August 1960

Bell Laboratories
RECORD

Reliability in Telephone Engineering

Use of Statistics in Device Development

Experiments in Person-to-Person DDD

Circuits for Teletypewriter Switching

Automatic Processing of Memory Code Plates

THE BELL LABORATORIES RECORD is published monthly by Bell Telephone Laboratories, Incorporated, 463 West Street, New York 14, N. Y., J. B. Fisk, President; K. Prince, Secretary; and T. J. Montigel, Treasurer. Subscription: $2.00 per year; Foreign, $2.60 per year. Checks should be made payable to Bell Laboratories Record and addressed to the Circulation Manager. Printed in U. S. A.

Bell Laboratories **RECORD**

Volume 38 • Number 8 • August 1960

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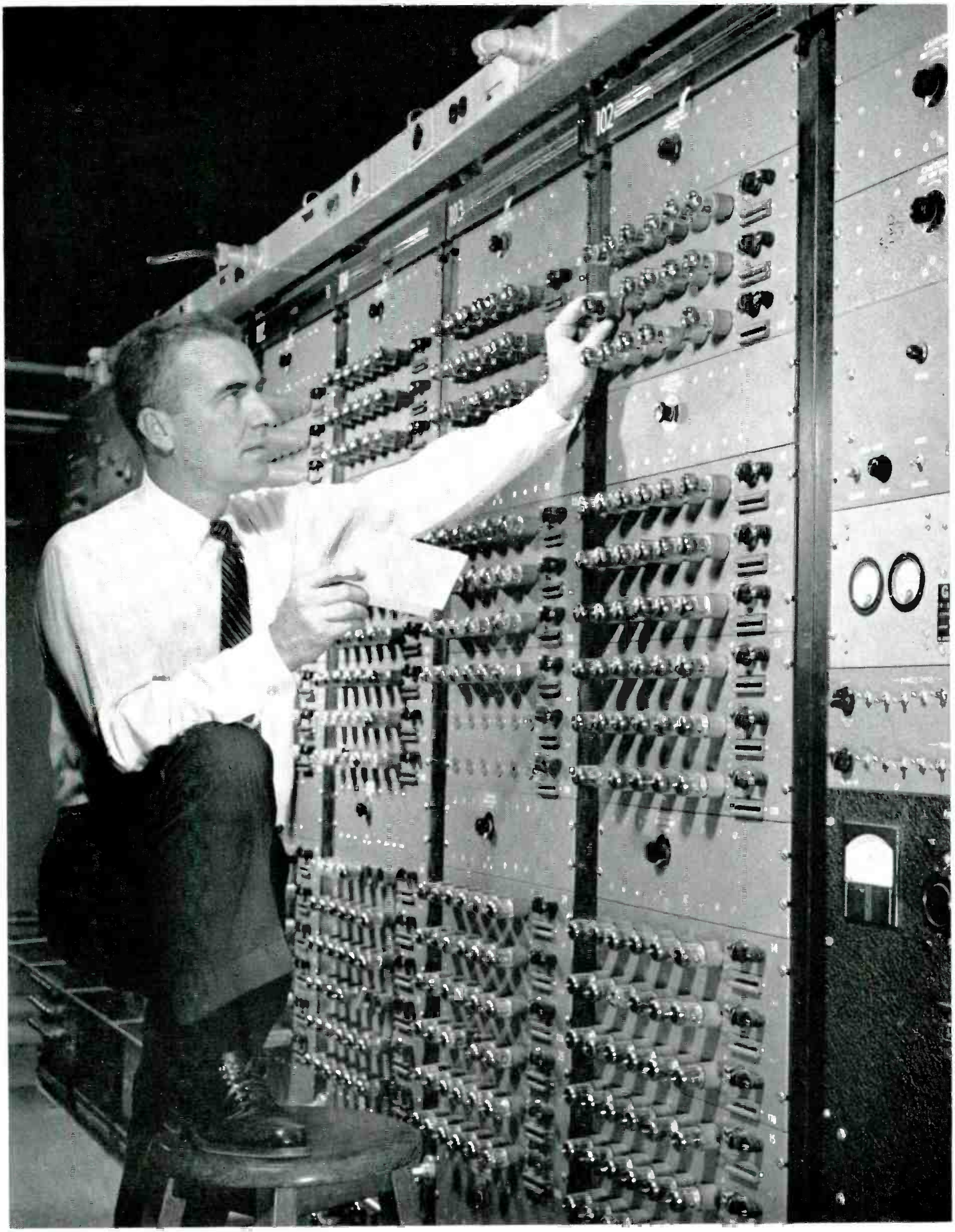
Cover

An experimental model of a new general-purpose cordless switchboard for handling most types of operator-assistance calls. This new board, with possible modifications, will be made available in a few years as part of proposed plan for implementing person-to-person DDD. (See page 299.)



Life-testing electron tubes for submarine cables. Here, Tom Ross of the Electron Tube Development Department checks tube corresponding to data automatically recorded on business-machine card.

One of the space age's most important concepts—reliability—is actually an old field that has endowed itself with new ideas, new terms and new significance. At Bell Laboratories, design for reliability has always been an important tradition.

R. B. Murphy

Reliability in Telephone Engineering

Reliability is not a new word in the dictionary, but it has acquired new significance in the past fifteen years. During this time, the engineer has seen "Reliability" develop as a distinct field of technical effort. It is now the subject of meetings attended by dozens of engineers and scientists, and it has gained the attention of many industries, where now can be found "Reliability Engineers" and "Reliability Groups."

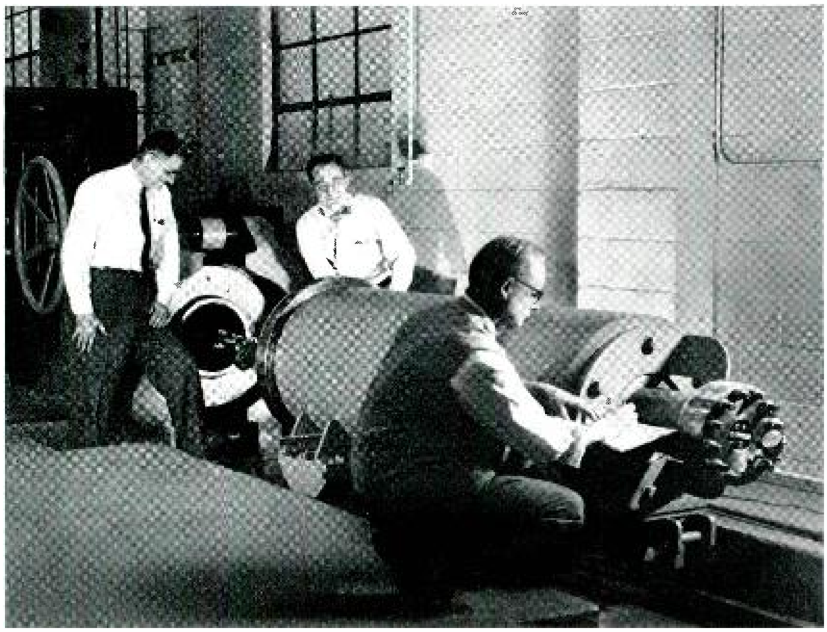
These developments are reminiscent of the pattern of growth in quality control and operations research. As in these fields, the implementation of the basic ideas of reliability can and does contribute substantially to quality objectives.

Designing for reliability is a tradition in Bell Laboratories. It is not a matter of chance but of deliberate effort and policy. There is an embarrassment of riches when it comes to examples. Indeed, it is impossible to do justice here to the successful applications of design principles used to achieve reliability in the telephone field. Later we shall encounter a few cases in point.

