Growing Quartz Crystals

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Of all the minerals on earth, quartz is the most common. Despite its general abundance, however, large, single crystals of near perfect form are quite rare in nature. Since these large crystals are extensively used in making oscillator elements and other communications components, the available supply may be inadequate to meet increasing demands. Experiments have therefore been made to investigate possible industrial production of artificial quartz crystals. The successful results of these experiments may make commercial production of such crystals feasible.

For more than 100 years, physical chemists and geologists have attempted to duplicate nature by growing quartz crystals in the laboratory. The first successful attempt, however, was made by Giorgio Spezia in Italy. In 1908, Spezia grew a quartz crystal about two-tenths of an inch long. This classic experiment first proved that it was possible to produce crystalline quartz artificially even though it required six months to grow one tiny crystal.

In the photograph at the top of the page, A. C. Walker (right) and A. J. Caporaso remove thermocouple wires from an autoclave in which quartz crystals have been grown.

Results of these early experiments were, of course, interesting to scientists although there was little commercial use for either natural or synthetic quartz. It was known that these crystals could convert mechanical to electrical energy and conversely convert electrical to mechanical energy, but no extensive applications of these piezoelectric properties were made until after World War I. As the communications industry expanded and new circuits and apparatus were developed, however, the uses of piezoelectric crystal plates in oscillators and filters increased rapidly. Most of these plates were made from natural quartz mined in

Fig. 1 — The author examining artificially grown quartz crystals.

Brazil, and this is still the principal source of these crystals.

As the need for piezoelectric materials increased, crystals other than quartz were investigated. In 1924, for example, A. M. Nicholson of Bell Telephone Laboratories obtained patents on the use of Rochelle Salts as piezoelectric crystals for oscillator control. During World War II, Bell Laboratories also developed ADP (ammonium dihydrogen phosphate) for use in sonar and in other military applications. These materials, however, did not provide a satisfactory over-all substitute for quartz.

The uncertainties of obtaining an adequate supply of natural quartz from Brazil to meet the constantly expanding needs of the military and the communications industry, coupled with the fact that large perfect quartz crystals are relatively rare in nature, made it desirable to discover a means of obtaining adequate piezoelectric crystals for these applications from some other source.

One result of this search was the development of a substitute for quartz called EDT (ethylene diamine tartrate). These water-soluble piezoelectric crystals were manufactured commercially and put into limited use in the Bell System at the end of World War II. Circuits from New York to St. Louis operating with EDT crystal units, for example, were put into service much earlier than would have been possible if these new crystals had not been developed. Quartz itself has some important properties, however, which have not been duplicated in any other piezoelectric materials. The most important of these is that it has an essentially constant frequency response over a relatively wide temperature range. Attempts were therefore made to try to find additional sources of quartz crystals.

At the end of World War II, it was learned that some work had been done in

Germany indicating that it might be possible to manufacture quartz crystals synthetically on a commercial scale. Bell Telephone Laboratories therefore instigated a program to develop the technique of producing these crystals. It was hoped that knowledge might be gained that would make the commercial production of quartz crystals feasible. As shown by Figure 1, large well-formed crystals have been obtained that are far superior to any grown by earlier investigators in the field.

Some of the successful attempts to grow quartz crystals by early investigators were made in autoclaves maintained near the critical point of water — the pressure (3,200 pounds per square inch) and temperature (374.2 degrees C) at which water and steam exist in equal densities in a fixed volume. A small seed crystal was suspended near the top of an autoclave and a supply of nutrient material consisting of broken bits of amorphous quartz placed at the bottom. About 30 per cent of the free space within the autoclave at room temperature was then filled with a weak alkaline solution of about 0.5 per cent sodium bicarbonate in water. The container was heated to 374 degrees C and kept at a substantially constant temperature during the growing period. Since amorphous quartz is about ten times more soluble than crystalline quartz in this hot alkaline solution, the solution is about 1,000 per cent super-saturated with respect to the crystalline phase, and hence the dissolved amorphous material deposits out on the seed crystal.

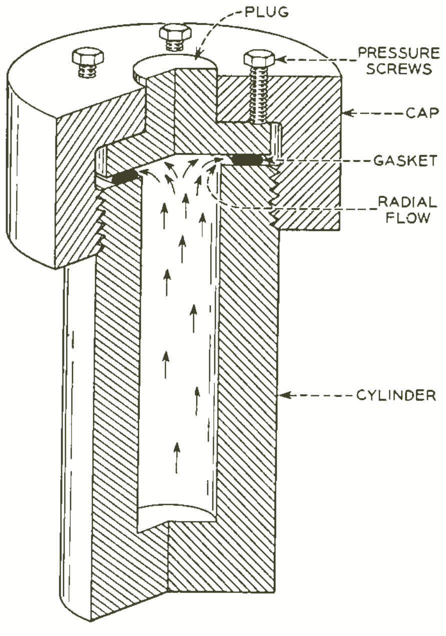

Fig. 2 — Cross section of an autoclave used in early attempts to grow quartz crystals.

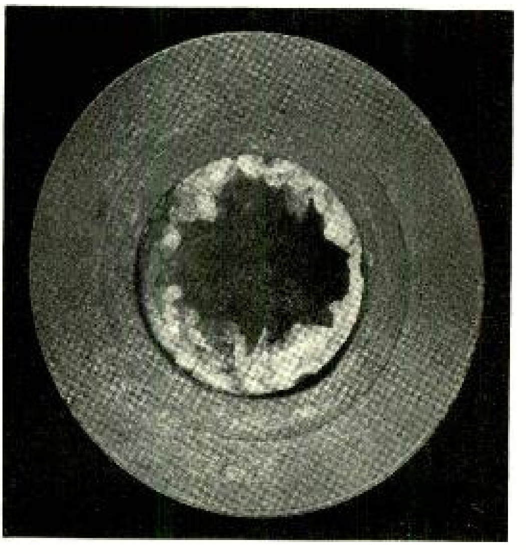

Fig. 3 — Section of an autoclave that leaked during a crystal growing run showing spurious quartz crystals adhering to inner walls.

An evaluation of this process showed that, although a rapid crystal growth was possible during the first few hours of operation, after about eight hours it practically stopped; the growth rate diminished to less than 0.001 inch per day. This seems to be due to the fact that, as the solution becomes more saturated, the dissolved quartz is no longer carried to the neighborhood of the seed but deposits out in the crystalline phase on the amorphous nutrient. As a result, the nutrient is prevented from further appreciable dissolution and seed growth practically ceases.

Subsequent studies indicated that there are a number of factors affecting the crystal growth rate, including the position of the seed crystal in the autoclave, the size of the nutrient aggregate, the concentration of the solvent, the temperature of the solution, the temperature gradient within it, the pressure, and the density of the solution. It was found that an appreciably improved growth rate could be attained by greatly increasing this last factor through an increase in the operating temperature and pressure. Subsequent experiments were therefore directed toward finding a means of operating at higher temperatures and pressures than had previously been used. A modified technique based on these principles has yielded growth rates of from 0.05 to 0.10 inch per day, resulting in quartz crystals weighing more than a pound grown in the brief period of 80 days. Nearly perfect crystals of this size are potentially valuable as oscillator plates in the communications industry, and their occurrence in nature is quite rare.

In this new method, temperatures of the order of 400 degrees C and pressures of about 15,000 pounds per square inch were used. The nutrient consisted of broken bits of crystalline rather than amorphous quartz, and the solvent was a 10 per cent solution of sodium bicarbonate or sodium hydroxide in water filling 80 per cent of the free space in the container at room temperature. The assembly was put on a hot plate and enclosed in a well-insulated oven, and as the autoclave was heated, a natural temperature gradient developed within it, ranging from about 400 degree C at the bottom to about 380 degrees C at the top. The broken quartz at the bottom of the container dissolved very rapidly in the hot alkaline solution, forming a strong sodium silicate solution substantially saturated with silica at 400 degrees C. Due to the temperature gradient within the autoclave, strong convection currents were established in the solution. These quickly transported the dissolved silica to the slightly cooler region in the vicinity of the seed where the solution became supersaturated with respect to silica. This basically important condition is necessary for crystal growth since only then does the silica deposit out of the solution and onto the seed in satisfactory quantities.

The convection currents present in the solution kept the liquid in continuous motion so that the growing surfaces on the seed were constantly bathed in fresh supersaturated liquid and the partially depleted solution was carried down to the bottom where it was again supersaturated in the high temperature region. This process occurred sufficiently rapidly to transport surprisingly large amounts of silica and the flow across the growing surfaces was uniform enough to produce clear crystal growth.

Early crystal growing experiments were performed in the simplest type containers, such as that illustrated in Figure 2. The pressure exerted in this type autoclave is due to the expansion of the solution with increasing temperature. If a safe pressure limit is exceeded the metallic gasket flows radially and leaks develop. These autoclaves have been operated at pressures up to 15,000 pounds per square inch at room temperature, but at 400 degrees C the safe working limit is about 5,000 pounds

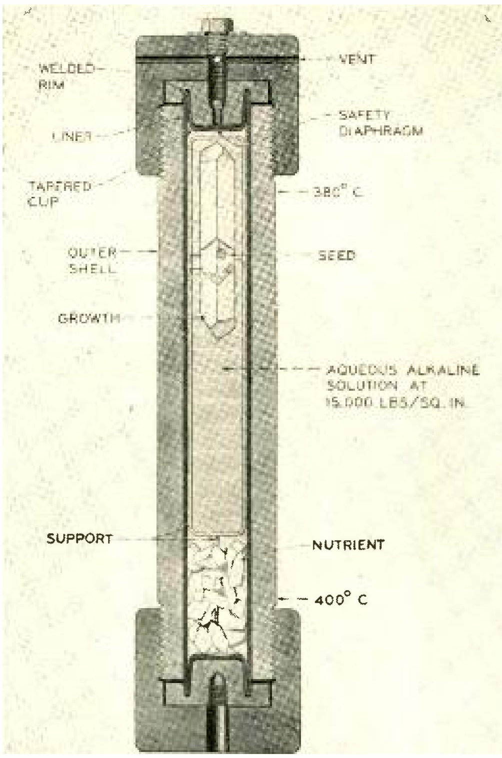

Fig. 4 – Cross section of an autoclave used in successful crystal growing experiments.

per square inch. This reduction is brought about by the unequal thermal expansion of the various parts that permits a radial flow, and hence leakage around the plug. Since the new method of growing quartz crystals, developed at Bell Telephone Laboratories, involved both a pressure of 15,000 pounds per square inch and a temperature of 400 degrees C, these simple containers could not be used.

A number of other high-pressure autoclaves of recent design were tried. It was found, however, that any containers depending upon a metallic gasket for a seal were impractical for use in this experimental work. Such gaskets are very difficult to keep tight if even slight imperfections develop in the seal. If the slightest leak exists, a condition develops like that illustrated in Figure 3. This illustration of a section of a bomb that leaked shows an uncontrolled growth of a great many small quartz crystals adhering to the wall of the container. Since minute leaks can occur in any type autoclave, this condition is frequently encountered. Cleaning such tiny crystals from the wall of a standard container is extremely difficult. It is equally difficult to dismantle any gasketed assembly without injuring it after such precipitation. Because of the close machine tolerances required, and the danger of seizure of the threaded members if they become caked with precipitated silica, the standard available autoclaves were considered inadequate. Since available containers could not be operated satisfactorily under the necessary conditions, the entire process of growing quartz crystals hinged on the successful development of an adequate new container.

To overcome the difficulties encountered with standard containers, the author in collaboration with other members of Bell Telephone Laboratories staff, including A. C. Walker, G. T. Kohman, C. N. Hickman and L. E. Abbott, developed a new autoclave design. A cross section of this bomb, which can be compared in principle to a straightened length of automobile tire, is illustrated in Figure 4. The closed and expendable member of the assembly – the inner tube – consisted of a seamless, relatively cheap, mild steel liner, the ends of which were closed by welding-in preformed tapered steel cups. This liner was encased in a heavy-walled supporting cylinder capped at either end by retaining members – the outer shoe of the tire. Under the influence of internal pressure, the liner stretched until it was supported at all points by the heavier outer members.

Fig. 5 – Loading seed-crystal plates into the inner liner of an autoclave.

After a crystal growing run was completed, the outer caps were removed and the exposed ends of the inner liner sawed off. This left an open cylinder from which the reagents, crystals, and supports could be removed easily. After the container had been emptied, a saw cut was made down the length of the liner to relieve the residual stress in the cylinder produced in the cooling process, and the liner dropped out. The tube was then discarded, but the outer casing was used repeatedly. In actual practice, a sheath of aluminum or cop-

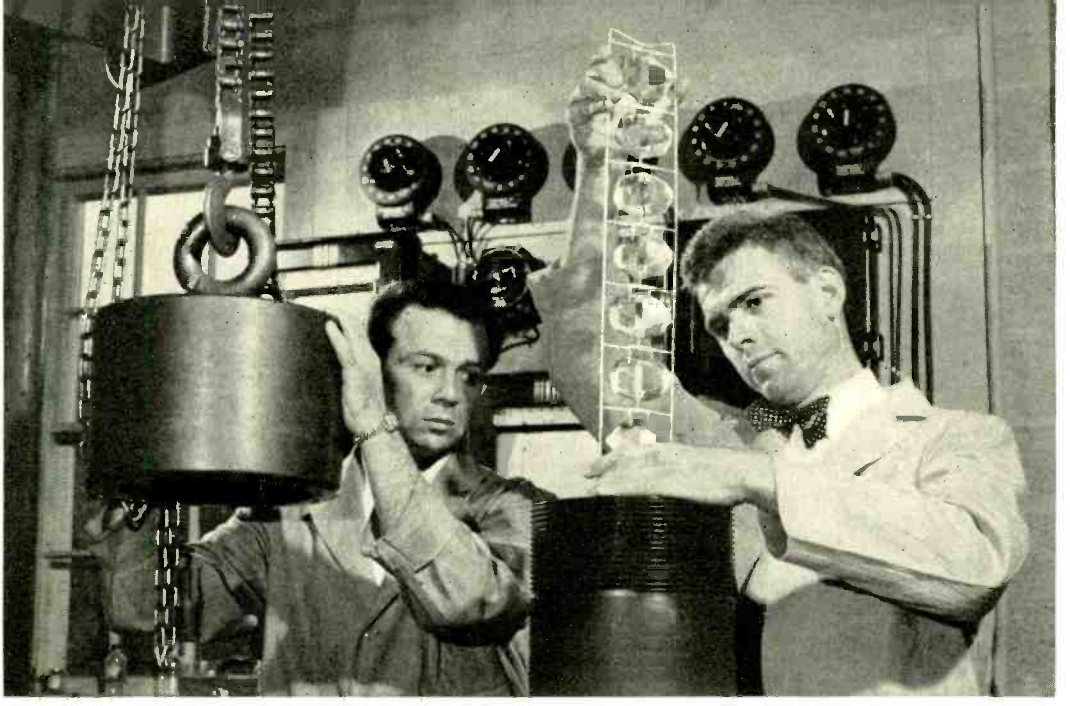

Fig. 6 — The author and A. J. Caporaso (left) removing a group of crystals from an autoclave.

per was inserted between the liner and the outer wall to protect the casing when the cut was made to remove the inner member.

Autoclaves of the type described have been made in sizes ranging from two to nine inches in outside diameter and from one to four feet in length. Stainless steel, manganese steel, chromium and molybdenum alloy steels, and even mild steel have been used in the construction of the outer shell and some of these units have been in almost constant operation for a period of several years.

As an interesting side-light, this work has made geologists question existing theories concerning the formation of quartz in nature. For many years it was believed that natural quartz was formed over long periods of geologic time. The results of these experiments indicate that it may actually have been formed in a short time.

The autoclave and the method described in this article have not only provided a means of growing large quartz crystals artificially — long a geologist's dream — but they also show that the process may soon be economically valuable.

THE AUTHOR: A member of the Laboratories' Chemical Research Department, ERNEST BUEHLER has spent the last eight years growing experimental crystals, studying the effects of heat treatment, growth rate, and mixing, upon their physical and electrical properties, as well as the segregation characteristics of various impurities within the crystals. Mr. Buehler joined the Laboratories in 1930 as a shop apprentice, becoming later an instrument maker. In 1941 he joined the shop planning group at Whippany, later transferring to the same group at Murray Hill. He was associated with David Kahn and Company before coming to the Laboratories, and has attended Brooklyn Polytechnic Institute and Newark College of Engineering.

