, the TRIMLINE® handset is attractive and easy to use largely because Bell Laboratories design engineers and materials specialists were able to reduce the size and weight of many of its components without compromising overall transmission performance.

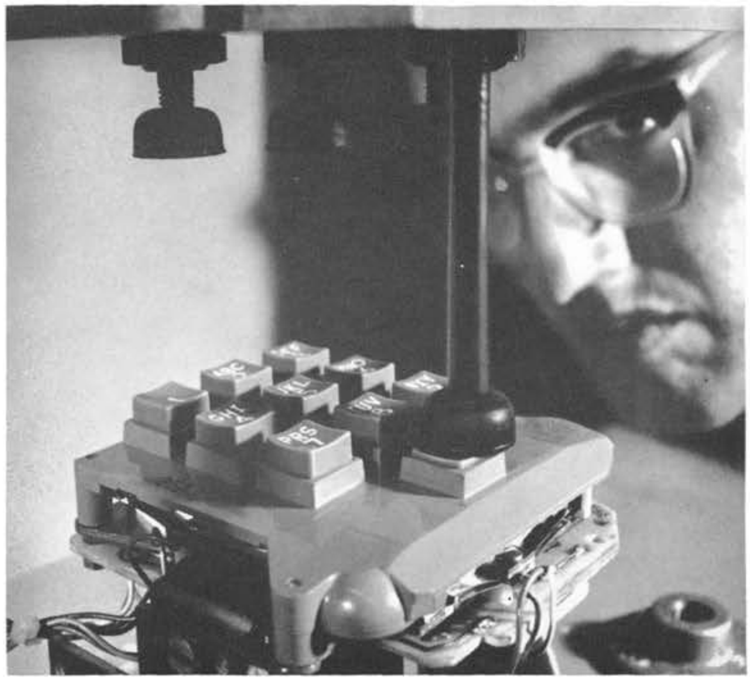
The scope of the job of designing telephone components is continually expanding. Designers of the first telephone sets could choose only from iron, brass alloys, copper, hard rubber, and fabrics. Today's designer can choose from an almost bewildering array of materials. For example, from numerous ferrous alloys he can choose the metal with the best combination of magnetic properties, strength, hardness, ductility, and corrosion resistance, as the use requires. Among the many plastics available are thin, durable films for membranes, hard, strong plastics for structural members, and self-lubricating plastic compounds for bearings and gears. Added to these are the semiconductor devices, the powdered ferrite magnetic compounds, and the new, thin-film and integrated circuits. Today some sixty different raw materials go into making a telephone. Among them are steel, aluminum, copper, tin, gold, silver, silk, rubber, wax, asphalt, rayon, nylon, many plastics, and even granules of anthracite coal.

To the designer, the advances in materials and device technology are an opportunity to build smaller and lighter components and thus smaller telephone sets. The new part must also be just as durable, long-lived, maintenance free and func-

The "dropping test" shown at the left tests the durability of the handsets and switchhooks for the TRIMLINE *and 500 type telephones. Each handset is suspended from two straps which are attached at the other end to an oscillating shaft. Handsets are checked periodically for any degradation in transmission quality. The counter at the top of the frame indicates that these handsets have been dropped on their bases over 10,000 times, yet their ordeal is only half over. Here A. E. Mulbarger checks the position of a test set base.*



In one life test, this dialing machine simulates normal dial windup. The motor-driven shaft oscillates through one-revolution cycles. During clockwise rotation, the strings wind up the dials. During the return (counterclockwise) cycle, the dials run down.



The counterpart of the dialing machine is this device used in life tests of the TOUCH-TONE *set. Plungers alternately depress the pushbuttons to test dial contacts. Short, square, plastic collars molded in the faceplate help align the pushbuttons with the dial.*

tionally adequate as the earlier component. In addition, all components must be compatible with overall external designs that meet human engineering criteria. Therefore, during the early development of a new telephone, a professional designer is retained for advice on styling and human factors in design. Other departments of Bell Laboratories also assist at this early stage in assessing new designs and in simulated field testing. (See "The Evolution of a Telephone," this issue, for a description of the role of human factors studies in telephone design.)

Field trials, which are especially important in evaluating the design of station apparatus, supply basically two types of information. During the production of the field trial models, the designers learn how difficult it will be to manufacture each type, sometimes discovering an unforeseen obstacle to economic production. The users of the field trial models contribute another kind of data: information concerning the effect of customer use and environment.