There is little question that the nation's defense effort supplied much of the impetus to reliability as it is now known. In fact, the association of reliability with military weapons systems and "failure rates" endows the concept of reliability with an appearance of newness which is not entirely deserved. Reliability may be said to be always a critical factor in engineering design, and as such it has been an object of concern for years. The tense realities of our times, however, have exposed the critical nature of reliability to a broader public, especially in the field of rockets and missiles. New techniques have been added, often because of problems arising in missiles and aircraft. Nevertheless, the ingredients of design which distinguish a reliable system from an unreliable one have always been sought in the design of telephone equipment.

Like the traditional apparel of young brides, reliability has "something old, something new." The ideas involved may be stated in terms of the vocabulary now current, but intrinsically they are not so new as the words may make them appear.

Engineers and others have grappled with the problem of defining the word reliability. Perhaps one could say that reliability in a device or in



Engineers at the Hanover, N. J., Laboratory test ability of cable structures to withstand pressures even greater than those at ocean bottom.

a unit of equipment is its ability to work satisfactorily. But what does it mean to work satisfactorily? Certainly there has been a great deal of recent emphasis on the influence of such environmental factors as temperature, humidity, shock, and vibration, as well as on length of life and on human engineering, particularly with operators and repairmen in mind.

It is inviting to compare reliability with quality control at this point. The two fields have a considerable degree of overlap. There has been much discussion of the scope and relative merits of each field and, at times, argument about the activities that are proper to and characteristic of each. Similar debates have taken place regarding systems engineering and operations research. It is often impossible to draw a line between quality control and reliability, or sometimes even to distinguish between these two activities in any way. In other cases, the difference in function between the two fields can be sharp and well defined, depending on how they are realized in organizational structure and on how the jobs are actually carried out.

Let us examine some of the ideas which have given reliability distinct substance and flavor. We have mentioned the matter of definitions: to some, it has seemed easier to define reliability in terms of a statistical measure. The Electronic Industries Association has adopted the definition, "Reliability is the probability that an equipment or device will perform its intended function for a specified period of time when used in the manner and for the purpose intended." But agreement on just what measure should be used is not universal. Indeed, the wide variety of engineering problems leads to different measures of reliability, depending on the problem.

Sometimes the appropriate measure is a probability of failure before a given time under specified environmental conditions; in other cases it may be per cent "up-time," or the average percentage of time a system is expected to be capable of operation.

Time, environment and people are important aspects in almost anyone's concept of reliability. The purpose of most reliability programs is to relate these factors to the intended function and to bring this knowledge to bear in design, manufacture and use so that the systems or devices involved work satisfactorily. To the designer, this means he wishes in the end to be in a position to *predict* satisfactory performance with a high degree of confidence.

There has been great emphasis in reliability symposia on the study of length of life of components, circuits, and systems. Statistical techniques have been widely applied for this purpose, with particular emphasis on statistical studies of systems whose lives are determined by the "weakest link." In such cases, the failure of a device or a circuit is considered to imply failure of the system. Great reliance has also been placed on the notion of "random failures"—the idea that probability of failure in a small time interval is approximately proportional to the length of the interval and independent of its distance from any reference point in time *(see box on page 287)*. Studies conducted along these lines indicate that often surprisingly long average life must be expected of components to have a good guarantee of system life of a comparatively short time.

A second point of emphasis has been the effect of different kinds and levels of "stresses." The word "stress" has been borrowed from the vocabulary of the mechanical and aeronautical engineer and applied with increasing liberality to electrical engineering. For example, stress may take the form of the expected ambient temperature within an amplifier enclosure when the amplifier is operating normally; it may be the effect of switching a transmission system from "standby" to "operate"; it may be the shock caused by dropping a piece of apparatus from a fixed height; it may be the peak demand for service in a central office. Sometimes the level of stress is specified in terms of other variables, such as season or time of day. It is a canon of the reliability field that designers must discover what the stresses on a system or component are or will be to anticipate and avoid consequent weaknesses in design.

Stresses may be roughly sorted into two groups: those introduced suddenly and not always predictably; and those of a continuing nature, which usually change in more or less predictable fashion with the passage of time. "Margin" is a common term for what might be called evasive action on the part of the designer against these two kinds of stresses. A typical sudden stress is the failure of a part of a system. Alarms, automatic checks of circuits, and parallel facilities ("redundancy") are common means of securing margin in this case. The usual objective of margin against sudden stress is to avoid abrupt and unforeseeable end of life, often called "catastrophic failure."

A typical continuing stress is the rms current through a resistor in a given circuit. If such a resistor were in a pulse circuit, a more pertinent stress might be peak current. In this instance, designers have frequently obtained margin by using resistors at well below their recommended handbook levels. Generally, the objective of margin against continuing stress is to minimize gradual degradation of life or performance.

It is characteristic of reliability work that different problems are associated with distinct levels of engineering—namely, materials, component, circuit, subsystem and system. Considerable attention has been given to the isolation of these levels, separate attacks on each, and the synthesis of the separate attacks at the system level. Even so, the reliability problems at different levels overlap and react with each other. We can further see, as we move up in the hierarchy of complexity, that even the nature of these problems changes.

One can say that a concern with "failure rates" is common to all levels, but the problems of human engineering become more evident as the hierarchical pyramid is ascended. For instance, at the subsystem level, the reliability of modular units depends to some extent on the fair certainty that the shock of turning on a new circuit does not cause it to fail, that damage to other parts during replacement is minimized, that the proper modular circuit will be changed when change is required, and that adjustments incidental to the change will not be inconsistently lengthy or complex. Human and technical factors are thus intertwined. At the peak of the pyramid, we may even stop for a moment and contemplate "factors" like fishing trawlers. As a matter of fact, the possibility of a fisherman's gear snagging the transatlantic cable *had* been considered during the design stage.

The considerations somewhat briefly treated above are typical of those brought forth in reliability symposia. One more might be mentioned: the reporting of failures. This idea has had a mixed reception for a number of reasons; the most prominent being the wide divergence in inclination and ability of the people involved to contribute to such a program.

A readily replaceable printed-circuit package for TASI. Thousands of packages make up units, rear.

On the other hand, the value of engineering analyses of failing material is not so widely disputed. The Bell System has used the Engineering Complaint for some years in this respect. Such complaints are usually submitted when an Associated Company feels the circumstances warrant remuneration for the material involved. However, engineering judgment has played the major part in determining the advisability of making a complaint.

As stated in the beginning, the essence of the ideas just reviewed is not new in engineering design in the communications field. What *is* new is a wider interest on the part of American industry and the appearance of new kinds of problems, particularly in the military sector, which have called for intensified effort and even new techniques. Present literature in the field of reliability does not always convey this impression.

Spread of Modern Concepts

Furthermore, as is often true in the spread of technical movements, a peculiar *mystique* has developed around reliability. There are even a few instances of what appears to be overzealous conversion. Television viewers have been treated, by courtesy of the sponsor, to the sight of a home receiver descending from the skies by parachute and landing with the impact of an airborne soldier. The receiver was alleged to be still in working order. To most of us, the inferences about the reliability of parachutes are stronger than those concerning the reliability of home receivers.

Another defect in the present progress of reliability has been a tendency toward a somewhat specious form of generality or universality. This has taken the form of uncritical devotion to certain theoretical precepts which may from time to time deviate from the substance of fact. For instance, the hierarchical conception of reliability discussed briefly above is one which some problems cannot be forced to fit. There have also been unwary interpretations of failure rates in terms of the average life of devices or equipment.