A New Test Chamber at Murray Hill

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Electronic equipment is frequently required to operate under ambient temperature and humidity conditions far different from those ordinarily encountered. To insure that the equipment will function reliably under all conditions likely to occur anywhere in the world both at ground level and at very high altitudes, special test chambers provide means for simulating such conditions.

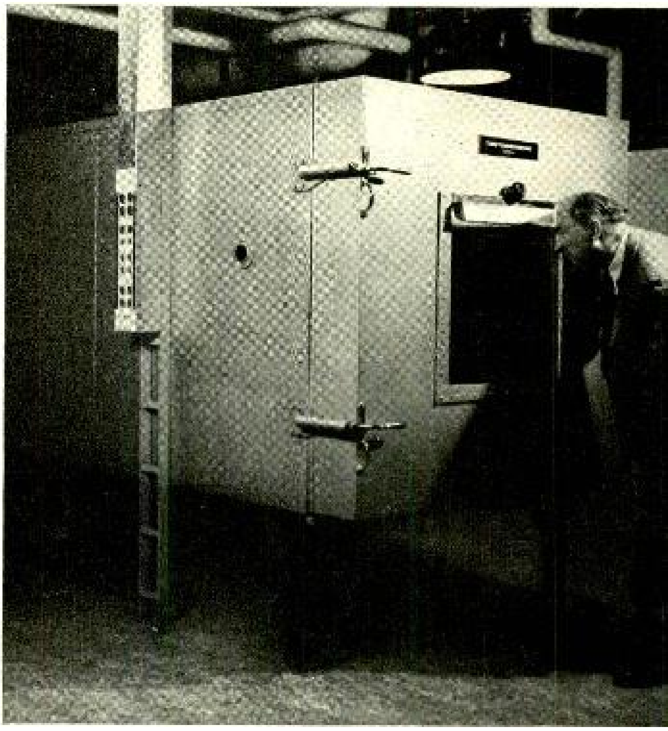


Fig. 1 — The new test chamber at Murray Hill.

Man has always been pushing back some frontier to an unprecedented point. Every new geographic or climatic frontier under his attack requires reference to associated scientific frontiers to obtain additional facts which may help him in his new endeavor. Global exploration and global defense subject man, together with his machines and his equipment, to adversities of temperature and humidity which are astounding and extreme. Authenticated world temperature extremes at ground level range from —90° F measured at Verkhoyansk, Siberia, to +136° F in Libya. World precipitation extremes range between 426 inches of annual rainfall at Cherrapunji, India, to a fall too slight to measure in parts of Egypt and the Sudan. In the United States alone, the temperature range is between —66° F in Wyoming and +134° F in Death Valley. Nevada is our driest state with an annual rainfall of 8.8 inches and Louisiana is our wettest state with an annual rainfall of 55.1 inches. The average annual rainfall for the United States is 29 inches. These extremes were all measured at ground level. If jet plane and guided missile altitudes were included, the temperature extremes that are involved would be enormously broadened.

This thumbnail sketch of world temperature and humidity conditions points up the engineering obstacles involved in the design of mechanical and electronic equipment even for domestic use, and more especially for world-wide use in remote areas and at various altitudes. To assist in meeting this challenge a new test chamber, Figure 1, and an associated compressor assembly has recently been installed at Murray Hill. A basement location was chosen to avoid excessive noise and vibration in general working areas. The dimensions of the units are given in Table I.

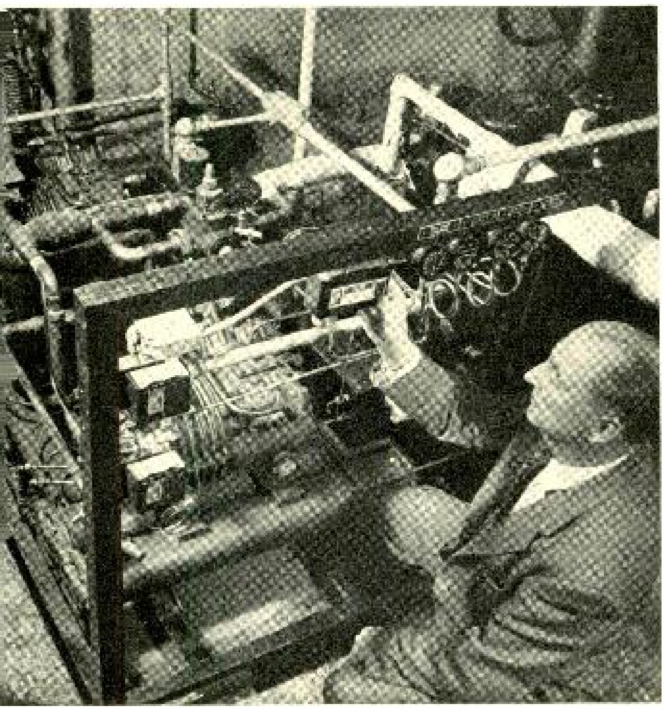


Fig. 2 – The refrigerating plant consists of a single 10 hp stage, at the right, and a secondary stage comprising two 3-hp units at the left. The author is checking the operation of the plant.

In addition to humidity control facilities, this test chamber is arranged to extend controlled temperature values in both directions from the ambient value. The increasing of temperatures is an ancient and common art, but the reduction of ambient temperature by artificial and controlled means is more recent. The refrigerant used in the new test chamber is Freon 22 (monochloro-difluoromethane) which boils at —43° F, at atmosphere pressure. For very reduced temperatures, a refrigerant, of course, can be subjected to a partial vacuum and with Freon 22 the boiling point is —110° F in a 26.6-inch vacuum; this is more than adequate to effect the design temperature of —80° F in the test chamber.

The compressor system, Figure 2, used in effecting reduced temperatures in the new test chamber is a two-stage unit. The primary stage is a twin cylinder compressor, belt driven by a 10-hp motor. The secondary stage comprises two 3-hp hermetic units operating in parallel. A hermetic unit is a sealed chamber housing both the compressor and the driving motor. The secondary stage may be used alone when the desired cooling effect falls within the capabilities of only this stage. When the full capacity of the two secondary compressors is exceeded, the primary unit may also be run to realize the full capability of the assembly. The large amount of power required to drive the compressors is occasioned by the need for unusual speed in reaching the minimum design temperature. The three compressor assemblies together with their condensers and some of their controls are mounted on a welded steel framework.

The test chamber is mounted on a welded steel framework apart from the compressor units, with only the suction and feed pipes connecting the units. These pipes are provided with flexible vibration reducing sections. The insulation in the test chamber is glass wool, compressed to a 9 pounds per cubic foot density, and installed to a thickness of about one foot on five sides of the chamber. The door is eight inches

TABLE I—DIMENSIONS OF TEST CHAMBER AT MURRAY HILL

Unit	*Width (feet)*	*Depth (feet)*	*Height (feet)*	*Volume (cu. ft.)*
Inner chamber	3	4	3	36
Over-all chamber	5	8½	6¼*	
Compressor assembly	6¼	6¼	4	

* Including Legs.

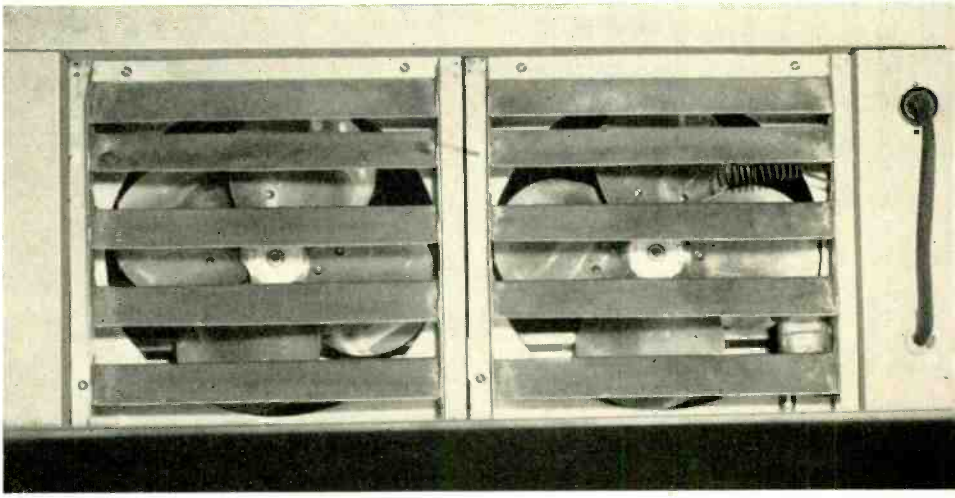


Fig. 3 — An interior view of the test chamber showing the two circulating fans at the rear.

thick. The work space in the chamber is lined with stainless steel which is seamed and soldered at all joints to provide a positive vaporproof barrier between the chamber and the insulation. The exterior surface of the insulation is also covered with a vapor barrier of asphalt to prevent moisture from penetrating the insulation from the outside and increasing its heat transfer coefficient.

Fig. 4 — A Bristol recorder and a control unit are mounted on one side of the test chamber. K. J. Ogaard is shown.

Drains are provided at the bottom of the chamber for dissipating water droplets from the test space and for emptying the humidifier pan. A gutter along the lower edge of the door aperture catches any drip from the work space when the door is open. Light for the test chamber is supplied by a fixture mounted on the exterior of the door above the multi-pane inspection port. To prevent excessive heat transmission through the inspection port, this section is made of seven parallel panes of plate glass, with air separation between adjacent panes. The inner pane of glass is specially treated to withstand the extremes of temperature without fracture. A manual windshield wiper is provided for clearing the glass on the inside when fogging occurs.

The working space in the chamber is provided with an adjustable shelf to secure the maximum use of the space when a number of small assemblies are to be tested. The air within the test chamber is circulated by two fans, Figure 3, located in a conditioning compartment at the rear of the work space. Special fan lubrication is provided so that bearings operate satisfactorily between —80° F and +200° F.

A Bristol controller and recorder for detecting the wet and dry bulb changes within the chamber together with associated relays for automatically controlling the condition chosen by the operation of certain switches are mounted on one side of the chamber as shown in Figure 4. The temperature detectors consist of thermometer bulbs located in the air stream at the rear of the work space. The wet bulb element is located close to a water pan, and includes a wick to keep its bulb moist.

Electric air heaters inside the chamber are used for raising the dry bulb temperature to the chosen control value. These heaters are Edison base nichrome cone element units with cleat receptacles. Six 1000-watt units are provided.

The humidifier is simply a water pan containing a bare copper coil for lowering the water temperature, and an electric immersion heater for increasing the water temperature.

The following performance is provided:

Temperature Range: —80° F to +200° F.

Relative Humidity: From 20% to 95% through a dry bulb temperature range between 35° F and 180° F.

Accuracy of Control: ±2° F for both the wet and dry bulb controls.

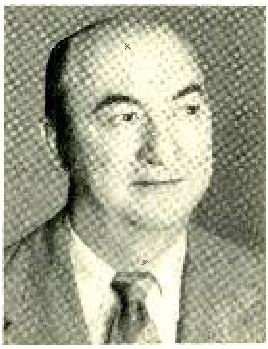
Rate of Temperature Reduction: From +80° F to —80° F in less than two hours.

Rate of Temperature Increase: From +80° F to +200° F in approximately one hour.

Heat Dissipation: 200 watts at —80° F or 500 watts at —60° F.

A trunking system is provided between the test chamber room and the power room on the fifth floor. Any test power available in the power room can be patched to the test chamber room, thus providing the same facilities as in any other laboratory. Also, transmission trunks are provided between the test chamber room and several laboratories in Building 2.

THE AUTHOR: Homer G. Jordan is engaged in the development of Type-N and Type-O carrier terminals in the Transmission Systems Development Department. Mr. Jordan joined Western Electric Company at Hawthorne in 1920, transferred to Kearny, and later to American Telephone and Telegraph Company before becoming a member of the Laboratories in 1934. From 1921 to 1931 he was concerned with engineering of central office equipment, mostly in a supervisory capacity. For the next ten years he was occupied with voice frequency and carrier transmission regulation and carrier system development. During World War II he was engaged in the development of special transmission systems for the armed forces, vacuum tube testing procedures and air-laid telephone wire. Since then he has been occupied with the development of power line carrier, radio control terminals for transatlantic radio and Type-N carrier order-wire and alarm systems. Mr. Jordan attended Northwestern University from 1919 to 1921 and Purdue University from 1921-1922.



N1 Carrier: System Equalization and Regulation

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J. B. Evans checks the repeater output.

An essential requirement of any carrier system is that all the frequencies be transmitted with equal attenuation. This is the problem of equalization. A standard method of solving it is to attenuate the stronger signals to match the weakest signals. In addition, automatic regulators are employed to erase those aberrations resulting from temperature fluctuations or inherent manufacturing variations. For the N-1 carrier system, a new method of equalization has been developed, as well as a more efficient regulator, as a step toward improved performance.

One of the difficulties in designing any new carrier system is to insure that all frequencies are transmitted with equal attenuation. This is usually accomplished by employing fixed equalization and dynamic regulation. The former corrects for the average transmission losses, while the latter corrects for manufacturing variations and for the effects of temperature changes.

Equalization for the N1 carrier system has been accomplished without the use of the "basic equalizer," usually employed in carrier systems. The "basic" method of equalization uses, at the input of each repeater, a network that attenuates the stronger signals so that all frequencies arrive at the input to the amplifier at the level of the weakest signal. All frequencies are then amplified by flat gain amplifiers.

Although the Type-N system also uses flat gain amplifiers, it accomplishes the required equalization by "frequency frogging"* without reducing the level of the stronger signals. With such a system the frequency at which the twelve-channel group is transmitted is alternated from high to low or *vice versa* over successive repeater sections. This change from one transmitting frequency band to another is accomplished by modulation at each repeater. Thus over one repeater section the low-group band from 44 kc to 140 kc is used for transmission, while over the next section the high group band from 164 kc to 260 kc is used. Along with this shifting of the entire twelve-channel group, there is an associated reversal of the numbered

* Record, *July*, 1952, *page*, 277.

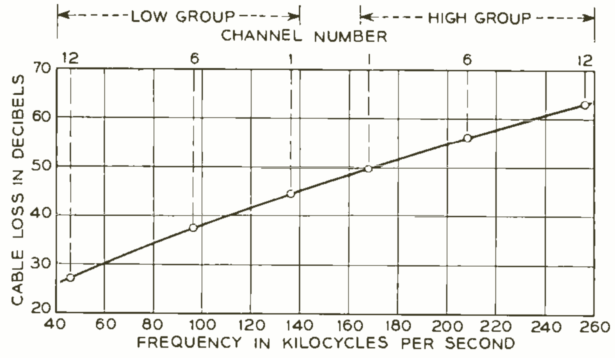


Fig. 1 – Typical repeater section loss characteristic.

channels within a group. Channels 1 to 12 are arranged in order of increasing frequency in the high group and in order of decreasing frequency in the low group; thus, in the low group, Channel 12 has the lowest frequency and loss and Channel 1, the highest. In the high group, on the other hand, Channel 1 has the lowest frequency and loss and Channel 12 the highest. By these means, the over-all loss through two successive repeater sections for any channel is approximately the same, as illustrated by Figure 1 and Table I.

Since the gain of the repeaters is fixed at the amount needed for a maximum length section, the loss over shorter sec-

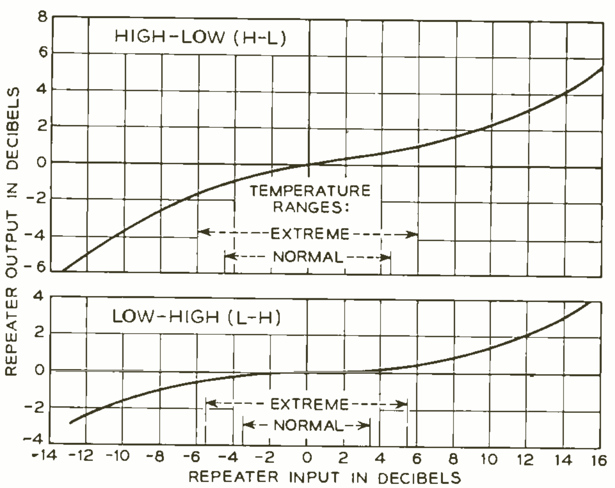


Fig. 2 – Regulation characteristics for the high-low and low-high repeaters.

tions must be "built-out" to equal that of a maximum section. The loss is composed primarily of "flat" loss and "slope" loss. The flat loss – which is the same for all frequencies – is supplied by attenuator or span pads, which are furnished in two db steps to 24 db. These pads make it possible to adjust the input to the repeater to within 1 db of the proper value. This small remainder is absorbed by the thermistor regulator, which will be described later.