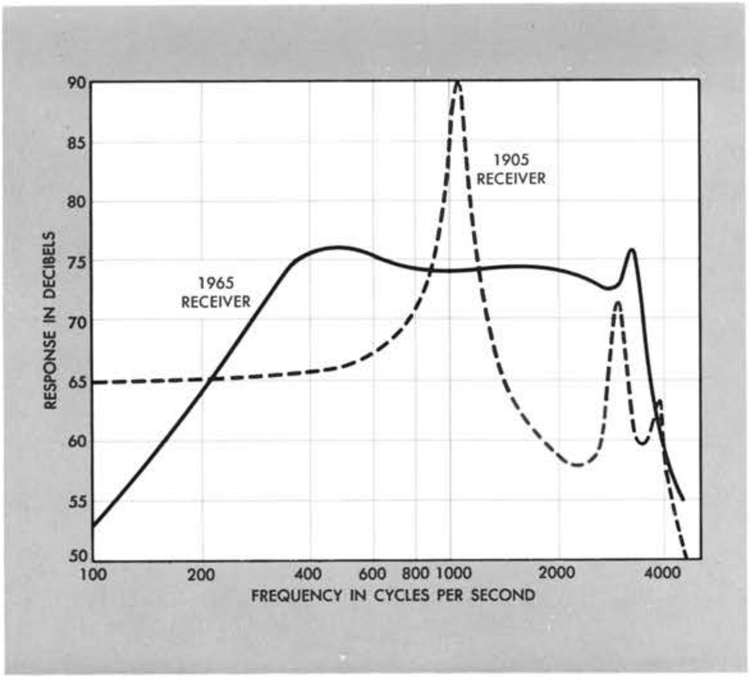
For example, three field trials greatly affected the final design of the TOUCH-TONE® dial. The button-operated frequency switches were found to be somewhat inaccessible on the first two models. Since these switches require final "touch-up" adjustments during manufacture and maintenance, they were moved to the periphery of the dial where they are more accessible to the craftsman.

To insure clearance between the pushbuttons and the faceplate of the TOUCH-TONE set, the original market trial models incorporated alignment pins between the faceplate and the rest of the dial. These pins were often broken by normal customer use, causing the faceplate to interfere with the buttons. Plastic collars around each button now reinforce their alignment, solving the problem (see photograph at right above).

A third change resulted from field trials of normal customer use. The emphasis in early pushbutton dial designs was to minimize the force required to push the buttons. However, the field trials showed that dialing errors were often caused by the caller inadvertently pushing adjacent buttons. Increasing the operating force for the buttons has reduced this type of dialing error.

Field trials often show how well new materials in an old component will perform under conditions of customer use. The new plastics, alloys, and magnetic materials that are always being developed at Bell Laboratories and elsewhere are con-

The dumbbell shape of the 1905 receiver was dictated by the long bar magnet required to produce an adequate signal. Technological advances have resulted in the LB1 receiver for the TRIMLINE handset. This unit is only 1/18 as heavy and 1/8 as high as the 1905 model.



For quality reproduction of the human voice, a telephone receiver must exhibit good frequency response across a bandwidth of about 3200 cycles, from 200 to 3400 cps. The intensity of normal conversation heard at a distance of three feet is about 60 to 70db.

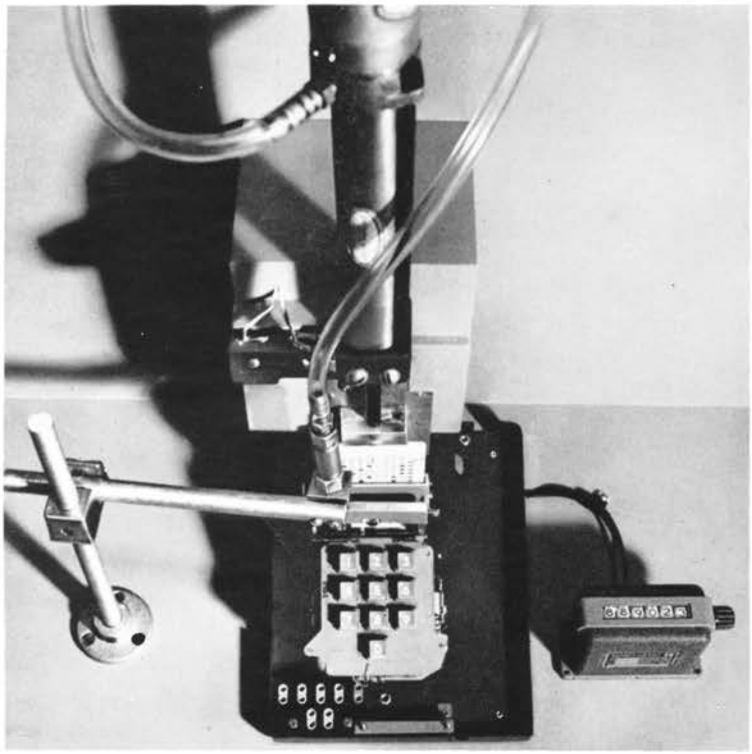
stantly tested in the search for ways to make better telephone components. The telephone receiver illustrates rather dramatically the improved designs made possible by new materials. In early telephones the receiver was a large dumbbell shaped instrument because a long magnet was needed to compensate for the poor magnetic materials then available. The receiver evolved eventually into the U1 receiver, designed with excellent acoustic characteristics for the 500 set. However, the ring magnet in the U1 unit was still too large and heavy for the TRIMLINE handset, where every effort was made to reduce size and weight.