Finally, perhaps too much time and money have been spent on ceremony. More meetings have been held in the name of reliability than could be considered professionally or economically justified. Indeed, with the extensive facilities for publication open to the engineer today, there is little chance that a man with an important idea will be unheard.

In the well established switching and transmission systems developed at Bell Laboratories, one does not have to look far to find principles of reliability applied in design. For instance, the design of common-control switching systems like No. 5 crossbar depended in part on extensive knowledge of the capability of various kinds of electromechanical apparatus and on a broad knowledge of the environmental conditions to which such apparatus would be exposed. The designers also had to know how many billions of operations the relays and switches could withstand and still give satisfactory service. The problem of "maintainability" was partly solved by the development of automatic trouble recorders.

Another obvious reliability problem in the design of the No. 5 system was to provide switching facilities in a way that would make the probability of blocking a call very small, without making the system too costly. A prime consideration here was the variable quantity of traffic. In the language now used in reliability work, we would speak of "redundancy of talking paths," although yesterday the words "alternate paths" would have served the same purpose.

In crossbar switching systems, the use of design principles for reliability is most striking in the safeguarding of the common-control function. For instance, on *each* call there is a sequence of continuity checks within the common control and in the switching and transmission path that services the call. Among these are a check of the customer's line and checks for false grounds, crosses and opens. Furthermore, there are checks on timing so that, for example, if a marker—the unit that sets up a call—takes more than a predetermined time to perform its function, a trouble recorder is summoned automatically, and a second trial to serve the call is initiated, using another marker.

The No. 5 crossbar system has by all accounts succeeded in achieving two important reliability objectives: continuity of service and low maintenance cost. It is a system that incorporates "margin" against "sudden" stresses by the provision of redundancy, second trial, and elaborate "guards." Thus we see that the fundamental concepts of design have a great deal to do with realizing reliability.

Even more than the No. 5 system, the electronic switching system (ESS), or electronic central office (ECO), is designed to devote a good part of its time to checking its own operations and diagnosing its own troubles. Another sort of checking being used increasingly in digital systems is supplied in the form of error-correcting codes, which Laboratories men have played a prominent role in developing.

An interesting example among transmission systems is the transatlantic cable. The design of

The tools of research include those of an abstract nature. A general example is mathematics, from which is drawn the specialty of statistical analysis. A popular tool at Bell Laboratories, statistics is used extensively in the development of electronic devices.

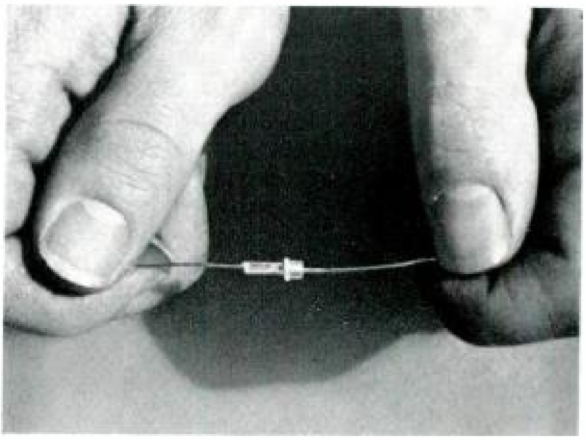
G. J. Levenbach

The Use of Statistics In Device Development

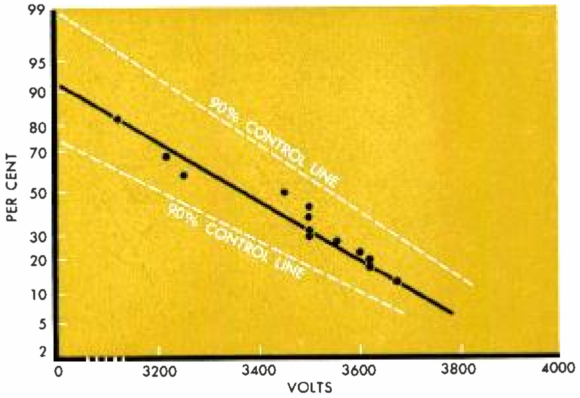
Statistics, as one dictionary describes it, is "The science which deals with the collection, classification, and use of numerical facts or data bearing on a subject or matter." This encompasses quite a field, and consequently, statisticians today must specialize. Statistical methods are based on probability theory. This is a branch of mathematics that has had much use at Bell Laboratories in such areas as information theory, trunking problems, quality control, and the organization of experiments and the interpretation of experimental data.

Statistical theoreticians have developed many procedures to operate on data. They can apply these procedures to almost any experimental situation, be it in agriculture, psychology or electronic development. This does not imply, however, that a set of "recipes" is available to supplant scientific investigation. The scientist will always have to apply his experience, judgment, and intuition. However, statistical methods can help him obtain numbers to measure quantitatively the unavoidable fluctuations in data inherent in any experiment. He can then use these values in his theoretical and mathematical conclusions.

Let us take the area of experiments as one application of statistics and examine a few examples of practical problems that have occurred



P-n junction capacitor on which was performed a statistical study of capacitance characteristics.



Capacitor breakdown measurements plotted on extreme-value probability paper. Ordinate gives percentage exceeding breakdown voltage on abscissa (See extreme-value distribution, page 295.)

at the Laboratories. When performing an experiment, one might expect a certain result—for example, on the basis of theory. On the other hand, one might have no clue as to what the experimental data will prove. In both cases, however, the experimenter will study the data very carefully. In the first case, he will want to see whether his expectations are borne out, and in the second case, he will want to find a general structure underlying his experiment.

Let us imagine ourselves for a moment watching the 17th century British physicist, Robert Boyle, doing his experiments with air. These led to his now famous law which says that at a certain temperature, the pressure of a gas and the volume it occupies are inversely proportional to each other. Conceivably, Boyle might have plotted on a graph his observations of pressure against volume and then "fitted" a line—tried to draw some kind of smooth curve—through the points. Having done this, he might have noticed that the inverse relationship would roughly correspond to his observed data. In Boyle's time, the kinetic theory of gases was not yet available to guide his thinking quantitatively. But actually, he did have some "theory" suggesting qualitatively that the pressure would rise when the volume decreased. If Boyle did plot the data, he probably attributed the discrepancies to measuring errors; after all, his measuring equipment was rather crude.

Today, however, measuring equipment is far from crude. Thus scientists would be concerned about the errors, and would try to find out if some systematic phenomenon caused them or if they just occurred at random. For example, they might take from a graph of plotted values the difference in a vertical direction between individual observations and a fitted line and study these differences, or "residuals," separately. But unambiguous results from such a procedure require something better than just fitting a line by eye.

About 1800, the German mathematician, Karl Friedrich Gauss, then only 18 years old, felt this need for something better when he started to evaluate certain astronomical observations. He thereby developed the method of "Least Squares," today widely used in curve-fitting problems. In this method, a set of data and the general equation of the curve to be fitted, permit the experimenter to determine the curve analytically by imposing the condition that the sum of the squares of the deviations from the line should be a minimum. The values are squared so that the pluses and minuses will not cancel each other. This sum of squares, evaluated during the fitting procedure, is a measure of the deviations from the line—the residuals. But it does not tell anything about the randomness of the residuals, which have to be investigated separately. This aspect will be illustrated below.