Slope loss is the loss that varies with frequency. The slope loss required to build out a repeater section is generally supplied by the slope adjustment in the repeater, which can be set for 0, 2, or 4 db.

TABLE I—TRANSMISSION EQUALIZATION IN TWO REPEATER SECTIONS

Cable Loss	*Channel 1*	*Channel 6*	*Channel 12*
Low Group	—44.3	—36.9	—27.4
High Group	—49.8	—56.0	—63.0
	—94.1	—92.9	—90.4
Repeater Gain			
Low-High	+47.8	+47.1	+45.0
High-Low	+46.4	+46.2	+45.5
	+94.2	+93.3	+90.5
Residual Error	+ 0.1	+ 0.4	+ 0.1

Slope is defined by the relative gain of Channel 12 to Channel 1, and is negative when Channel 12 has less gain than Channel 1. The slope setting usually required for this building-out is —2 db in each repeater; however, variations in length or in cable capacitance may require adjustment of more or less than 2 db in some instances. At the time of line-up, the settings are adjusted to compensate for these variances of the cables and repeaters in the particular system. Where very short repeater sections are employed, section loss (flat and slope) is built out with artificial lines equal to 2 or 4 miles of standard cable.

This flexibility in the control of loss, makes the system easily adaptable to many kinds of cable, and, as is frequently found, to a mixture of different kinds of cable, even within a single repeater section.

Were it not for this easy method of transmission adjustments, unusual sections would require measurements and individual treatments.

The repeater is arranged to mount four units of either span pad or two-mile artificial line sections. Four-mile artificial lines are mounted externally. Although normally used at the input to the repeater, the units may be used at the output or at both input and output.

In addition to the flat loss and slope loss of a repeater section, there is also a "bulge" component. As explained in an earlier article,* the total line loss of a repeater section is not linear with respect to frequency, but may be segregated into three components, flat, slope, and bulge. The bulge loss is the difference between the total line loss and the sum of the flat loss and linear slope loss. It is of the same kind for each repeater section and does not cancel out in successive sections. This component adds to the curvature in the gain-frequency characteristic of the repeater, and both curvatures are removed by a network called a "deviation equalizer," which has been introduced at about fifty-mile intervals. Recent improvements in the repeaters have made it possible to increase this interval. The deviation equalizer is designed for average cable and repeater characteristics. Individual systems have a small departure from the average characteristic, which increases in proportion to system length.

This method of line equalization provides sufficient balancing of transmission so that systems up to nearly 200 miles are permissible before the departures from the normal transmission characteristic exceeds the ±5 db adjustment that is provided by the receiving terminal. With the improved repeaters, this distance is expected to be doubled. It also permits the repeater sections to be some 15 per cent longer for the same repeater gain than they could be if the earlier basic-equalizer schemes were used.

For regulation of the N1 carrier system, a thermistor regulator is used in each repeater. This regulator uses the same thermistor bead that is used in the K2 carrier system but, as will be described, in a more efficient manner.

The regulator is required to compensate for transmission changes produced in the repeaters and the cable. Line-up equalization is adjusted at a mean operating temperature, but when the system is operated at other temperatures, variations in transmission occur in both the cable and the repeaters. These transmission changes are mostly in flat gain or loss, and to correct for them the gain of the repeaters is varied so as to hold the output power of each repeater to a nearly constant value. This is +12 dbm for the L-H (low-high) repeater and +3 dbm for the H-L (high-low) repeater. The regulator responds to the power of the twelve channel-carrier frequencies; the voice signals contribute but little since their average power is so much less than that of the carriers.

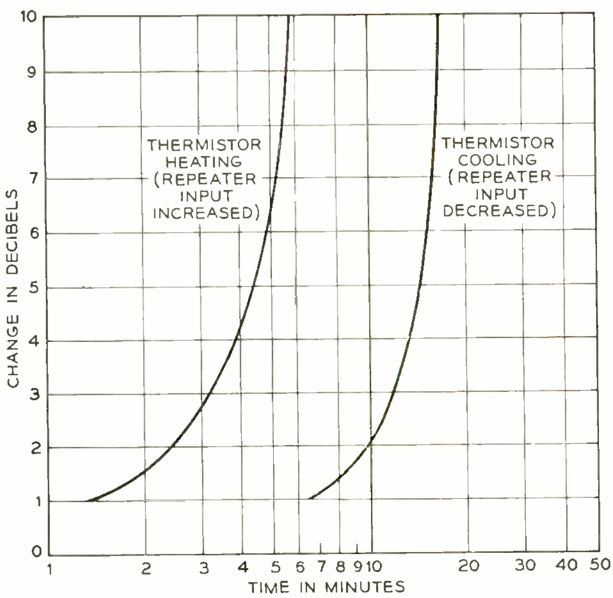


Fig. 3 — Heating and cooling characteristics of the thermistor beads used in the repeaters.

The regulator is in the feedback path of the repeater amplifier as part of a variable loss pad, and produces its regulating action by varying the feedback, and hence the amplifier gain. Regulation characteris-

* RECORD, *August*, 1952, *page*, 333.

Fig. 4 — E. H. Perkins (left) and J. B. Evans examine the modulator wiring of a repeater.

tics obtained for each type of repeater are shown in Figure 2. The regulation for the two types is somewhat different, that for the H-L repeater being slightly poorer. This condition results from the use of the same type of thermistor bead in both repeaters, with the H-L repeater having only one-eighth as much power to actuate it as the L-H repeater.

Operating temperatures usually considered as normal range from —15 degrees F to 110 degrees F. This range is indicated on the illustration. The regulating range is also indicated for temperatures between —30 degrees F and 130 degrees F, which are considered the extremes for general applications.

When several repeaters are used in tandem, the system regulation at the last repeater will be slightly poorer than at the first repeater. This is because each repeater does not regulate perfectly and there is thus a residue that is passed along from repeater to repeater. Within the range of the extreme temperatures considered, the effect is commercially negligible.

The thermistor bead in the regulator has a sufficiently long time constant so that it is not sensitive to short-time power changes such, for example, as the voice peaks. For long-time power changes, the heating time of the bead is only one-third as long as its cooling time. When the output is too high, therefore, the bead heats quickly and reduces the amplifier gain. When the output is too low, on the other hand, the bead cools slowly, and thus raises the gain more slowly. These characteristics affect the regulating time, as shown in Figure 3. For example, if the repeater output is increased by 2 db, the regulator will restore the output to within one-quarter db in two and one-half minutes, but if the input to the repeater is decreased by two db, it will take ten minutes to restore the output to within one-quarter db of its final value.

The thermistor is enclosed in an oven which uses an ambient control heater to keep the operating temperature of the bead, and hence the regulating action, unaffected by the repeater operating temperature. Adjustment of this control heater

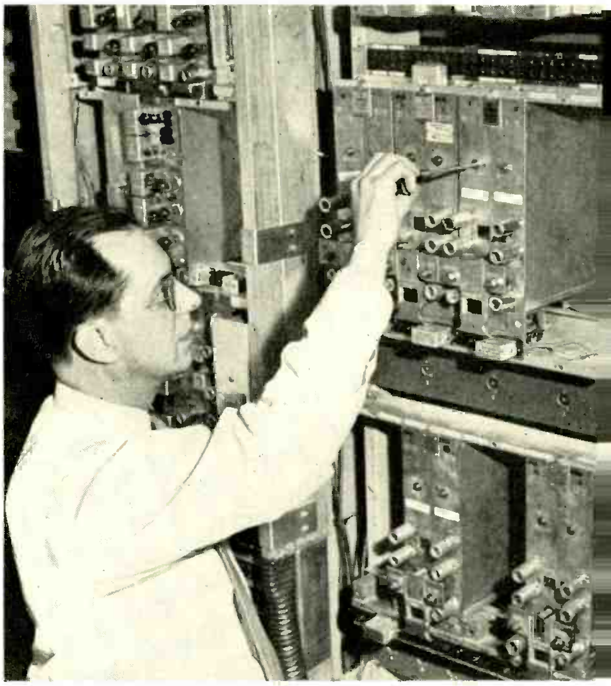


Fig. 5 — The author adjusts the repeater slope control in the laboratory test installation.

is different from that used in previous carrier systems and provides considerable improvement in the system regulation sensitivity. In the Type-K2 carrier system, the thermistor beads are set to operate at 190 degrees F, and the sensitivity of the most efficient bead is degraded by means of resistance padding to match that of the least efficient bead.

In the Type-N carrier system, the padding arrangement is avoided by adjusting the operating temperature of each bead to have the proper circuit response without padding. This is done by adjusting the ambient control heater so that the bead resistance is 8,860 ohms while dissipating one milliwatt of signal power. This adjustment provides operating temperatures of 190 degrees F for the poorest beads and as low as 135 degrees F for the most efficient beads. This lowered operating temperature materially extends the regulating range and increases the sensitivity in the most generally used center portion of the regulating characteristic. This type of adjustment is also appreciably cheaper than that employed for the K2 carrier thermistor, since the requirement for the individually designed padding circuit has been eliminated. Thus, the new design produces not only cheaper regulation, but one which exploits the best sensitivity of each bead while still providing system regulation having improved performance.

THE AUTHOR: Except for a four-year military absence, EDWIN H. PERKINS has been a member of the Laboratories since 1930. His work here has centered on the development of feedback amplifiers and regulating toll circuits for open wire and cable. Holder of a B.S. degree (1929) and an M.S. degree (1930) from M. I. T., Mr. Perkins is a member of the I.R.E., Kappa Eta Kappa, and the New York State Professional Engineers Society. While in the Air Matériel Command during World War II he was in charge of field installation and maintenance programs for electronics equipment including television, radio control, radio and radar countermeasures, and magnetic detection.

Color Television Tests

During March and April, a series of tests were conducted in which NTSC (National Television System Committee) color signals were transmitted over Bell System facilities. One set of tests used microwave facilities from New York to Washington where the signals were broadcast. In Washington, local loops were provided by both wire and radio. Other tests included a circuit from New York to Washington and return over both microwave and coaxial.

In demonstrations on April 14 for members of the House of Representatives Committee on Interstate and Foreign Commerce, and on April 16 for members of the NTSC and other guests, color signals broadcast by WNBT, New York were picked up in Princeton, N. J., and viewed on three color receivers. A short test was also made using Bell System facilities between New York and Princeton. These consisted of regular TD-2 facilities on the New York-Washington direct route as far as New Egypt, N. J., (second repeater south of New York) and then a one-section TE system to Princeton. Results observed over this path were judged to be about the same as signals received by direct broadcast.

In an FM system such as the TD-2 radio relay, the time required for a signal to travel from the transmitter to the receiver may vary slightly with the frequency of the signal and hence produce some distortion at the receiver. An experimental apparatus has been developed to provide an instantaneous picture of these distortion characteristics on the screen of a cathode ray tube. This information can be used in modifying circuits and apparatus to improve transmission quality.

The author (left) and H. A. Gorenflo measure the delay characteristics of an IF amplifier.

An Experimental Delay Distortion Scanner

W. J. ALBERSHEIM
Radio Research

Since a typical radio relay system such as the TD-2 operates by frequency modulation, it is less sensitive than an amplitude modulated system to transmission fading and the non-linear amplitude characteristics of amplifier tubes. An FM system, however, suffers from non-linear distortion and intermodulation if its overall envelope delay varies with frequency. This envelope delay is equal to the time required for a radio signal to travel from one end of a circuit to the other. The delay, in itself, does not produce a distortion if signals of various frequencies require the same time to traverse the length of the circuit. If the transit time varies with frequency, however, as it does in TD-2 type systems, some distortion will result.

To ensure high quality reception, this delay distortion, and hence the extreme difference in transit time over the entire 20-mc frequency band in each TD-2 channel, must be kept within predetermined limits. Since various elements in a system contribute to the delay distortion, it was necessary to devise a means for measuring not only the overall value, but also that introduced by various individual pieces of apparatus. After the delay characteristics have been determined, the apparatus can be modified or redesigned when necessary to reduce the amount of distortion introduced into the system.

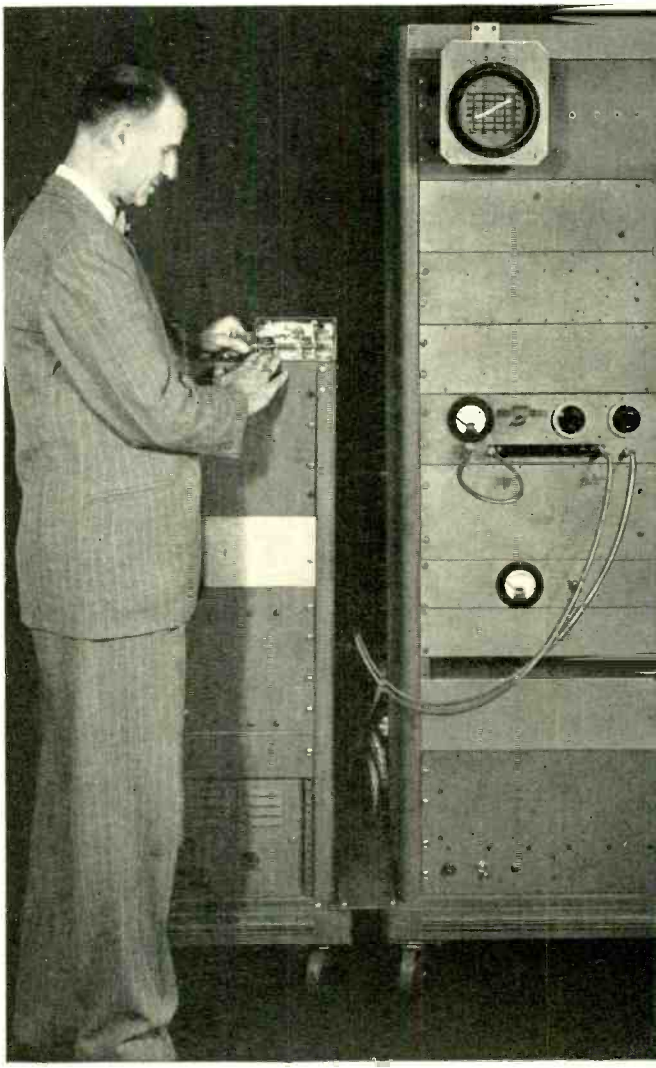
An experimental delay distortion scanner, developed by the author and L. E. Hunt, is illustrated in Figure 1. It provides a means of determining this distortion directly from a trace on the screen of a cathode ray tube. Mr. Hunt is shown using the apparatus to measure the delay characteristics of an equalizer, and the resulting trace can be seen on the screen near the top of the cabinet at the right of the photograph. A close-up view of the screen in Figure 2 shows two traces and a superimposed grid. In this application, the scanner is being used to compare the traces resulting from a standard equalizer and a similar unit with unknown delay characteristics. As shown in the figure, the vertical scale on the grid represents milli-microseconds of delay and the horizontal scale, frequency in megacycles.

Although the delay distortion is determined from the amplitude of a trace on the CRO tube, the operation of this experimental scanner is based on a comparison of the phase of two signals. The phases of the various frequencies in a complex signal bear a particular relationship to each other at the instant that signal leaves the transmitter and, if the transit times for the various frequencies are equal, the same phase relationship will exist at the receiver. If the transit times vary with frequency, however, this phase relationship will be changed in transmission. In this way, the overall delay distortion in a transmission system can be determined if it is possible to measure the relative change in phase of the various frequencies during transit from the transmitter to the receiver.

Prior to the development of this experimental scanner, measurements of envelope delay distortion were made over closed-loop circuits using a point-by-point method. In this technique, two signals with neighboring frequencies are transmitted over the closed-loop circuit and the difference in the amount of phase shift introduced to each is measured. Signals with frequencies of 60 and 61 mc, for example, may be transmitted, and the difference in the phase shifts noted at the receiver; half this value is approximately proportional to the envelope delay at a frequency of 60.5 mc. This process is then repeated with another pair of signals, 61 and 62 mc perhaps, and so on until the entire frequency band has been surveyed. The resulting phase shift values are then transformed to the corresponding envelope delays, and a plot is made of delay versus frequency. This method, however, is inadequate for use in the TD-2 system since amplitude compression in the radio circuit interferes with the transmission of two separate test frequencies. Moreover, point-by-point measurements require considerable time, and hence do not immediately show the effect of minor circuit adjustments. Due to the time consumed, measurements of this type over long circuits are also subject to errors caused by slow frequency drifts. In addition, tests that must be performed exclusively on loop circuits do not provide a means of indicating which part of the distortion is caused by the outgoing line and which by the return line.