Technical advances have resulted in a new unit, coded the LB1 receiver, for the TRIMLINE handset. This design features a simple bar magnet in conjunction with a small magnetic armature attached to the center of a new light-weight aluminum diaphragm. The LB1 receiver is one-third the weight of the U1 unit and provides equivalent performance. The contrast between the LB1 receiver and the 1905 receiver is of course even more pronounced: a reduction to 1/18 the original weight and 1/8 the original height (see photograph on this page).

Just as dramatic as this change in external appearance, moreover, is the improved fidelity of the LB1 model. In spite of its small size, the LB1 transmits a much wider effective bandwidth than the 1905 model. The overall output level has also increased (see graph above). These technical improvements mean clearer, more recognizable voice reproduction for the customer. Although the LB1 receiver was designed primarily for the TRIMLINE set, it will now serve as a possible replacement for virtually all receivers currently in service.

Beyond the more glamorous task of inventing better components are the equally important jobs of testing and, if necessary, modification. Before any component goes into production it must pass a battery of tests, which reveal its capabilities and limitations. Often a part can be modified after the tests to improve its performance, maintenance, or life characteristics. Sometimes a slight modification will make a component more economical to manufacture.

Life tests, measuring strength and durability, are an important part of evaluating new components. For example, conditions of normal use for transmitters and receivers are simulated by a test in which telephone handsets are repeatedly raised and dropped on the handset bases (see



In the life test for the Card Dialer mechanism a pneumatic plunger simulates actual use by repeatedly inserting a 10 digit dialing card up to 200,000 times. The counter on the right registers ten digits per cycle and shows the total number of digits dialed.

photograph on page 34). Periodic tests during the trials reveal any changes in the transmission characteristics of the instruments. Only if the components perform successfully after many simulated years of use is the design accepted.

To simulate normal use in the life testing of a telephone dial, a machine continually winds up the dial and allows it to run down well over one million times (see photograph at left on page 36). If any abnormal wear or faulty operation is observed during the test, the design is modified until the defect is corrected. Other tests simulate abuse such as "snap wind-up" and "forced run-down." The former sometimes occurs when the caller uses a pencil or some other dialing tool and violently snaps the dial against the stop in winding it up. Forced run-down occurs if the customer tries to force the dial to return faster than normal, thereby subjecting the governor to excess wear and strain. Although life testing for these two abuses is shorter than the test for normal use, the dial still undergoes many thousands of operations.

Environmental tests also vary with the type of component. When the material of a standard part is changed, additional tests are usually required to evaluate the new model. For example, several new plastics now used for gears and bearings in recent dial designs have permitted size and weight reductions, but they have also required more elaborate durability and environmental tests. When dial mechanisms were made entirely of metal, the effects of temperature and humidity were not significant. But plastics are less stable in temperature and humidity extremes. Environmental tests now conducted at the Indianapolis Laboratory simulate the sub-zero cold of Alaska, the extreme heat of the southwestern desert, and both the heat and high humidity of the Gulf States. When these tests reveal difficulties in the use of a new material, materials experts help find a way to overcome the problem or suggest a substitute material.

The problems presented by the diverse environments in which the telephones must operate are not only mechanical, however. Temperature and humidity extremes also adversely affect the magnetic and electrical properties of some materials. The components of the solid state oscillator circuit in the TOUCH-TONE pushbutton dial, for example, must be highly stable, because the frequencies generated by this circuit (not the conventional dial pulses) signal the central office. One of the elements in this circuit is a powdered ferrite core transformer. Tests of the original transformer in the environmental chamber revealed larger inductance variations than could be tolerated under all temperature conditions. Since then improvements in the transformer have made it suitable for any environment it will encounter. Bell Laboratories engineers at the Allentown Laboratory (ferrite devices), the Merrimack Valley Laboratory (transformers), and the Indianapolis Laboratory (dials) coordinated efforts to solve this particular problem.

The search for ways to use new materials in better telephone components continues at Indianapolis. By improving components in existing Bell System telephones and by developing and testing new components that will lead to the telephone sets of the future, Bell Laboratories plays an important role in station apparatus design.