The development of many products encompasses three phases. These are "conception," "construction," and "evaluation," in that order, and they repeat in a cycle until the product has been fully developed. The cyclical aspect arises when the results of evaluation bring about a new conception which, in turn, results in another construction and consequently, another evaluation. The cycle will terminate when the product is sufficiently improved to permit final manufacture.

Mathematical Model

In studying semiconductor devices, physicists often use a mathematical "model" of the physical phenomena. Here they are using the evaluating phase of development. Obviously, they will be interested in how well the model fits the experimental results. Thus, they might discover discrepancies leading to further improvements of either the model, the experimental technique, or both.

The p-n junction capacitor is a case in point. One of the offshoots of semiconductor development, this two-electrode device provides, for high-frequency applications, a variable capacitance in a small package. For a typical unit, a measured characteristic—capacitance versus voltage—is plotted as in the top part of the diagram at the right. This curve represents a mathematical model for the p-n junction capacitor. Physicists claim that, over a limited range of voltage, it can be represented theoretically by an equation containing three unknown constants.

Given a set of capacitance measurements at different voltages, as in the diagram, we have to determine these three constants. Fitting a straight line to data requires only two unknown constants—the slope and the intercept with any fixed vertical line. Our case, however, is nonlinear and has three constants, each of which represents some physical aspect of the operation of the device. Thus, our solution is much more involved.

Thanks to the particular structure of our equation, however, we can proceed as follows. We *guess* the value of one constant and then apply the straight-line technique to the remaining two. From the chosen value of the first constant, we get not only the estimated values for the other two, but also the value of the sum of squares of the residuals. We go on to explore many different values of the first constant, obtaining corresponding values for the sum of the squares of the residuals. Estimates for all three constants corresponding to the minimum of this sum of squares become our final estimates, thus adhering to the principle of "least squares."

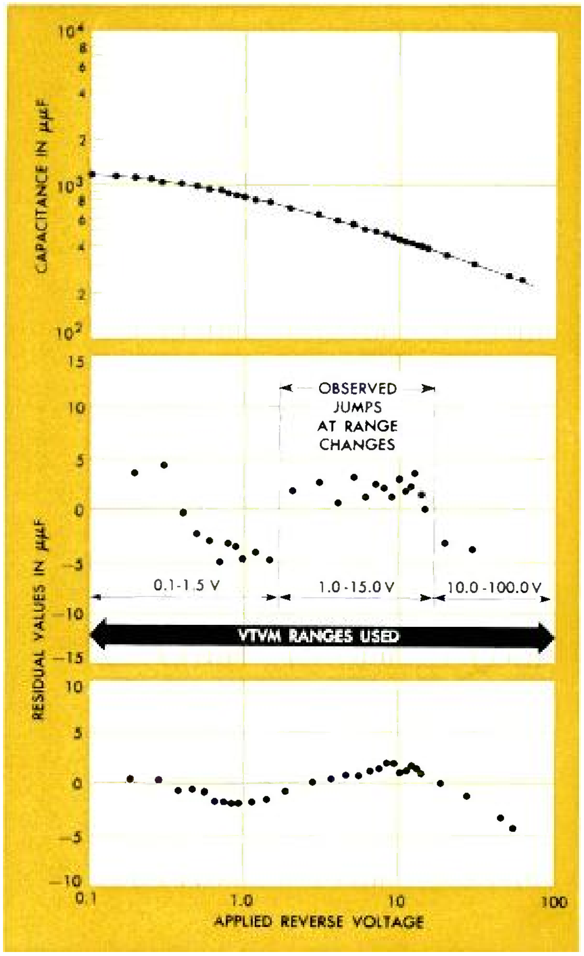
What the Residuals Show

Fortunately, an electronic computer is available at the Laboratories to do these calculations (RECORD, *October*, 1959). Once the program for this computer has been written, we can try virtually as many values of the first constant as we like. The curve in the top part of the diagram has been drawn using the estimated constants for a particular unit. To the eye, and on the scale drawn, the fit looks pretty good. We get a somewhat different picture, however, when we plot the residuals.

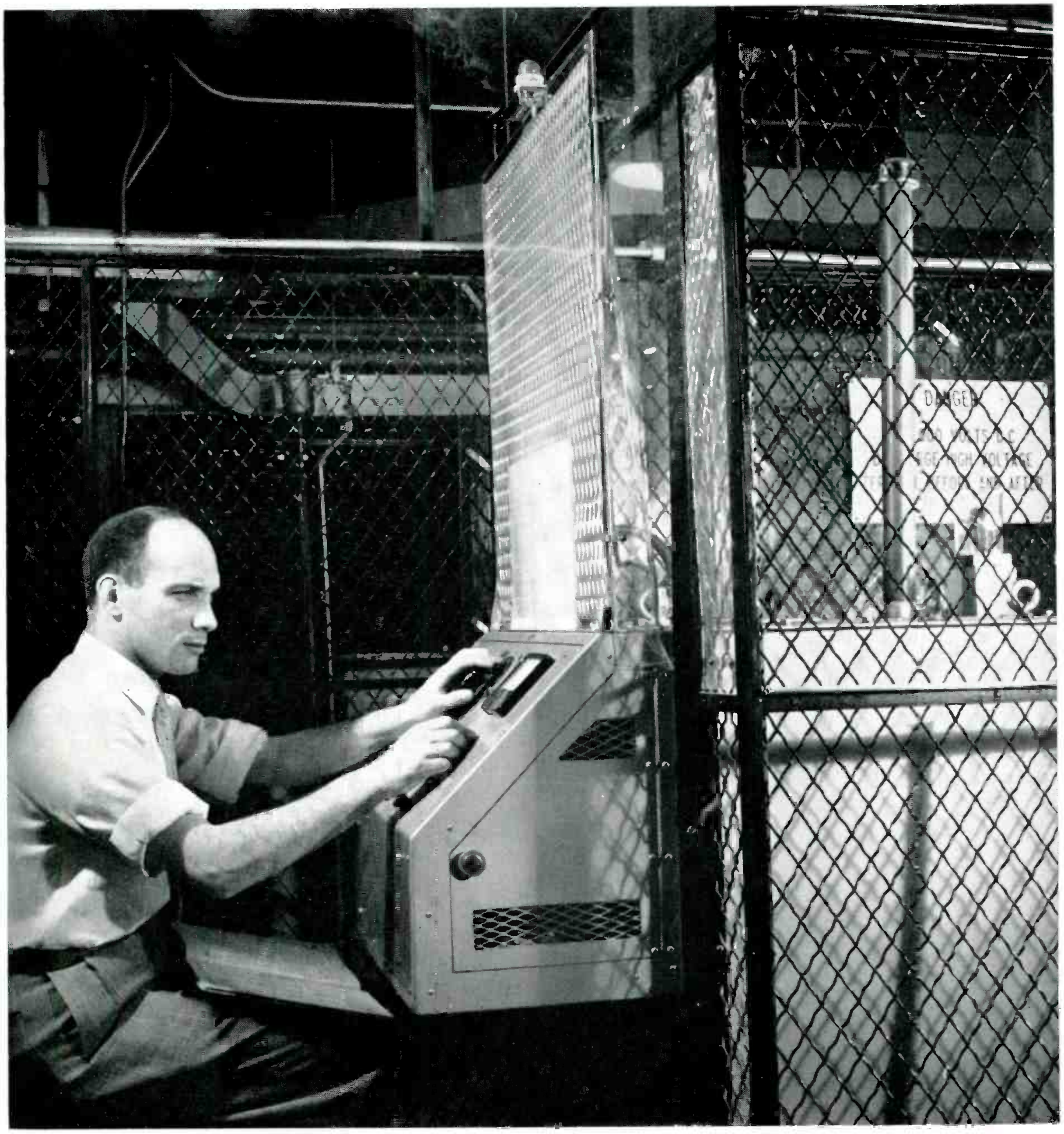
The middle part of the diagram is a plot of these residuals at a certain stage of the investigation. It shows a systematic factor in addition to random error. This factor—the "jumps" in the residuals—coincides with the switching of the voltmeter used from one measuring range to the next. The experimenter can avoid this with a better voltmeter, as illustrated in the bottom part of the diagram. In effect, the use of residuals corresponds to using a magnifier.