The new experimental Delay Distortion Scanner is not subject to these limitations, and is capable of providing an instantaneous picture of the delay distortion characteristics in closed-loop or one-way

Fig. 1 – L. E. Hunt measuring the delay characteristics of an equalizer with a delay distortion scanner.



transmission systems. Envelope delay variations as small as one milli-microsecond can be measured over a range of several hundred milli-microseconds, and the operation is not affected by severe amplitude compression in any TD-2 transmission link. This apparatus is designed to measure the delay distortion characteristics in the 60- to 80-mc intermediate frequency band since that is common to all TD-2 channels while

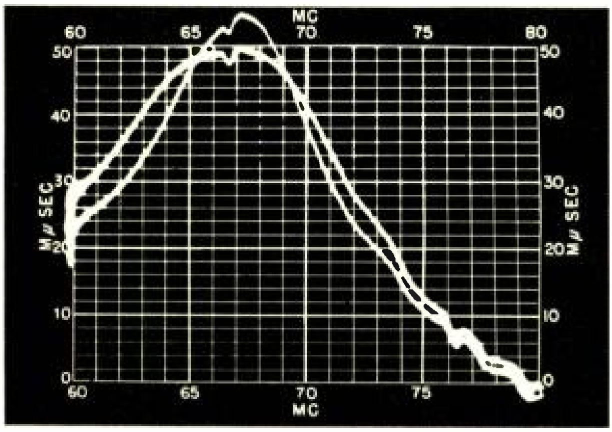


Fig. 2 — Superimposed traces on the screen of a CRO tube produced by a standard equalizer and a similar unit under test.

the microwave bands are spread over a range of 500 megacycles.

The experimental equipment used to make these delay distortion measurements consists of a sending unit placed at one terminal of the transmission circuit to be investigated and a receiving unit at the other. The components included in these units are indicated by the block diagram in Figure 3. At the sender unit, the output of a 60-cycle sawtooth oscillator is used to control the frequency of a 170 to 190-mc FM oscillator. The resulting output of this oscillator varies cyclically from 170 to 190 mc sixty times per second as shown in Figure 4. Simultaneously, a small amount of 200-kc signal from a stable crystal-oscillator in the sender is used to modulate the frequency of a 110-mc FM-oscillator. This modulated 110-mc signal is then combined with the 170 to 190-mc sawtooth signal in a converter and the resulting "beat" signal is a 60 to 80-mc sawtooth wave modulated by a 200 kc signal. The 60 to 80-mc wave at the output of the sender represents the TD-2 intermediate frequency carrier, and each frequency in this band is modulated by the stable 200-kc signal.

The modulated carrier forming the output of the sender unit is amplified and passed through the transmission circuit under test to an FM demodulator in the receiving unit. In the transmission circuit, the phase of the 200-kc signal is altered by the envelope delay variations; that is, the phase of the 200-kc signal varies with the frequency of the 60 to 80-mc carrier, indicating by the magnitude of these variations the amount of delay distortion introduced. Changes in transmission time with carrier frequency produce cyclic variations in the phase of the 200-kc signal — one cycle per sawtooth sweep — which can be applied to the screen of a CRO tube.

At the receiver unit, the signal from the unknown transmission circuit passes through an attenuator to an FM-demodulator containing an FM-receiver and a frequency separator, as shown in Figure 3. This separator isolates the 60-cycle sawtooth wave and the 200-kc modulating signal. The required envelope delay information is contained in the relative phase changes of the 200-kc signals associated with the various frequencies in the 60 to 80-mc band. This envelope delay information must be applied to the deflection plates of a CRO tube in such a way that the delay versus frequency characteristics of the transmission circuit being tested can be read directly.

To accomplish this, the phase variations are transformed to proportional amplitude variations indicating milli-microseconds of delay as shown by the traces in Figure 2. A uniform frequency scale, to indicate the frequency corresponding to a particular phase shift, is provided by amplifying the 60-cycle sawtooth wave from the frequency separator and applying it to the horizontal deflection plates of the CRO tube. The tube is biased in such a way that the minimum sawtooth voltage, corresponding to a 60-mc frequency, locates the horizontal trace at the left of the tube face, and the maximum voltage, corresponding to 80 mc, locates it at the right.

The phase variations in the 200-kc output of the frequency separator corresponding to the various frequencies in the carrier range are transformed to amplitude variations by vector addition of the modulated signal to a phase standard. This standard is synchronized with the 200-kc signal generated at the sender unit and is equally stable. If the unknown transmission circuit is a piece of local equipment or a closed-loop circuit, part of the output of the 200-kc crystal oscillator in the sender can be used as the phase standard. For long distance, one-way measurements, however, the arrangement illustrated in Figure 3 is used. In this application, the phase standard is regenerated at the receiver from the phase modulated 200-kc output of the frequency separator. This is done through a special filtering circuit that makes use of the fact that, with a constant scanning rate of 60 cps, the 200-kc phase-modulated signal becomes a periodic function consisting of a pure 200-kc sine-wave and of sidebands spaced at 60-cycle intervals from the fundamental frequency. A crystal band-pass filter of about 10-cycle band width is used to attenuate all these sidebands by more than 40 db, leaving in its output only the pure unmodulated signal for use as a standard.

At this point, as shown in Figure 3, the phase-modulated signal and the reference standard signal exist in separate branches of the receiver circuit. In the next step, they pass through phase adjustors that introduce a standard reference phase angle, θ – about 30 degrees – between the two. These signals are then amplified and their amplitudes adjusted to make that of the modulated signal equal to about 0.87 times that of the reference signal. They are then fed into a phase comparator where the instantaneous difference from the reference phase angle is transformed to a difference in amplitude. This process is illustrated diagrammatically in Figure 5. As shown, the length of the vector formed by the difference between the vectors representing the modulated and unmodulated signals, changes in proportion to the small changes

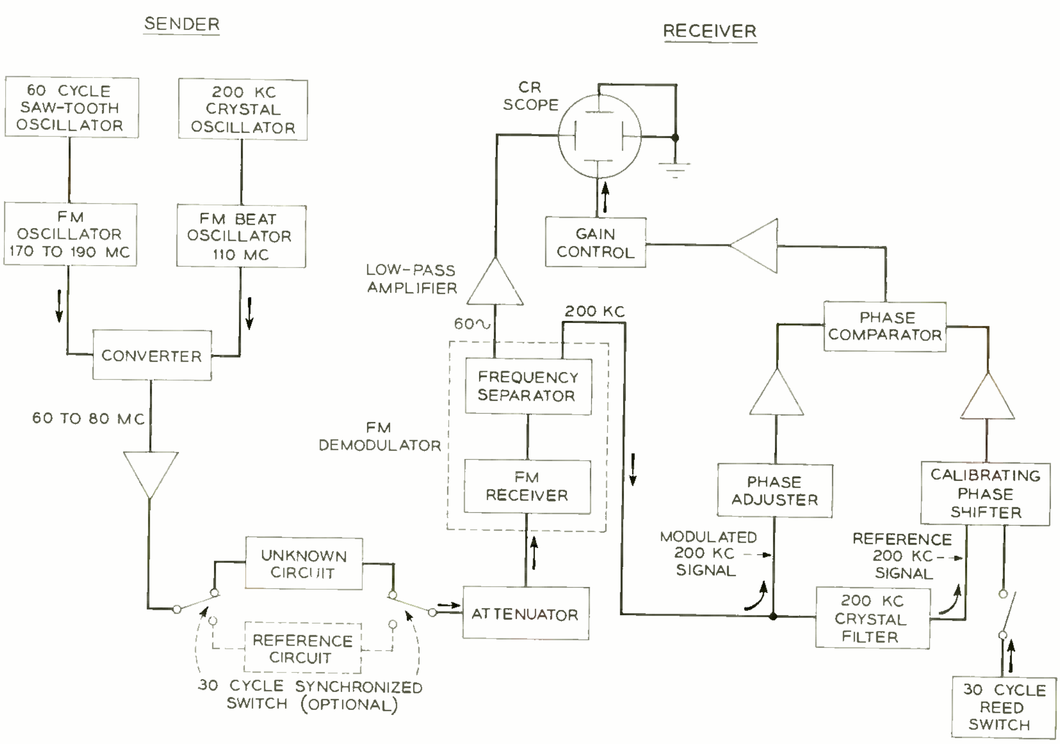


Fig. 3 – Block diagram showing the principal components in a delay distortion scanner.

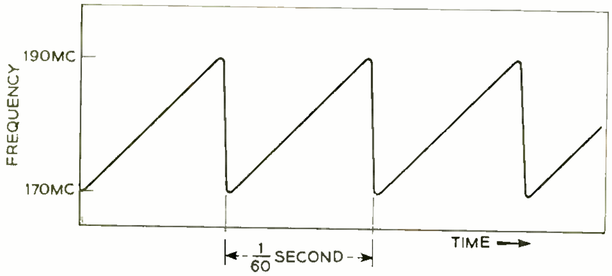


Fig. 4 — Method of sweeping the 20-mc TD-2 intermediate frequency carrier band.

in the total phase angle ($\theta \pm \delta$). The amplitude change in this vector is applied to the vertical deflection plates of the CRO tube through an amplifer and gain control and gives a measure of the envelope delay distortion produced by the intervening transmission circuit.

The vertical scale of the CRO tube is calibrated in milli-microseconds of delay by alternating the traces produced by a circuit introducing a known phase shift, and those produced by the reference standard through the 30-cycle reed switch indicated at the lower right of Figure 3. This known phase shift was set at 1.44 degrees and, since each milli-mocrosecond of delay in a 200-kc signal changes its phase by 0.072 degrees, the 1.44-degree shift corresponds to a delay of 20 milli-microseconds. The scale is then calibrated by setting the vertical gain control to give a one-inch separation between the traces produced by the 200-kc standard and that of the reference delay circuit. This results in a scale of 0.05 inches of vertical deflection per milli-microsecond of delay.

For measurements of lumped networks or of looped transmission circuits, the sending and receiving units of the scanner are located together, preferably in a single cabinet with a common power supply. For one-way measurements of long-line delay distortion, a complete set of scanner equipment can be provided at each end of the

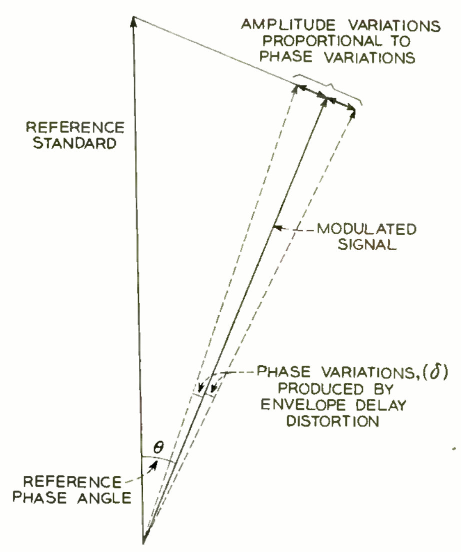


Fig. 5 — Vector diagram illustrating the method used to transform phase to amplitude variations.

THE AUTHOR: WALTER J. ALBERSHEIM came to the United States from Germany in 1924 and joined Electrical Research Products, Inc., in 1929, devoting the next eleven years to research in methods and design of sound recording apparatus before transferring to the Laboratories in 1940. He has since been engaged in research on microwave techniques, radar systems, FM theory, and the measurement and correction of delay distortion. His patents include more than three dozen, relating to vacuum tubes, radar and microwave circuits, sound recording systems, and various electrical measuring devices. Mr. Albersheim holds the following degrees from Aachen Institute of Technology: B.S., 1920; E.E., 1922; Eng. D., 1924; and has attended the Munich Institute of Technology. He is a senior member of the I.R.E., a member of the New York Academy of Science, and the Society of Motion Picture and Television Engineers.

line, but it is possible to obtain the one-way distortions in both directions in a two-way communication system by having a complete scanner at the near end of the line and only the relatively small, inexpensive sending unit at the far end. The separate sender serves to scan the delay distortion in the incoming direction, and the complete equipment, to scan the delay distortion in the loop. The outgoing distortion is then found by subtracting the incoming distortion from that of the loop.

This equipment can also be used for rapid testing or adjustment of factory-made delay lines and equalizers. In this application, a second synchronized 30-cycle switch (preferably electronic) shown at the lower left of Figure 3, is used to alternately trace the delay characteristics of a standard piece of equipment or reference circuit and the unknown circuit. These traces are compared, and the equipment under test adjusted until its trace matches that of the standard within prescribed limits. If the reference circuit has a zero delay, it supplies a base line, and absolute delays as well as delay distortions can be compared.

In addition to the applications described, the experimental delay distortion scanner can also be used as a sensitive detector for small impedance mismatches. In this application, a long spur line is connected to the transmission circuit and terminated by the equipment to be tested. Any mismatch at the end of the spur line produces echoes and hence sinusoidal variations in phase due to envelope delay. These delay variations can be detected by the scanner and minimized by adjusting the match between the unknown network and the line. Impedance mismatches of less than one per cent can be made plainly visible by this method.

An experimental scanner of the type described has been successfully employed to test the delay distortion in TD-2 and similar radio relay systems.

More Long Lines Services

Several additions to the Bell System have been announced recently by the Long Lines Department of the American Telephone and Telegraph Company, with others still in the planning stage. A new radio relay system is now operating between Pittsburgh and St. Louis, providing a second microwave route across the Midwest. The new microwave route interconnects with the transcontinental radio relay route at Pittsburgh, and with other nationwide facilities at St. Louis. The 600-mile system was installed to provide facilities for present and future communications requirements of this important industrial area.

A new microwave link constructed by the Bell Telephone Company of Pennsylvania and Long Lines has begun carrying network television programs to station WFBG-TV in Altoona, and three eastbound channels from Dayton to Columbus, Ohio, have also been equipped for network television transmission. The three new channels replace other facilities providing network service until now. An additional southbound television channel is now in service between Omaha and Dallas, and provides TV stations in and around Dallas with a third program source.

Little Rock, Arkansas, is now connected to the Bell System's nationwide communication facilities at Memphis by a 142-mile coaxial cable. This cable will supplement existing wire facilities and provide additional telephone service to this area. It can also be adapted for network television.

Erection work is under way on towers along the Chicago-Milwaukee-Minneapolis radio relay route, to provide microwave service out of Chicago. A radio relay route between Buffalo and Cleveland is in the planning stage, and a construction permit has been asked of the Federal Communications Commission. It will augment existing facilities and provide a link in a second radio relay route between New York and Chicago. Application for authority to construct a radio relay route between Atlanta and Jackson, Mississippi, has also been filed with the FCC.

A New Teletypewriter

W. J. ZENNER
Teletype Corporation

Trends in teletypewriter design have been directed principally towards reduced maintenance, increased speed of operation and reduction of noise. Steps in these directions have been made in a new model teletypewriter which contains several new features. One of these is a small type-box less than one-tenth the weight of the older carriage.

During the past twenty or more years the use of teletypewriters has grown to such an extent that more than 60,000 machines are now in operation in the Bell System. The Model 15 teletypewriter* was designed for general page teletypewriter service, and this machine has given very satisfactory service for a long time. Now, an improved machine, designated Model 28, has been developed by the Teletype Corporation for use in the Bell System. The new teletypewriter performs the same general functions as the present Model 15, but has many more capabilities than the older model. It is expected that, eventually, Model 28 will replace Model 15.

Increased speed of operation, of course, was one objective in developing the new model, but this was accompanied by several other objectives, all of which have been attained. The new machine is quieter in operation, is more pleasing in appearance, and operates with low maintenance at speeds up to 100 words per minute.

Of the several improvements in the new machine, the most obvious is the printing mechanism. The type pallets, instead of being mounted on bars in the conventional manner are carried in a small rectangular box about ½ inch thick, 1 inch wide and 2 inches long (Figure 1). The pallets are arranged in four horizontal rows, each row having a capacity of sixteen characters. To type a character, the type-box is moved to bring the desired character to the printing point, and a printing hammer, shown in Figure 3, operates to drive the type pallet against the typewriter ribbon and paper. Each pallet is provided with a return spring that restores the pallet to its normal position after printing. After the printing hammer has operated, the type-box returns to its initial position below the printed line on the paper, so that the typing becomes visible.