We must remember here that the least-squares procedure yields only estimates for the constants in the equation. And since our measurements are subject to error, we want to know how precise these estimates are. Physicists would apply to these estimates the concept of "probable" errors, specifying their values to be exceeded only fifty per cent of the time in an experiment. Statisticians, however, prefer to limit values of the error such that they will be exceeded a smaller fraction of time—for example, five per cent. In any case, if for a particular constant these limits turn out to be very wide, either the experiment has not measured the constant accurately enough, or it is necessary to modify the model to obtain a better description of the physical world.

Let us now consider, from a different example, the results of an experiment on a set of devices measured for one particular characteristic. The



Top curve represents mathematical model of p-n junction capacitor. Plotted points appear in same part of illustration. Residual values are plotted against the same abscissa (middle), giving a magnifying effect. Apparent "jumps" in values are eliminated (bottom) with more accurate meter.



Jack Prins operates high-voltage tester in breakdown experiments on paper capacitors. Device is subjected to steadily increasing voltage to find the point at which its dielectric breaks down. Because of high voltages used in breakdown tests, the device is tested in protective cage, right.

restriction to one characteristic simplifies the exposition. Having obtained a set of measurements in this type of experiment, we like to compress the information so that a few parameters will describe the results adequately. We can do this with a mathematical expression for the distribution of the observed characteristic. From the data, we estimate the parameters in this mathematical expression, one at a time, making the problem similar to the previous one on the p-n junction capacitor. Then we use this expression, for example, to compare the results with those obtained in other experiments on similar devices.

A typical application of this use of statistics arose in connection with electrical breakdown measurements on paper capacitors. These capacitors, with special paper as their dielectric, have been used in large quantities in the Bell System for many years. It is inconvenient to apply breakdown tests to single layers of paper. For this reason, such a test is usually performed on finished capacitors, permitting at the same time a check for defects in the whole structure.

Each capacitor could break down at many spots in its dielectric, depending on the voltage applied across its terminals. However, in the test setup, gradually increasing the voltage causes the unit to break down at the weakest spot. Measuring these voltage values for a set of capacitors of the same type gives us a distribution of the "weakness" of the weakest spots. This corresponds to what is called the "extreme-value" distribution method. The method is illustrated in the graph on page 290.

Reducing Measurements

Many phenomena can be described by this distribution. Examples include: heaviest daily rainfall in a particular season, highest flood of a river in a year, strongest gust of wind encountered by an airplane in a certain area. In practical applications of extreme-value distribution, results are plotted on special probability paper, so that the measurements will lie on a straight line. Because a straight line is determined by two parameters, this paper automatically achieves one step in our objective: to reduce measurements to a few significant parameters.

One conclusion can easily be drawn from such a graph. Our capacitors belong to a "family" from which we picked units to be measured. Thus we can read directly what percentage of them will exceed a certain breakdown voltage. But it is often necessary to find out how precise is the estimate of this percentage. As indicated in the figure on page 295, lines drawn on either side of the fitted line are one way to determine the percentage limits. They indicate the care we must use in drawing conclusions from small samples.

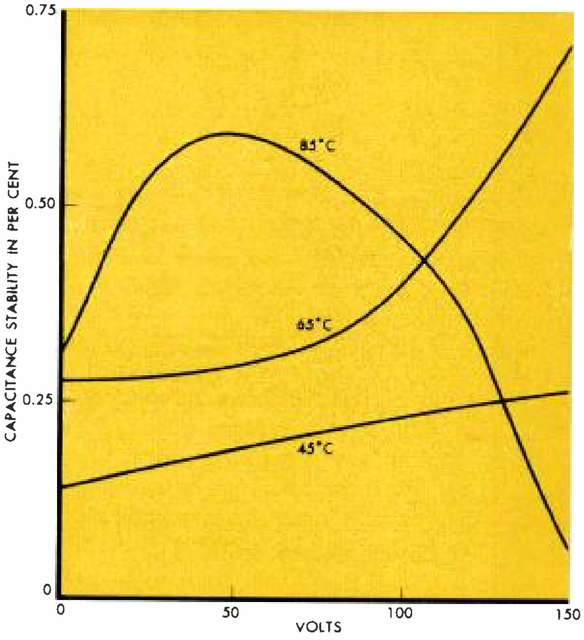
Now let us examine a situation where several factors are studied simultaneously for their effects on experimental units. Factors such as temperature, humidity, or applied voltage all may influence a characteristic of a new component. Other types of factors might be a group of different manufacturers, or even different sources of raw material.

Traditionally, these investigations have been performed by varying one factor at a time while keeping all the others constant. Subsequently, the second factor is varied, while the first and all others are held constant. This procedure is continued until all of the factors which influence component characteristics have been studied.

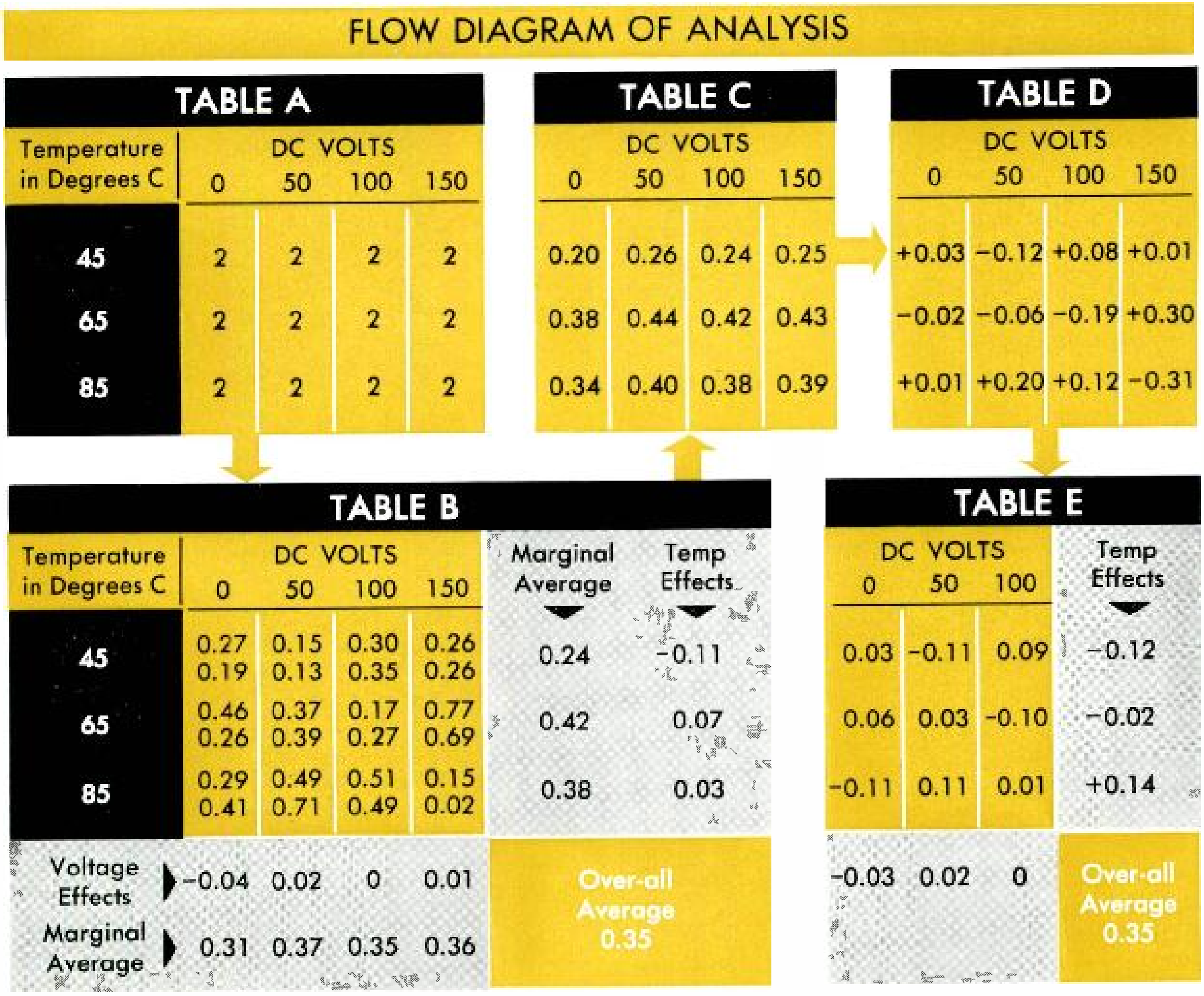
In many practical situations, however, the behavior of one factor depends on a particular value of another. For the paper capacitors, for example, this would mean that changes in capacitance with voltage are not similar under different temperature conditions. In other words, curves plotted for two different temperatures would not be parallel. In such a situation, we say that there is an "interaction" between voltage and temperature, and if interactions are suspected to be present we should determine their importance by redesigning our experiments.