Characters in the left half of the box are letters; those in the right half are figures. A shift mechanism is used to change from

* RECORD, *October*, 1938, *page* 530.

letters to figures. Movement of the type-box, in selecting the desired character to be printed, is controlled by two index mechanisms, one controlling the vertical motion to select the proper row of type, and the second controlling the horizontal motion to select the desired character in that row. These two motions together form a rectangular co-ordinate system for all the thirty-two permutations of the standard five-unit telegraph code*. A unique toggle-type coupling mechanism is provided in the drive system so that the type-box can be stopped in various positions in a gentle manner and without noticeable impact. With this mechanism, the movement of the type-box toward its final position is at high speed, but as the type-box approaches the selected position, the toggle mechanism reduces its speed. At the end of the type-box travel, where further motion is blocked by the index mechanism, the speed of the type-box is about one-fifth of that at which it would have passed this position.

Elimination of the conventional type "basket" greatly reduces the size and weight of the carriage that travels back and forth across the page, starting and stopping for each character printed. A comparison of the old and new type assemblies is illustrated in Figure 4. In a standard Model 15 teletypewriter, the moving carriage assembly weighs slightly over 5 pounds; the carriage assembly in the Model 28 has a total weight of 8 ounces. This 10 to 1 weight reduction results in a very fast carriage return, the carriage returning easily within the time of two character intervals (signals received for carriage return and paper feed) at 100 words per minute. Gravity has no significant effect on the carriage motion. The machine can be operated safely on shipboard or in other locations where it might not be in a level position.

Since the pallets are carried in an accurately made box instead of at the ends of type bars, as in the older machine, type alignment is controlled by manufacture of the parts with no further adjustment required. Stability of alignment, too, is greater, and this should reduce maintenance.

This small light-weight carriage also makes possible an over-all reduction in size and weight of the machine, and permits the use of stamped sheet metal framing instead of the massive cast framework used

* Record, *loc. cit.*

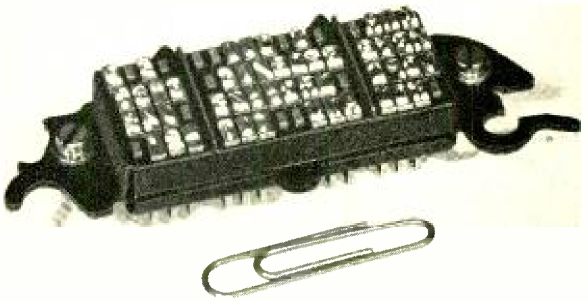


Fig. 1 (right) — The type-box, shown in comparison with an ordinary paper clip.

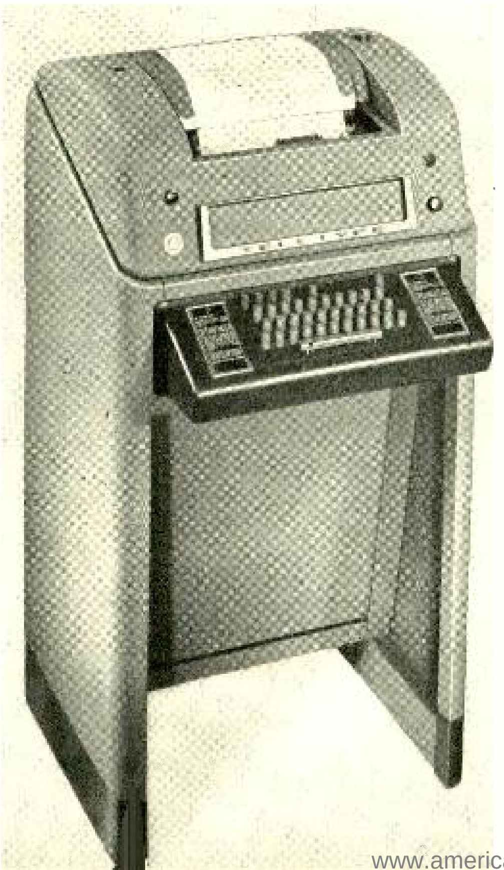


Fig. 2 (below) — The Model 28 teletypewriter.

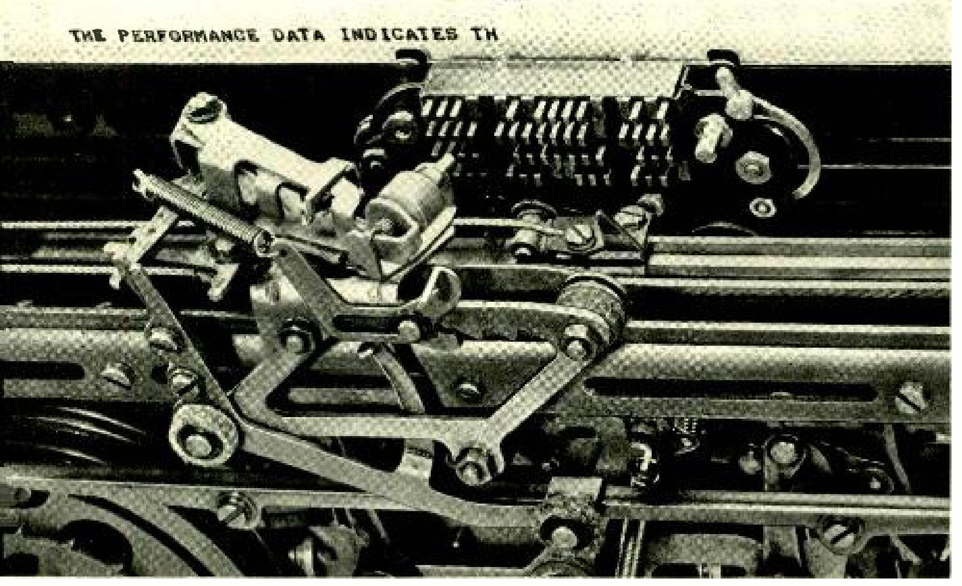


Fig. 3 — When the type-box is in the desired position, the printing hammer drives the type pallet against the ribbon and paper.

on the older machines. The weight of the Model 28 teletypewriter is 38 pounds, not including the cabinet and accessories.

At the right end of the type-box, a small manually operated clamping lever holds the box in its supporting carriage. This clamping lever may be released with a light finger motion so that the type-box can be withdrawn from the machine without using tools. Thus the box may easily be cleaned without brushing dirt into the mechanism of the machine. Also, the type-box may be exchanged in a matter of seconds for another having different character faces.

Since each character is separately mounted on an individual type pallet, only one operates at a time. In the older machines, with two characters on a single pallet, there is a possibility of printing part of the other character on a pallet if the adjustment is not exact, or if one of the characters is worn, or if several carbon copies are being made so that the surface of the paper is somewhat "spongy." The Model 28 is capable of making the same number of carbon copies as present machines, and because the same hammer blow is applied for all characters, the printing impression is more uniform than that of a type bar machine. This characteristic is very important when a large number of copies are being made. The printing blow can readily be increased for multiple copy work by adjusting the tension of a spring by means of a manually operated position lever (Figure 3). Because of the simplicity of the printing mechanism, it is possible to make the shift from figures to letters and vice versa within the printing mechanism rather than by raising and lowering the platen roller. This simplifies paper handling and improves the readability of the printed record, since the paper remains stationary at all times except during line feed.

The ribbon spools are mounted on the machine itself rather than on the type carriage, thus providing a straight course for the ribbon travel. This not only facilitates changing ribbons, since the path is obvious and the number of guides is a minimum, but in combination with the more gentle blow of the new type hammer, it results in approximately doubling the life of the ribbon as compared to the older machines.

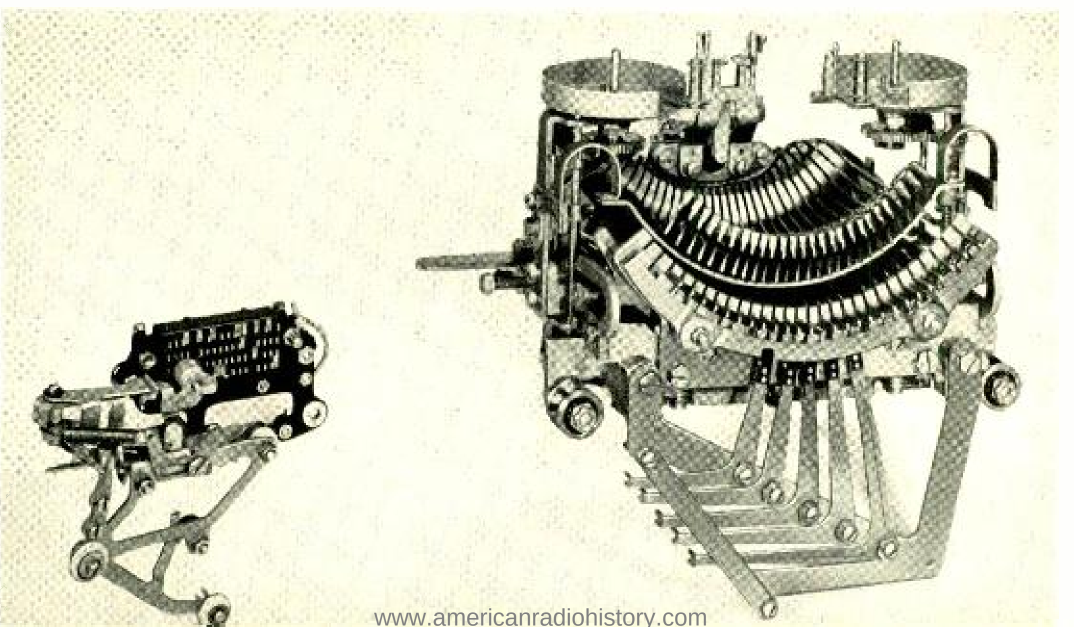
Another machine element that improves operation, reduces maintenance, and contributes to good receiving margins — that is, ability to tolerate distortion of signal pulses — is a newly designed clutch. Clutches of the new design are used not only for driving the selector cams, but for the various other power actions, such as moving the type box, feeding the paper, spacing, etc. This clutch is an all-steel internal expansion friction clutch, that disengages in the stopped condition, whereas the older clutch depends upon slippage between felt washers and steel plates when a stop is interposed, so that the driven member is mechanically held from turning. Figure 5 illustrates the method of operation. The continuously rotating driving member is a steel drum, the inner surface of which is grooved, hardened, and ground to give a flat surface on the tops of the grooves. The grooves between the flat surfaces permit wear products to fall away from the working surfaces. Within this drum, two hardened steel members act as drive shoes and are pressed into contact with the rotating drum by a spring-operated pry bar. The leverage system is so designed that through a system of very rigid force-multiplying levers, a small spring produces high normal pressure between the hardened steel friction surfaces. Since the clutch disengages in the idling position, the load on the motor at that time is very small. Life of the clutch equals that of the rest of the machine.

Performance of non-printing operations, such as line feed, carriage return, and shift, is controlled by a new mechanism contained in a separate subassembly called a "stunt box". This unit, which is accessible from the rear, extends across the full width of the typing unit and engages code bars that also extend across the machine. Notches in the code bars engage the function bars (Figure 6) of the stunt box. The stunt box has forty-two slots, each of which may hold a function bar capable of responding to an assigned code, making it possible to control forty-two functions. Of these forty-two, approximately ten are reserved for the common functions, such as line feed, carriage return, and shift, and the remaining thirty-two are available for special purposes. Stunt boxes are interchangeable.

The keyboard mechanism in the Model 28 is also different from earlier designs. When the operator depresses a key, a latch is tripped which permits the code bars to move endwise by spring action. In the older machines, depressing a key moved the code bars directly, so that there was considerable variation in the forces required for different code combinations. Thus the new action results in a lighter, shallower, and more uniform key touch.

When the key lever is depressed, one of the bars that moves longitudinally trips the clutch latch and allows the clutch to engage a cam-operated mechanical distributor. This causes the code pattern to be translated into a start-stop electrical signal, the signal itself coming from a single contact assembly mechanically operated by the distributor. This contact has the form of a transfer switch and therefore permits either open or closed signal transmission or transmission of signals of alternate polarity. The contact is mounted in a metal box for mechanical protection

Fig. 4 — A comparison of the new type-box with the older "basket" carriage. The new type-box assembly weighs only a tenth of the older moving carriage.



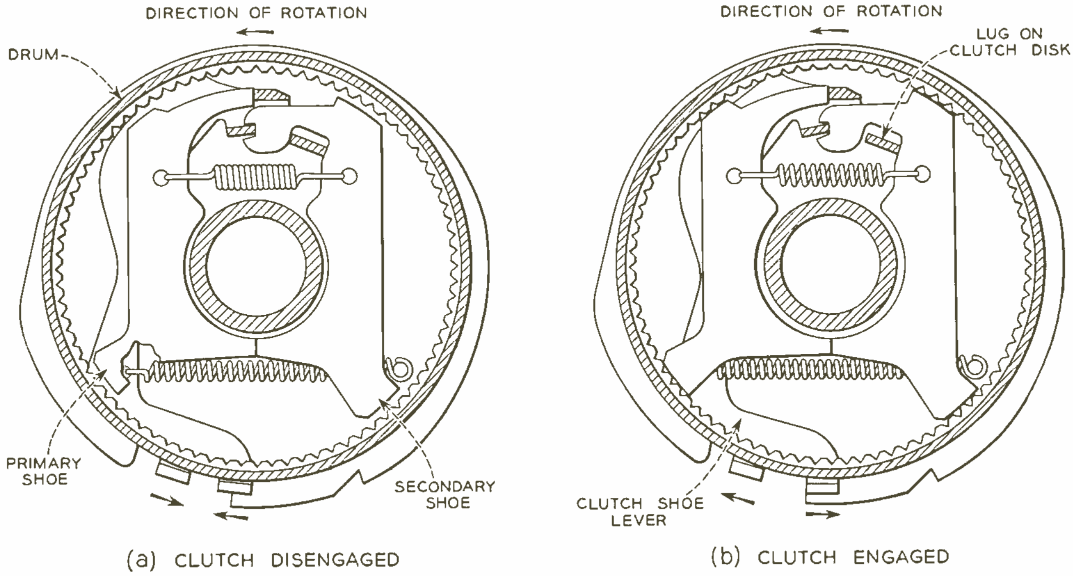
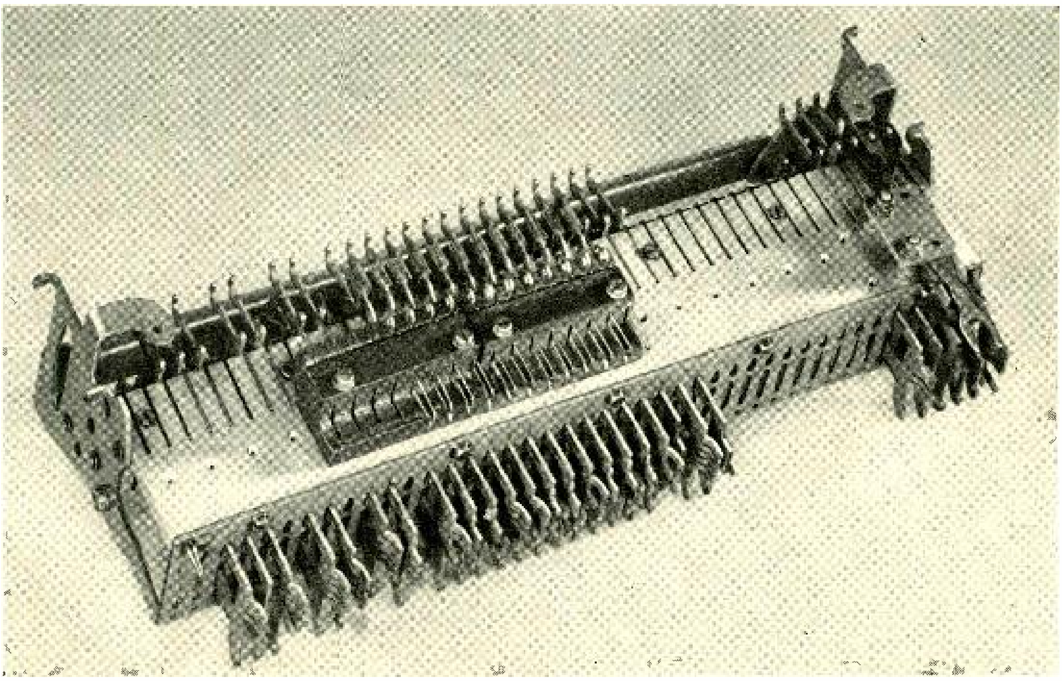


Fig. 5 — The clutch used on the Model 28 teletypewriter is an internal expansion friction clutch.

Fig. 6 — The "Stunt Box" for the Model 28 teletypewriter contains code bars for performing non-printing operations, such as line feed, carriage return, shift, etc.



and magnetic shielding (against radio interference), and requires no adjustment other than in positioning the box itself.

In designing the cabinet for the new machine, consideration was given to improved operating convenience as well as appearance. The equipment is housed in a new floor model cabinet (Figure 2) with all mechanical controls brought to the front so that the machines can be mounted side by side in rows. Even the manual platen crank has been eliminated and replaced with a rapid motor-driven feedout controlled by a button on the keyboard. A lamp within the cabinet illuminates the copy, and the angle of the window above the copy has been chosen so that glare is practically eliminated. The upper section of the cabinet swings open to provide access for insertion of paper and ribbons and for maintenance. Figure 7 shows how the teletypewriter itself may be swung upward

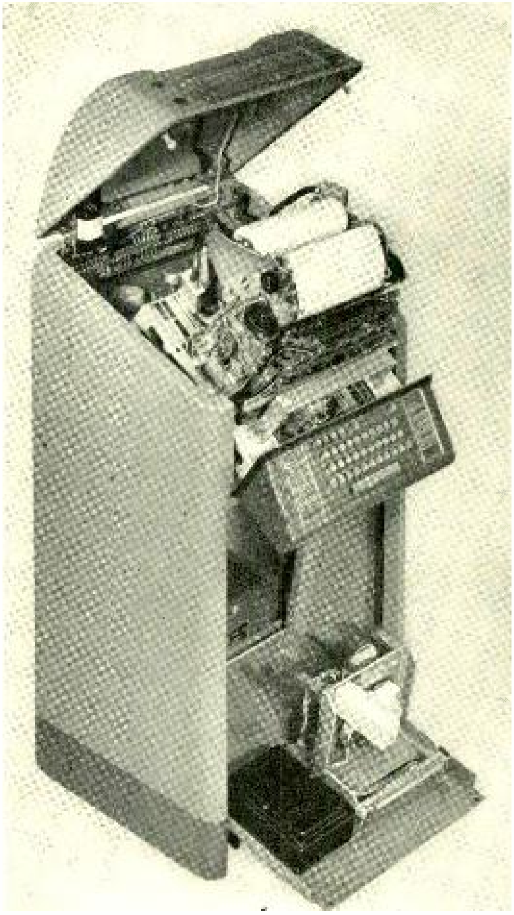


Fig. 7 — The teletypewriter is pivotally mounted and swings outward for maintenance. The panel near the bottom also pivots to provide convenient access to telephone station apparatus that may be mounted on it. Incoming wires are connected to terminal blocks behind the teletypewriter.

THE AUTHOR: W. J. Zenner, Vice President of Teletype Corporation in Chicago, received the degree of B.S. in Electrical Engineering from Armour Institute of Technology. He also holds the degree of Electrical Engineer from the same institute. Prior to his graduation in 1928 he was with the Western Electric Company for three years. Starting with the Teletype Corporation in 1928 he was a group supervisor in the Development and Research Department, becoming chief engineer in 1943; in 1946 he became development and research consultant, being made Vice President in charge of Product Development and Sales in 1952. Mr. Zenner is the inventor and co-inventor of telegraph apparatus covered by seventy-five U. S. patents. He is a member of the Western Society of Engineers, the Armed Forces Communication Association, and President of the Board of Education, District 62 in Des Plaines, Illinois.

and forward to give access to both sides and rear of the machine.

Electrical accessories such as the line relay, motor control relay and fuses, have been placed in a box behind the machine. This permits installation of a standard machine where circuit termination requirements vary. In the cabinet below the teletypewriter a shelf is provided for a rectifier or other apparatus, and in addition, a front panel pivotally mounted to this shelf swings downward (as shown in Figure 7) providing a mounting surface for auxiliary equipment if this is desired. Since operating experience indicates the Model 28 requires less maintenance than other teletypewriter equipment, it is expected that its field of use will be extended to include more remote locations. For example, Model 28 is being installed on ships of the United States Navy, and the Air Force has selected this model for use principally in areas not served by communication companies.

A Bell System service trial was completed in 1951. Urgent needs of the Armed Forces were given priority in early production.

Papers Published by Members of the Laboratories

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Andrus, J., see J. K. Galt.

Arnold, S. M., see Miss S. E. Koonce.

Benedict, T. S., and W. Shockley, Microwave Observation of the Collision Frequency of Electrons in Germanium, Phys. Rev., **89**, pp. 1152-1153, Mar. 1, 1953.

Bozorth, R. M., see H. J. Williams.

Bozorth, R. M., The Permalloy Problem, Revs. Mod. Phys., **25**, pp. 42-48, Jan., 1953.

Fine, M. E., Elasticity and Thermal Expansion of Germanium between —195 and 275°C., J. Appl. Phys., **24**, pp. 338-340, Mar., 1953.

Fine, M. E., Magnetomechanical Effects in an Antiferromagnet, CoO, Revs. Mod. Phys., **25**, p. 158, Jan., 1953.

Galt, J. K., J. Andrus, and H. G. Hopper, Motion of Domain Walls in Ferrite Crystals, Revs. Mod. Phys., **25**, pp. 93-97, Jan., 1953.

Heidenreich, R. D., see E. A. Nesbitt.

Hogan, C. L., Ferromagnetic Faraday Effect at Microwave Frequencies and Its Applications, Revs. Mod. Phys., **25**, pp. 253-262, Jan., 1953.

Hopper, H. G., see J. K. Galt.

Kock, W. E., Acoustic Gyrator, Arch. Elektr. Übertragung, **7**, p. 106, Feb., 1953.

Kock, W. E., Elektrotechnische Zeitschrift, **74**, p. 166 Mar. 1, 1953.

Koonce, Miss S. E., and S. M. Arnold, Growth of Metal Whiskers, J. Appl. Phys. **24**, pp. 365-366, Mar., 1953.

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Shockley, W., see T. S. Benedict.

Williams, H. J., and R. M. Bozorth, Magnetic Study of Low Temperature Transformation in Magnetite, Revs. Mod. Phys., **25**, pp. 79-80, Jan., 1953.

Wright, S. B., Higher Frequencies for Ground-Air Communications, Air Univ. Quart. Rev., **5**, No. 4, pp. 60-70, 1952-1953.

The AMA Called-Office Name Translator

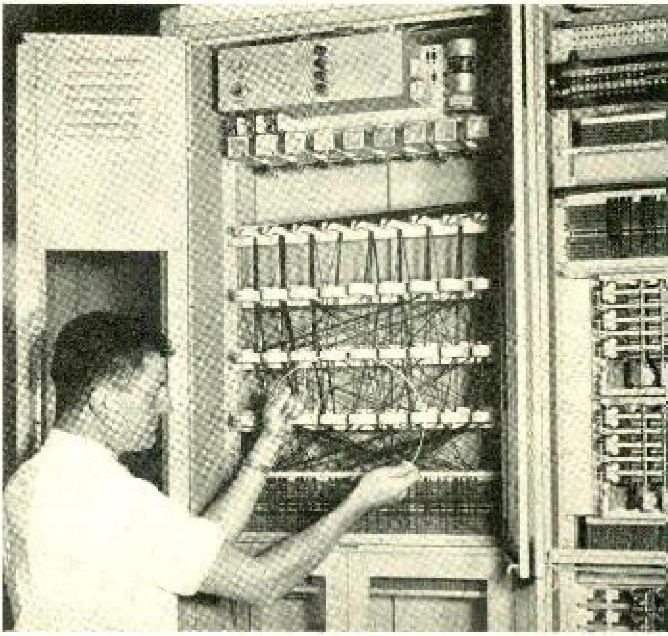
D. E. BRANSON
Switching Development

Part of the information required for customer billing by Automatic Message Accounting equipment is the designation of the central office to which each call is directed. This information is supplied to the AMA equipment as a sequence of three digits, and a special circuit is provided to translate it to the familiar sequence of two letters and a numeral in the final presentation.

In an AMA accounting center, the information required for subscriber billing is processed through a number of stages as described in previous issues of the RECORD*. In one of these stages, all the calls to be charged to a particular subscriber in a billing month are assembled by a Sorter, and then passed to a Printer circuit where the information is translated and printed in a form that can be utilized by accounting center personnel. Most of this translation is relatively straightforward and has been described in previous articles. The designation of the called office, indicated on the third line of a typical detailed entry as shown in Figure 2, however, requires a more elaborate translation.

The more complex nature of this translation can be illustrated by a specific example: a subscriber dials the FUlton-9 central office in Philadelphia as FU-9 but this information is recorded on the AMA tape as 389. Reference to any telephone dial will show, however, that the 3 in this sequence might represent a D or an E as well as an F, and the 8, a T or a V as well as a U. The FU then, is only one of 9 possible letter pairs which can be formed by selecting one of the letters D, E, F and adding a T, U, or V. These 9 pairs are indicated in Table I. This situation is further complicated by the fact that an AMA center may serve a relatively large geographic region which might well include several central offices designated by the same number sequence. In this example, 389 refers to the FUlton-9 exchange in Philadelphia while

Fig. 1 – Called office name translator as set up at Bell Telephone Laboratories, West Street, with W. B. Groth threading the ring coils.



* *A bibliography of articles on AMA is given on page 424 of the November, 1952, issue of the* RECORD.

the same sequence designates the EVergreen-9 office in New York. These AMA regions, therefore, are divided into a number of dial areas identified by a digit referred to as the called area index, and within each area, a particular three-digit sequence has a unique translation. The Philadelphia area in this example is arbitrarily designated by the index 0 and the New York area by the index 1. A series of four digits is thus required on an AMA tape to specify the called office: one to indicate the dial area, and three to designate the particular central office within that area.

To carry out the translation, the called office name translator, illustrated in Figure 1, has been developed. This translator serves as an accessory to the Printer, and converts each four-digit sequence to a dial area index and called office designation: a numeral, two letters, and a numeral. The translation is then transmitted to the Printer where it is used to print the called office abbreviation on toll slips.

When a called office name translator is used in an accounting center serving only one dial area, a called area index is not required and the task of the apparatus is to translate a three-digit sequence to a pair of letters followed by a numeral. If the New York area were the only one served, for example, the sequence 389 would always be translated as EV-9. Since the first and second digits of a sequence can each have any one of eight values corresponding to the positions two through nine on a telephone dial, 64 two-letter central office abbreviations are possible. The third digit of a sequence, however, can have any of ten possible values for the central office numeral, and the 64-letter pairs and ten numerals provide a total of 640 possible combinations. The translator must provide a means whereby a three-digit sequence on an AMA tape can select the proper one of these combinations.

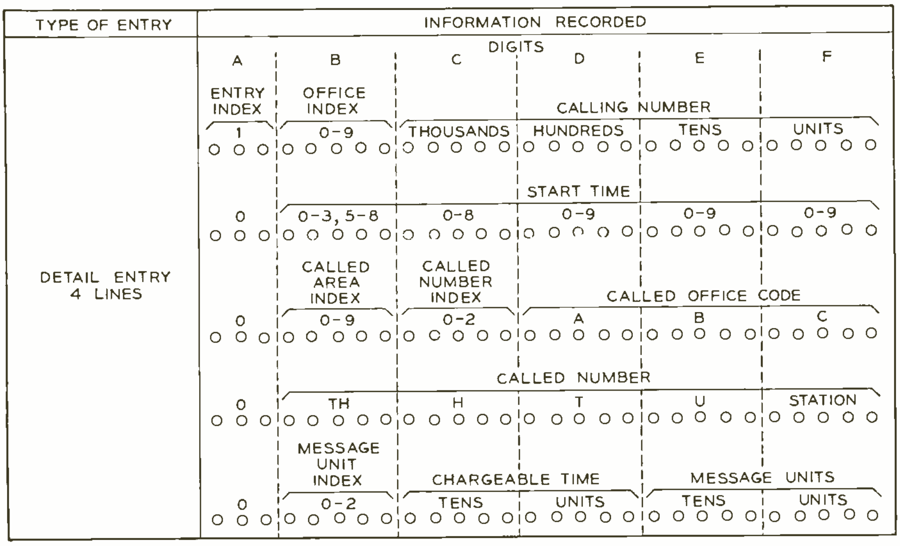


Fig. 2 — Typical detailed output entry perforated by the computer.

Eight horizontal rows and eight vertical columns on each of two 10 x 10 crossbar switches having five contacts per crosspoint are used in this translator to provide the 640 unique positions required to represent the possible central office designations, and a particular three-digit sequence selects one of these positions. To accomplish this, the first digit of the sequence causes the select magnets of the horizontal rows corresponding to its value to operate. As illustrated in Figure 3, the first digit 3 causes the operation of the number three crossbar select magnets. The second digit 8 of the sequence completes a circuit to the hold magnets corresponding to its value on both switches. In the illustration of Figure 3, the digit 8 closes a path to the number eight hold magnets, and thus the 3-8 crosspoints are chosen. Only one

DIGIT 8 LETTER GROUP	DIGIT 3 LETTER GROUP		
	D	E	F
T	DT	ET	FT
U	DU	EU	FU
V	DV	EV	FV

TABLE I—THE NINE POSSIBLE LETTER PAIRS FORMED BY ONE LETTER FROM THE GROUP D, E, F, AND ONE FROM THE GROUP T, U, V

of these two crosspoints is actually closed, however, and this choice is governed by the third digit. If this digit has any of the values zero through four, the hold magnet for the indicated vertical on the first switch is operated. If the value lies in the range five to nine, however, the corresponding crosspoint on the second switch is closed. The third digit in the example 389 indicates that the 3-8 crosspoint on the second switch should be closed as shown in the diagram.

Each of the crosspoints is equipped with five individual contacts. On the first switch, the five contacts at crosspoint 3-8 represent the sequences 380 through 384 and the contacts on the corresponding crosspoint of the second switch represent the sequences 385 through 389. The third digit of a sequence causes a ground to be applied to all the switch contacts corresponding to its value. In Figure 3, the ground is applied to all the number 9 contacts. Since the 3-8 crosspoint on the second switch is the only one closed, however, contact 389 provides the only complete path for ground. In this way, a three-digit sequence selects a unique position of 640 possibilities.

To complete the translation process, an AMA printer must be directed to print the central office designation corresponding to the selected switch contact. The 24 printer character relays corresponding to the letters on a telephone dial are divided into eight groups of three each as they are arranged on the dial. The first digit of a sequence, in addition to activating select magnets, closes a path to its corresponding group of printer character relays. As shown

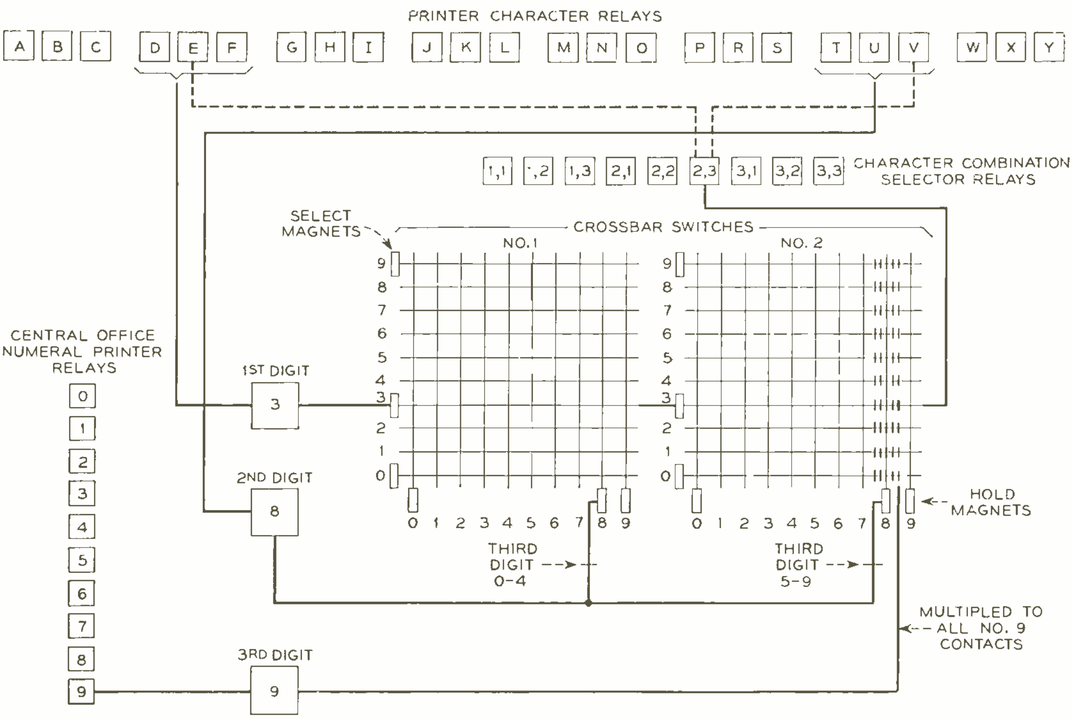


Fig. 3 — Block diagram of called office name translator as used for single area translations.