To illustrate, let us discuss part of an experiment performed during development of an electrolytic capacitor with tantalum foil electrodes. Because they are small for their voltage and capacitance rating, these are widely used in communication equipment.

In one stage of this development, scientists had to explore the characteristics of the device under a variety of conditions. For example, they studied the stability of the capacitance for a



General information on relationship between temperature and voltage breakdown on test capacitors. A more formal analysis would be required for cases having a large number of parameters.



FLOW DIAGRAM OF ANALYSIS

TABLE A

Temperature in Degrees C	DC VOLTS 0	50	100	150
45	2	2	2	2
65	2	2	2	2
85	2	2	2	2

TABLE B

Temperature in Degrees C	DC VOLTS 0	50	100	150	Marginal Average	Temp Effects
45	0.27 0.19	0.15 0.13	0.30 0.35	0.26 0.26	0.24	−0.11
65	0.46 0.26	0.37 0.39	0.17 0.27	0.77 0.69	0.42	0.07
85	0.29 0.41	0.49 0.71	0.51 0.49	0.15 0.02	0.38	0.03
Voltage Effects	−0.04	0.02	0	0.01	Over-all Average 0.35	
Marginal Average	0.31	0.37	0.35	0.36		

TABLE C

DC VOLTS 0	50	100	150
0.20	0.26	0.24	0.25
0.38	0.44	0.42	0.43
0.34	0.40	0.38	0.39

TABLE D

DC VOLTS 0	50	100	150
+0.03	−0.12	+0.08	+0.01
−0.02	−0.06	−0.19	+0.30
+0.01	+0.20	+0.12	−0.31

TABLE E

DC VOLTS 0	50	100	Temp Effects
0.03	−0.11	0.09	−0.12
0.06	0.03	−0.10	−0.02
−0.11	0.11	0.01	+0.14
−0.03	0.02	0	Over-all Average 0.35

particular time under various voltages and temperatures. At this stage in the development of the tantalum capacitor, not too much was known of its actual properties. However, since designers were interested in voltage and temperature up to 150 volts and 85 degrees C, respectively, the basic part of the experiment was made in these ranges. (*See set of tables on this page.*) Each "cell" contained two capacitors (Table A) which were subjected to the voltage and temperature listed for a fixed period of time. The change in capacitance as measured before and after the treatment, indicated the stability.

Yardstick from Results

One set of results, expressed in per cent change, is listed in Table B. Because of the way the experiment is set up, the same number of capacitors is examined at each temperature and voltage. Thus their averages can be compared directly because they have the same "weight." The question is, how significant are the observed differences? Clearly, we need a yardstick for this. And since in the beginning stages of the development of a device we are usually in a state of ignorance, we must derive the yardstick from the experimental results themselves. The statistical procedure applied in cases like this is the "Analysis of Variance," whose description falls outside the scope of this article. Once such an analysis has been made, however, we can explain the results with a few simple diagrams.

In this particular experiment, we can obtain a yardstick as follows. The capacitors in the same cell are subjected to identical conditions during the test. Therefore, the differences between those pairs—differences in the change of capacitance before and after—are attributable to the fact that not all units will behave exactly alike, even if they are from the same "family." Other causes come from errors introduced in the measuring process. These latter phenomena are, in a way, the "noise" of our experiment, and the parameter variations are only significant if they are larger than this noise.

Consider the differences between the two numbers in each cell gotten by subtracting in Table B the bottom per cent change from the top one. These differences, divided by two, are listed below in order of value. (Note that two sets of values are identical.)

−0.11 −0.06 −0.05 −0.02 −0.01
0
+0.01 +0.04
+0.01 +0.04 +0.06 +0.10

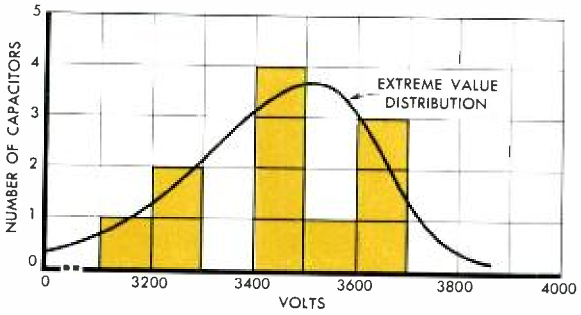
If we assume that the errors follow a normal distribution with an average equal to zero, we would estimate from the above data the standard deviation of that distribution to be 0.04 per cent.

Now we are nearly ready to compare the differences between the marginal averages in Table B with the yardstick just obtained. But first we have to check the interactions between voltage and temperature. To do this, we compare the marginal averages with the average for all the data. In Table B, the column labelled "Voltage Effects" gives the deviation of each marginal average from this over-all average. The row labelled "Temperature Effects" is treated in a similar manner.

Using these effects, we can build up a set of so-called "predicted" values that we might expect to find if the three values—the over-all average, the temperature, and the voltage effects—explained the whole picture (Table C). For example, adding 0.35, −0.11, and −0.04 gives us 0.20, the predicted value for the cell in the upper left corner of the table. To compare this with the actual value, we average the two observations in the same cell

$$\frac{0.27 + 0.19}{2} = 0.23$$

and note a discrepancy of 0.03 (0.23 − 0.20). This again, is a sort of residual.



Result of voltage breakdown tests on group of 11 paper capacitors. Measurements give distribution of weakness of weakest spots, correspond to "extreme-value" distribution (see plot on page 290).