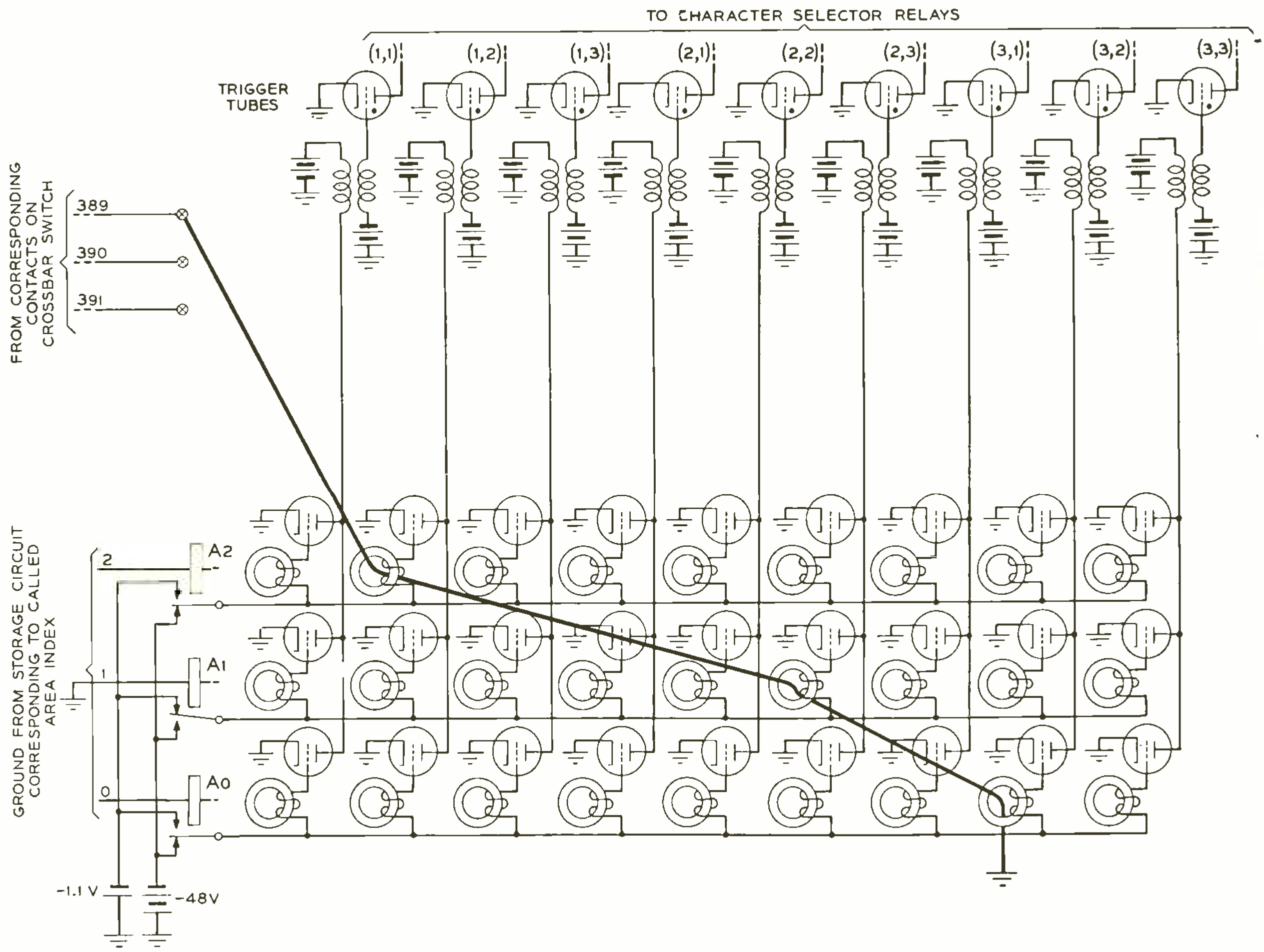


Fig. 4 — Nine ring coils corresponding to each of three dial areas with the line from the 389 contact on the crossbar switch threading one coil in each group.

in Figure 3, the digit "3" closes a path to the characters D, E, and F. The second digit similarly closes a path to the printer character group corresponding to its value. In this way, two of the eight possible relay groups are selected.

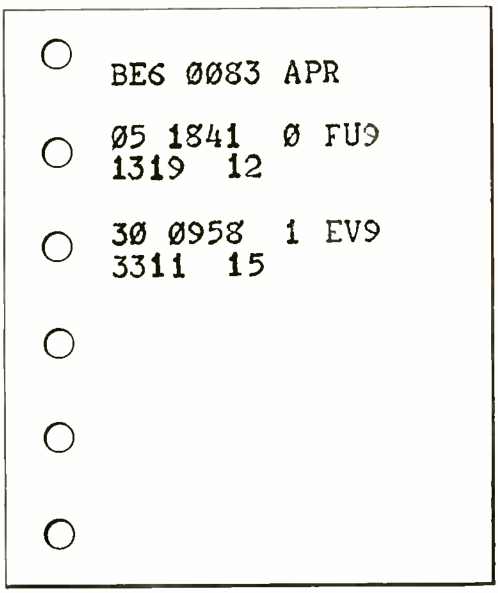
In the remaining step, the correct letter-pair of the nine possibilities provided by the six characters in these two groups must be selected. This is done through the use of one of nine character combination selector relays. Each of the 640 contacts in use on the crossbar switches is cross-connected to one of these nine relays and they, in turn, are connected to the printer relays in such a way that they direct the printing of the desired one of three characters in each of two groups. Since circuit paths to only two of the groups have been completed by the first two digits in the sequence however, the characters indicated by the combination selector relays in these groups are the only ones that operate. The crossbar switch contact 389 in Figure 3, for example, is wired to the selector relay "2, 3." This relay applies ground to the second character in the first group and the third character in the second group. In this way, the character relays EV are activated. The third digit of a sequence causes the central office numeral to be printed directly, and the translation is thus completed.

The preceding account describes the use of the called office name translator in accounting centers which serve only one dial area. The process is considerably more complicated, however, in the more typical situation of several areas served by the same center. In actual practice, as many as three dial areas are involved and it is possible for the same three-digit sequence to occur in two or three of them. The translator must then include a provision for supplying a different translation of the same sequence for each dial area in which it may appear, and the choice of the particular translation is governed by the called area index. The apparatus required to select the proper translation consists essentially of an additional group of relays, a set of ring coils* with associated amplifiers, and a set of gas tubes.

The operation of a called office name translator in regions including more than one dial area is an extension of that previously described. In a multi-area application, however, the circuit is so arranged that the third dialed digit causes an alternating current rather than a ground to be placed on the selected contacts of the crossbar switch. In the example of Figure 3, ac is supplied to contact 389. From the switch contact, the signal follows the path indicated in Figure 4 to the character combination selector relay rather than the direct route shown in Figure 3 for a single area translation.

The diagram in Figure 4 illustrates the arrangement of ring coils, amplifiers, and trigger tubes used in a translator serving three dial areas. As shown, there are nine ring coil-amplifier combinations for each dial area with one combination per area connected to each character combination selector relay. This ring coil array is also evident in the open rack at the left of Figure 1.

A lead from each crossbar switch contact is threaded through a coil corresponding to the Selector relay that yields the desired translation for each dial area. In Figure 4, the lead from contact 389 passes through a coil in the dial area zero group that is associated with relay "3, 2." The same lead encounters the coil for relay "2, 3," in the area 1 group, and that for the relay "1, 2" in area 2. The grids of the amplifier tubes associated with the ring coils are normally maintained at a potential of 48 volts below ground and hence the associated trigger tubes illustrated in the figure are kept far below their operating threshold. A storage circuit, containing the called area index, however, applies ground on a lead to operate one of three relays, A0-A2. This relay, A0 in the case of the 0 Philadelphia dial area or A1 for the number 1 New York area, changes the grid potential on the 9 amplifiers in the bank of


BE6 ØØ83 APR

Ø5 1841 Ø FU9
1319 12

3Ø Ø958 1 EV9
3311 15

Fig. 5 — Sample toll slip from printer showing calls to the FUlton-9 and EVergreen-9 offices.

coils corresponding to its area, from −48 to −1.1 volts. For the four-digit sequence 1389, relay A1 is operated to raise the grid potential of the 9 amplifiers for area 1 to −1.1 volts.

The ac signal on the lead from contact 389 induces a voltage in the ring coils it encounters but this voltage has no effect on the associated amplifier tubes that have grid potentials of −48 volts. The ac signal, however, will be amplified with a grid potential of 1.1 volts. The ac on the lead from contact 389 in Figure 4 does not affect the

* RECORD, *February,* 1951, *page* 62.

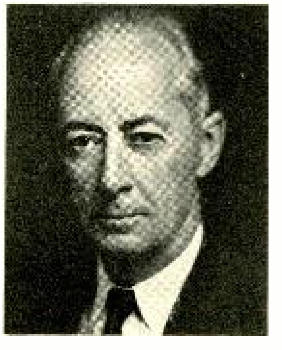
amplifier-coil combination through which it passes in the area 2 group since this grid potential remains at −48 volts. Similarly, the combination in area 0 is unaffected, but the induced voltage in the area 1 coil makes its associated amplifier tube conducting and this fires trigger tube "2, 3". This tube, in turn operates Character Combination Selector relay "2, 3" which directs the printer to type EV-9 as previously described. The dial area index is typed by the printer circuit directly.

If the FUlton-9 central office in the Philadelphia dial area had been called, the four-numeral sequence would have been 0389, differing from the EVergreen-9 sequence only in the dial area index. In this case, relay AO would have raised the grid potential of the amplifiers, in its bank and activated Character Selector relay "3, 2". This directs the circuit to operate the third character relay in the first set, the F, and the second in the second set, the U, and the designation FU-9 is then printed. Figure 5 shows a sample toll slip on which the called office name translator has directed the printer to type the combination 0FU9 from the sequence 0389 and 1EV9 from 1389.

Several variations in translation are provided for in this apparatus since it may be necessary to convert central office designations of one numeral, of one letter, of two numerals, of one letter and one numeral, and of two letters. For these, additional coils and their associated relays are required.

A very thorough check feature is incorporated in this circuit which requires the operation of one and only one relay in a group before the typing of any character can proceed. Any improper functioning of this circuit or inproper recording of a central office designation operates a trouble alarm.

THE AUTHOR: In nineteen years' association with the Laboratories' Telegraph Development Department, David E. Branson has been credited with more than twenty patents on secret Morse telegraphy, picture transmission, polar relays, and carrier telegraphy. Recently he has been engaged in the development and modification of A.M.A. and teletypewriter switching systems. Mr. Branson received a B.S. degree in 1917 from Purdue and was employed at A.T.&T. before joining the Laboratories in 1934. He was attached to the Bureau of Steam Engineering, U.S.N., during World War I and is a member of the A.I.E.E., Tau Beta Pi, Eta Kappa Nu, and Sigma Xi.



Dr. Kelly on Prudential Board

M. J. Kelly, President of the Laboratories, was recently appointed one of six public members of the Prudential Life Insurance Board of Directors, pursuant to legislation signed a few days earlier by New Jersey's Governor Driscoll.

The new legislation was described as necessary by its sponsor, Assemblyman G. C. Thomas of Union because of Prudential's influence over "the economic stability of the state and of the nation." Appointed by the state's Chief Justice A. T. Vanderbilt, the new directors increase the board membership to twenty-three.

The law affects "any mutual life insurance corporation" which has more than 10,000,000 policies in force. It applies only to Prudential, which has 37,000,000 policyholders and 10 million dollars in assets.

Construction Supplement Filed

Approval of a $11,130,000 program, covering construction and installation of telephone plant, was sought recently by the Long Lines Department of the A T & T and fifteen Associated Companies in a supplemental application filed with the FCC. The original application, filed on October 31, 1952, was approved February 6, 1953. Projects outlined in the supplement would add to existing facilities 1,600,000 miles of telephone channels, 38,000 miles of telegraph channels and nine audio circuits that are used with sound program and television networks.

Equipping cable and radio relay facilities with carrier systems will provide many additional telephone channels. Most of these will be used in connection with the installation of additional long distance telephone switching equipment in the New York and Chicago areas to take care of telephone traffic growth. The switching systems will be used in operator long distance dialing.

New construction proposed in the supplement included a 33-mile cable between Arlington and Triangle, Va. This cable is needed to meet rapidly increasing telephone requirements in this area.

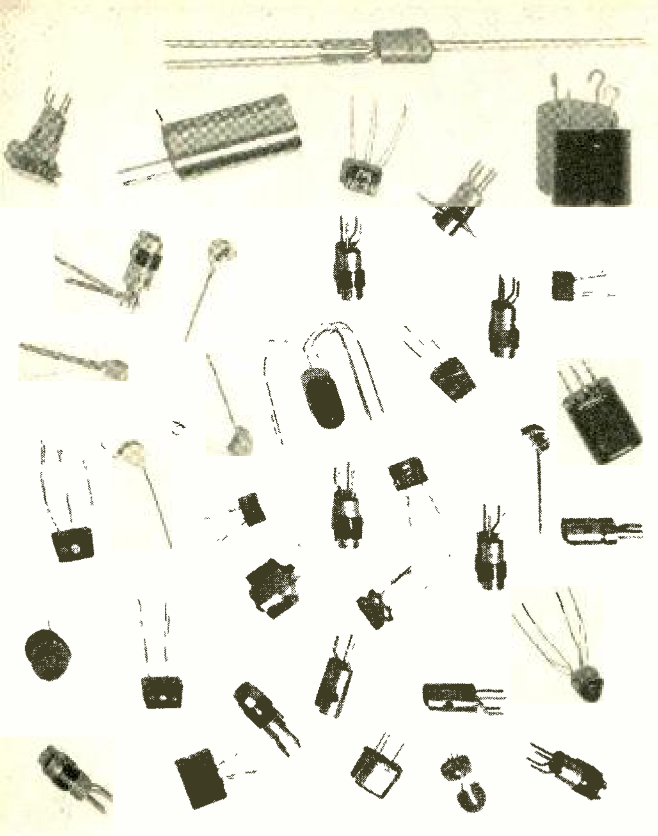
Dr. Compton Visits Murray Hill

One of the Laboratories' outstanding visitors in recent weeks was Karl T. Compton, chairman of the board of directors of the Massachusetts Institute of Technology and past president of the Institute. During a two-day visit to Murray Hill, he observed the work being done in the research laboratories and in transistor development.

Dr. Compton was one of the pioneers in physical electronics when he was a professor of physics at Princeton. He has also served on many boards and councils as a scientific advisor to the government.

J. A. Becker (left) and K. G. McKay (center) show Dr. Compton the model of a single crystal of tungsten, the surface of which is in the form of a hemisphere. The colored marbles represent the atoms.

While in the vicinity Dr. Compton established a regional chapter of the Scientific Research Society of America, of which he is national president. The formation of this chapter was initiated by the Summit Association of Scientists whose membership consists largely of Laboratories people.



Fifth Anniversary of Transistor Announcement

Some of the nearly forty experimental types of transistors which have been developed at the Laboratories. In the illustration the transistors appear about half their actual size.

Just five years ago – June 30, 1948 – a group of science writers, general reporters, and other members of the press attended an historic demonstration at the West Street headquarters of the Laboratories.

The stories these men and women wrote for their newspapers or magazines covered one of the most significant milestones in the history of electronics. It was the announcement by the Laboratories of the invention of the transistor by two of its members, John Bardeen and Walter H. Brattain. The transistor is a revolutionary little device, hardly the size of a shoelace tip, yet capable of doing most of the things a vacuum tube can do and many other things as well, all on amazingly small amounts of power.

Behind this report to the public was the fascinating story of how fundamental research, long a keystone of the Bell System, had led to the discovery of an entirely new physical principle and the birth of a device destined to have tremendous impact on the science of electronics, including important military applications.

In the brief span of five years since that time, the transistor has undergone intensive development work. Today it is admirably matching, and in some ways even surpassing, the scientific predictions made for its future at the time it was invented.

The transistor has already gone into use in the Bell System's nation-wide communications network. Late last year, equipment using transistors to generate signaling tones was installed in dial switching equipment in Englewood, N. J., associated with the first installation of customer long distance dialing. In March, the transistor went to work in another way in Pittsburgh, Pa., as part of a "card translator" for the automatic routing of long distance telephone calls. By year-end, nearly sixty such card translators, each of them incorporating approximately 230 transistors, will be installed in various key cities throughout the nation.