Whole Set Comparison

Table D illustrates this comparison for the whole set. Each of these residuals can be identified with a particular combination of temperature and voltage. Here we observe considerably larger values for some residuals than appear in the list at the left. This signifies that the three values mentioned above are insufficient to explain the capacitor's behavior. The interaction of temperature and voltage must also be taken into account. From Table D we see that the interactions grow in importance as the temperature and voltage rise. In other words, this set of capacitors becomes less predictable under the stress of increasing temperature and voltage.

As an extension of the method, we can omit the highest voltage from the data and calculate the interactions in the same way as above. Table E shows that the interactions are then indistinguishable from the "noise," represented in the list above. Therefore, for this voltage range, it may be adequate to confine ourselves to the marginal averages for describing the capacitor's behavior. A formal analysis of this case shows that in regard to instability, variations in temperature are significant; variations with voltage are not. Much of the information, in fact, could have been obtained by examining a plot of the observed points, as in the graph on page 293. However, when the number of factors increases, or the effects become more subtle, a formal analysis is mandatory.

These examples are only a small fraction of the ways in which statistical analysis is put to work at Bell Laboratories. And because technology, especially here, is expanding so rapidly, scientists and engineers need every available short cut to final development of a device. Thus, we can expect statistical methods to play an even greater role in future laboratory experiments.

In communications research, the future becomes the present whenever we can answer questions about a system before the system is built. A dependable "answerman" for such questions is Bell Laboratories Sibyl simulator. This device is now being used to collect information on how users will react to a satellite-relay communications system even before the satellite goes up.

SIMULATING SPEECH THROUGH SPACE

News of Human Factors Engineering

Communications in outer space, once only a theme for science-fiction writers, is now an accepted fact of life. For more than two years, we have been on speaking terms with several artificial satellites—one as far as eight million miles away. From them we are learning something of the nature of the universe. Now, they're about to help us learn something of a technology relatively close to home. We are going to find out if radiotelephony can add to its aviary of transmission methods a new, high-flying bird—the relaying of signals from one place to another on earth via an orbiting satellite.

To pursue this idea, the Bell System and the National Aeronautics and Space Administration are jointly sponsoring "Project Echo"—a pilot study of satellite communications that involves placing in orbit a 100-foot diameter balloon with an aluminized surface. Using this big shiny sphere as a bounce medium, scientists in Goldstone, California and Holmdel, New Jersey will talk to each other in a radically new way. Essential to the success of this project are a number of recent refinements in transmitting and receiving equipment. Chief among them are two accomplishments by Bell Laboratories—an extremely low-noise receiving antenna (RECORD, *May*, 1960) and a highly efficient solid-state amplifier, the maser (RECORD, *May*, 1960).

Any new system presents problems, however, and this one will be no exception. One important problem to be resolved in telephone transmission via satellite is that of transmission delay. Consider, for example, a telephone call going over a multi-link connection between New York City and San Francisco. The "round-trip" delay on such a circuit might be as long as four or five hundredths of a second. Signals relayed via low-altitude satellites (3000 miles high) would take somewhat longer. However, these delays wouldn't ordinarily interfere with a two-way telephone conversation.

But now suppose this connection goes by way of a satellite 22,300 miles up—the height an active satellite must achieve to travel "with" the earth and appear to be stationary over one spot. Then the round-trip delay will be about *six-tenths* of a second, and this probably will affect the conversation. Fast as they are, electromagnetic signals do have the finite speed of 186,000 miles per second. And the conversation of our example will travel from New York to the satellite, to San Francisco, to the satellite, and back to New York—a distance of just under 100,000 miles.

Laboratory Experiment

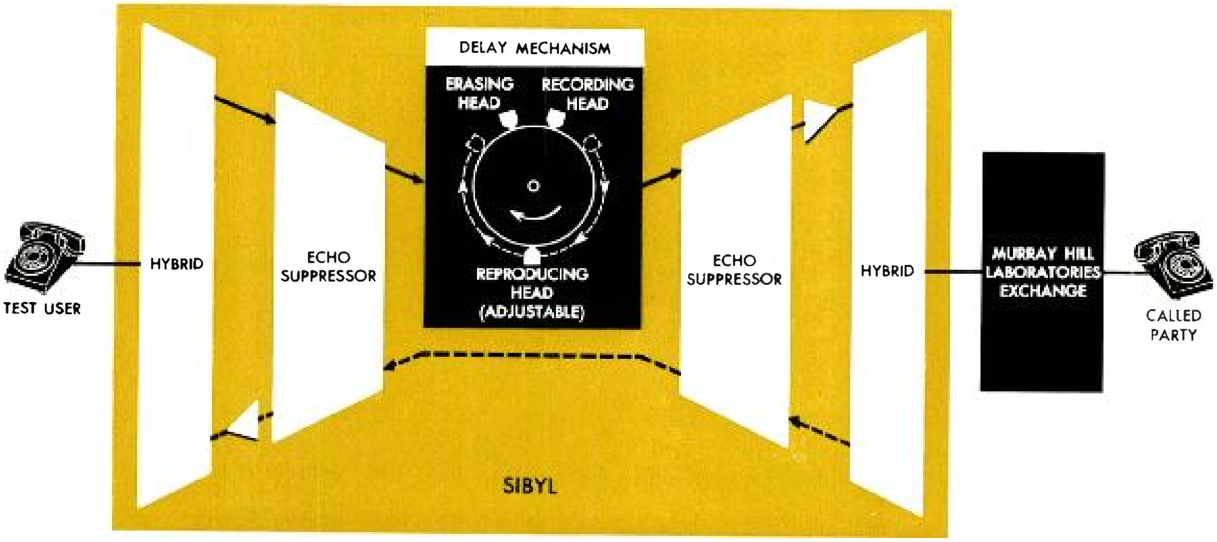
An example of what this problem involves can be seen in a laboratory experiment in which two telephone talkers alternately read off a series of numbers. Without a delay, the counting can proceed steadily—"1, *2*, 3, *4*, 5, *6*. . . ." But a 0.6-second delay in this circuit would cause both talkers to hear a "staggered" series of numbers. For example, to the first talker it would sound something like "1 . . . , *2*, 3 . . . , 4, *5*. . . ." This probably would cause interruptions and general confusion. What Bell Laboratories is interested in here is how much this "abnormal" transmission will affect long-distance conversations.

Fortunately, we don't need to send up a set of complicated and expensive satellites to find out how big a problem this is. We don't even need one satellite. At the Laboratories a versatile simulation device called "Sibyl" (RECORD, *November*, 1958) is already finding out just how much delay a telephone user can tolerate and still successfully hold a conversation.

Sibyl works by intercepting the telephone lines of test users so that it may give them simulated services in their normal work environment. At the same time, this simulating device automatically collects objective data on the performance of a man-machine system while, of course, preserving the privacy of the actual conversation. In conducting the test on transmission delay, Sibyl is testifying to her multipurpose nature—the only additions necessary have been a simple delay mechanism and a control panel.

The Human Factors Engineering Group at the Laboratories has arranged a program to connect the telephones of 100 Laboratories employees to the modified Sibyl setup. These volunteers are divided into five groups of twenty, each group to experience a separate delay varying from 0.05 sec. to 1.2 sec. All users will participate at their normal work locations. The 100 pairs of telephone wires have been temporarily intercepted at the switching office for the Murray Hill Laboratories, and brought to the simulation machine. Here, they enter the various switching and recording devices and the delay mechanism.