There are also plans to use these small but powerful amplifying devices in many other ways in the telephone plant – to boost voice signals, to generate signaling tones, to modulate voice-carrying electrical currents, and as switches to set up individual voice paths between telephones in a complex communications network.

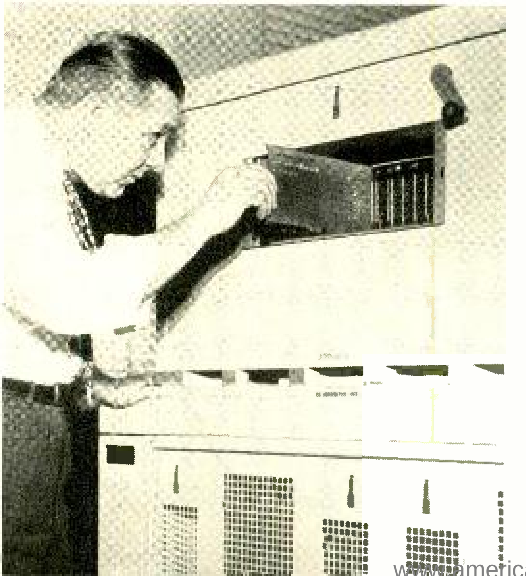
The transistor has also aroused widespread interest throughout the radio and television industry and several companies have already announced hearing aids employing transistors instead of the conventional vacuum tubes.

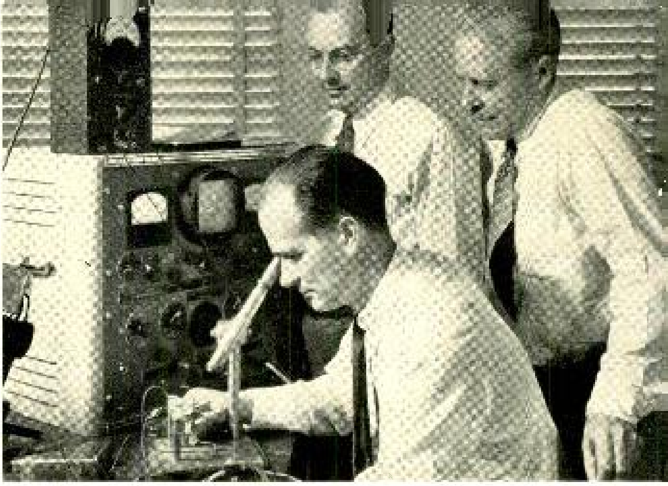
While the military uses of transistors are necessarily classified, it is no secret that their rugged qualities, their small size and their remarkably small power requirements make them exceptionally attractive for many important military applications.

The transistor, for all of its insignificant appearance, does some amazing things. It will serve as an amplifier or an oscillator, but one must look hard to find any other resemblance to the familiar vacuum tube now used to do those basic jobs. The transistor is rugged, has no vacuum, no grid, no plate, no cathode and, therefore, there is no warm-up delay — it operates instantly. The first type to be announced, known as the point-contact transistor, consists of two thin wires resting on a tiny wafer of germanium and spaced only a few thousandths of an inch apart. The flow of current in one of the fine points controls the flow in the other point.

Another type of transistor, invented by Dr. William Shockley, also at the Laboratories, is known as the junction transistor. It is more effective in certain applications than the point-contact device, is freer from noise and is more efficient. It also operates on even less power than the earlier type. Predicted theoretically by Dr. Shockley more than two years before it was demonstrated, the junction transistor consists essentially of a tiny sandwich of germanium, treated so that its alternate layers have different electrical properties. It occupies only about 1/400 of a cubic inch.

Transistors are an integral part of the new card translator, a device for the automatic routing of operator or customer dialed toll calls.





An historic photograph taken at the time of the announcement of the invention of the transistor at Bell Telephone Laboratories five years ago, shows Dr. William Shockley, seated, and Dr. John Bardeen (standing left) and Dr. Walter H. Brattain. The equipment is that with which transistor action was first discovered.

Since transistors need no heater to supply electrons, they require very little power — in fact, less than a thousandth of that used in an ordinary flashlight bulb.

Transistor action depends to a large extent on the extreme purity of the semiconducting element, germanium. The Laboratories has developed a remarkable process by which germanium can be rendered so pure that there will be no more than one foreign atom in one hundred million germanium atoms.

Compared with the relatively slow development of vacuum tubes and other electronic devices, transistor development has been swift indeed. The Laboratories now has nearly forty experimental types, some of which foretell applications of the highest order of usefulness. At the present time forty companies are licensed to make and sell transistors and many other companies are licensed to make use of transistors in equipments they manufacture.

To acquaint others with transistor theory and technology, the Laboratories has given intensive courses to representatives of the outside firms licensed by Western Electric Company to manufacture transistors. It has published numerous papers and books and sent speakers over the country to lecture on the new art and has conducted a school for university professors.

Dr. William Shockley guided the research program leading to the transistor.

The device invented by Bardeen and Brattain was the point-contact transistor, which in the initial demonstration was shown to be readily adaptable to the electronic techniques of radio, television and public address systems. The transistor was used to amplify the electronic speech waves traveling between two telephones. It was used in a radio set constructed entirely without vacuum tubes. It also was used to

Some Transistor Chronology

June, 1948 — The point-contact transistor made its first public appearance at the West Street headquarters of the Laboratories in New York. It had been demonstrated privately to the military a short time before this announcement to the press.

March, 1950 — Invention of the phototransistor by the Laboratories' Dr. J. N. Shive was announced. An entirely new type of "electric eye" — much smaller and sturdier than present photo-electric cells and possibly cheaper — it is a transistor controlled by light rather than by electric current.

July, 1951 — The junction transistor, a radically new and in many ways more effective type, invented by Dr. Shockley, was announced. Morgan Sparks built the first of the new type transistors, using crystal processes developed by G. K. Teal and J. B. Little. Among others, R. L. Wallace, Jr., and W. J. Pietenpol worked on their development and use. The junction transistor was described as "extremely small, occupying only about 1/400 of a cubic inch" and even less power-consuming than the original point-contact type.

The Laboratories also announced that development work on the point-contact type had resulted in understanding problems involved in reliability and reproducibility, thus bringing regular production nearer.

September, 1951 — A transistor symposium held at Murray Hill. Nearly 300 guests attended the sessions; represented were industry, the Army, Navy, Air Force, government agencies and their contractors, and several universities.

October, 1951 — Production of the first transistors begun by the manufacturing department of Western Electric at its Allentown plant.

April, 1952 — Transistor technology symposium held at Murray Hill and Allentown, Pa. This was concerned with the development of transistors, phototransistors and related semiconductor devices.

June, 1952 — Sixty-three faculty members, representing 33 universities, colleges, and institutions of technology attended the first transistor school, sponsored by the Laboratories and held at Murray Hill. The school was designed to facilitate the introduction of transistor physics into university courses.

August, 1952 — First announcement of a "tetrode" transistor, invented at the Laboratories by R. L. Wallace, Jr. By adding a fourth electrode, Wallace was able to produce a transistor usable at frequencies at least ten times higher than would otherwise be possible.

October, 1952 — The transistor went to work for the first time in the nation's telephone network. Oscillators employing transistor units were installed in dial switching equipment in Englewood, N. J., as part of the customer long distance dialing trial. The first commercial oscillator model was assembled in the Laboratories by F. E. Blount, assisted by D. Houk.

End of 1952 — First over-the-counter consumer product to make use of transistors was put on the market by manufacturers of hearing aids.

March, 1953 — A most important use of the transistor was made public when the Laboratories announced development of the "card translator," which will serve as an automatic routing device for setting up long distance calls across the country. The card translator makes use of both the phototransistor and the current-amplifying transistor.

generate a standard frequency tone, thus demonstrating its role as an oscillator. And a television repeater was shown, the circuits of which had been revised so that transistors provided the necessary amplification.

Soon after the transistor's invention the Laboratories organized a development group under J. A. Morton, and rapidly went on to find new types of transistors and more and more uses for the various types. It made the first transistors more reliable, and found ways to reproduce them so that they would be uniform in performance characteristics. It discovered how to put them to use in the telephone system itself.

A glance backward over the history of the transistor reveals a continuing story of concentrated effort, crowned by one significant achievement after another.

Patents Issued to Members of Bell Telephone Laboratories During April

Branson, D. E. and Locke, G. A. – *Teletypewriter Switching System* – 2,635,139.

Brown, J. T. L. – *Mercury Dispenser* – 2,634,028.

Buchanan, R. B. – *Recording-Completing Cord and Trunk Circuits* – 2,636,944.

Carbrey, R. L. – *Pulse Code Modulation Communication System* – 2,636,159.

Christensen, H. – *Process for Making a Thermistor by Oxidation of a Nickel Manganese Alloy* – 2,636,012.

Clarke, W. J. – *Housing for Electrical Circuit Units* – 2,636,073.

Cutler, C. C. – *Stereoscopic Object Location System Using Radar Technique* – 2,637,025.

Davey, J. R. – *Telegraph Hub Repeater Circuits* – 2,634,333.

Davey, J. R. – *Hub Telegraph Repeater* – 2,636,-942.

Doba, S., Jr. – *Balanced Diode Clamper Circuit for Low Frequency Restoration* – 2,636,080.

Feldman, C. B. H. – *Supervisory Circuits for Pulse Code Modulation* – 2,636,081.

Flint, E. W. – *Automatic Accounting Device* – 2,635,807.

Fogarty, E. J. and Rippere, R. O. – *Aircraft Pilot Trainer* – 2,636,285.

Ford, G. T. and Walsh, E. J. – *Thermal Structure for Electron Discharge Devices* – 2,634,384.

Goddard, C. T. – *Electron Discharge Device of the Cavity Resonator Type* – 2,635,207.

Graham, R. E. – *Motor Control System* – 2,636,-149.

Holden, W. H. T. – *Translating Circuit* – 2,637,-017.

Hussey, L. W. – *Diode Gate* – 2,636,133.

Krom, M. E. – *Electric Delay System* – 2,636,931.

Locke, G. A., see D. E. Branson.

Madden, J. J. – *Linear Dial Call Transmitter* – 2,635,230.

Michael, H. J. – *Two-Way Trunk for Pulse Conversion Systems* – 2,636,947.

Peek, R. L., Jr. – *Stress-Coupled Core and Crystal Transformer* – 2,636,135.

Peters, H. – *Method of Bonding Polyethylene to Vulcanized Rubber and Article Produced Thereby* – 2,635,975.

Pierce, J. R. – *Generation of Microwaves* – 2,635,-206.

Pierce, J. R. – *High-Frequency Amplifier* – 2,636-948.

Pierce, J. R. – *Traveling Wave Electron Discharge Device* – 2,637,001.

Potter, R. K. – *Velocity Measuring System Utilizing Radio Technique* – 2,634,413.

Retallack, J. B. – *Computing Circuits for Automatic Billing Systems* – 2,634,910.

Rippere, R. O., see E. J. Fogarty.

Schimpf, L. G. – *Light Repeater for Pulse Communication Systems* – 2,634,366.

Smith, E. M. – *Tape Handling Device* – 2,636,729.

Southworth, G. C. – *Selective Electromagnetic Wave System* – 2,636,125.

Steinberg, J. C. – *Speech Analyzing and Synthesizing Communications System* – 2,635,146.

Taylor, E. R. – *Microwave Circuit Stabilization Means* – 2,636,116.

Townsend, M. A. – *Multicathode Gaseous Discharge Device and Circuits* – 2,635,810.

Vance, R. L. – *Photoelectric Device* – 2,636,128.

Walsh, E. J., see G. T. Ford.

Young, W. R., Jr. – *Radiotelephone Receiving System Employing a Plurality of Receivers* – 2,636,982.

Talks by Members of the Laboratories

During the month of May, a number of Laboratories people gave talks before professional and educational groups. Following is a list of the speakers, titles, and place of presentation.

Anderson, A. R., Ferroelectric and Ferromagnetic Memories, Joint Study Group, A.I.E.E. and I.R.E., N.Y.C.

Biondi, F. J., Magnetron Cathode Development, Magnetron Cathode Symposium – Panel on Electron Tubes, RDB Committee on Electronics, N.Y.C.

Bodle, D. W., Lightning Protection for Radio Broadcast Transmitters and Associated Plant, I.R.E. Boston Chapter of Broadcast Engineers, Boston, Mass.

Burns, R. M., Chemistry in the Communication Industry, Christopher Columbus High School, N.Y.C.

Burns, R. M., Corrosion of Metals, Armed Services Association, N.Y.C.

Burns, R. M., Chemical Industry in the Future, Rensselaer Polytechnic Institute, Troy, N.Y.

Burns, R. M., Protective Coating for Metals, University of Wisconsin Corrosion Control Institute, Madison, Wis.

Campbell, W. E., Radio Interview on "Lubrication Engineering," Station WNBX, Cleveland, Ohio.

Clark, M. A., An Acoustic Lens as a Directional Microphone, Acoustical Society Meeting, Philadelphia, Pa.

Dacey, G. C., Field-Effect Transistor, Columbia University, N.Y.C.

Davis, K. H., Automatic Recognition of Phonetic Elements in Speech, Acoustical Society Meeting, Philadelphia, Pa.

Davis, K. H., See Dudley, H. W.

Dudley, H. W., and Davis, K. H., A Narrow Band Speech Transmission System Employing the Recognition of Phonetic Elements, Acoustical Society Meeting, Philadelphia, Pa.

Ferrell, E. B., Fundamental Concept of Statistical Analysis, Conference Series on Quality Control, Rutgers University, New Brunswick, New Jersey.

Fox, A. G., Behavior of Ferrites in Waveguides, Ferrite Symposium, I.R.E. New York Section, N.Y.C.

Frost, G. R., See Keister, W.

Griffin, J. P., See Warner, A. W.

Haynes, J. R., Some Fundamental Experiments in Transistor Physics, Physics Colloquium, Dartmouth College, Hanover, N.H.

Hogan, C. L., Electromagnetic Phenomena in Ferrites, American Physical Society, Washington, D.C.

Hogan, C. L., The Ferromagnetic Faraday Effect in Microwave Frequencies, Lehigh University, Bethlehem, Pa. and I.R.E. New York Section, N.Y.C.

Janssen, W. F., Precision Ceramics, American Lava Corporation, Chattanooga, Tenn.

Keister, W., Can a Machine Think?, District No. 3, A.I.E.E. Student Prize Paper Contest, Columbia University, N.Y.C.

Keister, W., and Frost, G. R., Discussion and Demonstration of Thinking Machine, Michigan State College East Lansing, Mich.

Mason, W. P., Low Frequency-Temperature Coefficient Barium Titanate Ceramics Which Are Stable with Time, Symposium, Department of Commerce, Washington, D. C., and Acoustical Society Meeting, Philadelphia, Pa.

Miller, R. L., Improvements in the Vocoder, Acoustical Society Meeting, Philadelphia, Pa.

Pearson, G. L., The Properties and Uses of Thermistors, Physics Colloquium, Radio Corporation of America, Princeton, N.J.

Peterson, G. E., On the Nature of Speech, Columbia University, N.Y.C.

Reiss, H., Chemical Effects Due to the Ionization of Impurities in Semiconductors, Chemistry Colloquium, Columbia Graduate School, Columbia University, N.Y.C.

Ross, I. M., Field-Effect Transistor, Princeton University, Princeton, New Jersey.

Schimpf, L. G., Transistor Applications, RCA Institute Alumni Association, N.Y.C.

Sharp, W. O., Submarine Cable Tube, Men's Club of the Watchung Avenue Presbyterian Church, North Plainfield, N. J.

Slepian, D., Measuring Information, A.I.E.E. Columbus Section, Columbus, Ohio and I.R.E. Cleveland Section, Cleveland, Ohio.

Stone, H. A., Transistors and Miniature Components, The Bristol Company, Engineers' Club, Waterbury, Conn.

Vogel, F. L., Dislocation in Low Angle Crystal Boundaries, American Physical Society, Division of Solid State Physics, Washington, D.C.

Wallace, R. L., Jr., High Frequency Properties of Junction Tetrode Transistors, Applied Science Colloquium, Harvard University, Cambridge, Mass.

Wannier, J. H., Ising Model, Watson Laboratories, N.Y.C.

Warner, A. W. and Griffin, J. P., Improvements in Crystal Units for Precise Frequency Control, Squier Laboratory Frequency Control Symposium, Asbury Park, N.J.