Basically, the delay mechanism serves to put the test user's conversation on a magnetic drum. Thus, on those calls being purposely delayed, the called party hears recorded speech. Riding the drum's surface as it revolves is a recording head,



Arrangement of Sibyl modification for simulated transmission by satellite. Major innovation is the adjustable delay mechanism with privacy-providing erasing feature. Echo suppressors deliver "life-like" feature. Despite their drawbacks, these will be required in actual system.

R. W. Lank adjusts the delay mechanism used to conduct simulated tests of satellite transmission.

a reproducing head, and an erasing head. The circumferential distance between the recording and reproducing heads is adjustable, permitting variation in delay corresponding to varying heights of satellites. This gives the test program a unique advantage over the actual satellite which, of course, cannot adjust its height. The erasing head serves Sibyl's avowed purpose of maintaining user privacy. Conversation is erased immediately after it is transmitted.

During the week-long test period, each participant experiences delay on some of his calls. Since the probability of connection to a satellite path is random, the user's delayed calls can be adjusted to correspond to the average number of long-distance calls he would make in a normal week of telephone communication. A user's reaction to quality of transmission varies from call to call, depending on such factors as its relative importance. And it is better to obtain his judgment of "adequacy" as soon as possible after each call, rather than adopt the conventional procedure of waiting days or weeks to get a final, single over-all appraisal. Immediate reaction results in the detailed information helpful to understanding the process—in this case, the delay in transmission on a normal telephone call.

The test user "votes" on each call to indicate its acceptability. He expresses his judgment, after he finishes the conversation but just before he hangs up, by dialing the digit "7" if the call seemed "normal," "8" if he observed delay but was not bothered by it, and "9" if he deemed the quality of the call inadequate.

In addition, the user can operate an "emergency button" by dialing "2" any time during important and possibly one-time calls that exhibit too much delay for coherence. For faulty memories, the Human Factors Group has provided a "vote reminder" in the form of a small sign on the user's telephone. This pops up when he lifts his handset and must be pushed down manually before he can hang up. The sign's message, brief but explicit, is "Vote!"

Accompanying the delay in long-range transmission is the equally annoying problem of "echo." Ordinarily, in a circuit as long as that proposed for a satellite relay system, the talker can hear his own voice, also about six-tenths of a second after he has spoken. In the Sibyl arrangement this is overcome with a commonly used "echo suppressor," arranged to cut off the low-level signals representing the talker's voice returning to his own telephone. But such cut-off arrangements have a disadvantage, especially in delayed circuits. Because a conversant may sometimes think his message is not getting through, he will repeat it. As a result, both parties talk at once and effectively "chop off" some of each other's words. Nevertheless, this is probably an inherent weakness in satellite relay systems and thus it is proper for the Sibyl test program to study user's reactions to it.

Thanks to Sibyl's versatility, some interesting questions await answers from this simulated test. For example, will the test users be able to tolerate a 0.6-second delay? Will long-distance calls tend to shorten because the caller feels a need to limit his conversation to the bare essentials? And most important, will telephone customers trust their important conversations to a system that may involve delayed transmission, or will they go for the emergency button and seek some other means of communication?

Characteristically, Bell Laboratories is providing answers in the present to these questions of the future. Using the foresight gained from the Sibyl study, we can anticipate the potential reactions of long-distance callers, and thus begin to modify satellite communications systems even before such systems become available.

Despite the continued expansion of DDD, long-distance traffic still requires many operators to assist on person-to-person, collect and other special toll calls. As a start toward mechanization of this type of telephone traffic, a study has been made of the methods and circuits necessary for applying the speed and convenience of DDD to the completion of such calls.

G. H. Peterson

CURRENT EXPERIMENTS IN PERSON-TO-PERSON DDD

Customer dialing has been a part of telephone communications almost as long as the telephone itself. The first commercial automatic exchange was installed at La Porte, Indiana, in 1892—only 16 years after Alexander Graham Bell invented the telephone. A customer connected to this pioneer switching center operated a key to produce the pulses which directed his call through the exchange. This key arrangement gradually gave way to dialing as we now know it.

Dialing remained a "new-fangled" and rather unimportant aspect of the rapidly growing telephone business for some time, however. In 1925, for example, only about 15 per cent of the world's telephones were equipped for dialing. By contrast, over 96 per cent of the telephones in the present Bell System are equipped for dialing, and the convenience, speed and reliability of dialing local and "extended-area" calls have achieved widespread public acceptance.

Direct-distance dialing (DDD) now extends, in many areas of the United States and Canada, the benefits of customer dialing to long-distance calls made from noncoin telephones. At present, these DDD calls are properly completed, and the chargeable time starts, when anyone at the called station answers (thus the term station-to-station call). All of these customer-dialed toll calls are served by Automatic Message Accounting (AMA) facilities so that the billing data can be obtained. At present this is done either with operator assistance or automatically. Bills for customer-dialed DDD calls are always rendered in detail to the calling customer.

A few years hence, when DDD is extended to all of the Bell System, traffic experts expect that about one-half of all long-distance calls will be dialed directly by customers. The other half (which now involves about three-fourths of the toll-operator effort) will still require the assistance of operators, either to complete the call or record billing data.

Most of these assistance calls can be divided into two general types: (1) person-to-person calls,

Close-up of operator positions at Poughkeepsie trial. Pushbuttons are for keying special information to the CAMA equipment, and the lever keys enable operator to perform special services.

which are charged at different rates than station-to-station calls; and (2) collect calls for which the charges are "reversed" to the called station. Chargeable time on such calls does not extend from the time anyone answers at the called telephone. It starts in the first case only when a particular person is reached, and in the second case when someone at the called telephone agrees to accept the charges.

Similar to the collect calls are "special billing" calls, such as credit-card service, which requires verification and recording of the credit-card number for billing purposes, and charge-to-third-telephone calls. Here, the customer charges the call to the number of a telephone not involved in the connection, and the operator must record, and in some cases verify, the number of this third telephone.

Because of the time and work involved on such calls, only about one-quarter of the operator work required at toll switchboards will be removed, even when regular, station DDD is fully implemented. This is far from removing one-half of the work, as one might expect from the anticipated ratio of customer-dialed calls to operator-assisted calls. Also, operators, and many of them, will always be required to help automatic switching systems perform special operations which exceed the ability of the customer or the facilities available at his telephone. In many cases, these operators furnish services which otherwise could not be provided, such as supplying directory-number information.

With continued growth of the Bell System, an increase in the volume of long-distance calls will be inevitable. This poses an important problem: the anticipated growth in the volume of long-distance calls that require the assistance of an operator could exceed the potential economic supply of switchboard operators required to handle them. If this situation were encountered in the near future, it would have an effect on the speed and cost of toll service that would be to the disadvantage of the customer. Here, then, is a genuine problem in "providing the best possible service at the least possible cost."

Historically, a study by C. E. Brooks of the Laboratories in 1947 proposed extending DDD to include person-to-person calls by the use of a distinctive prefix. A few years later, the possibility of a toll-operator shortage was foreseen by the New York Telephone Company. That the problem might become acute in New York is quite logical when one considers that this Company handles about ten per cent of all the telephone traffic of the Bell System. The New York Company suggested that the toll-switchboard problem might be eased if arrangements could be devised to allow customers to dial person-to-person and collect toll calls with a minimum of operator assistance.

Accordingly, systems engineers at Bell Laboratories were requested to undertake a detailed engineering review and study of the general problem and to originate and evaluate various plans for handling long-distance calls which cannot be handled by DDD. This article describes an outgrowth of the New York Company's proposals and this study program—an experiment aimed at improving, through a reduction in operator work time, the handling of special long-distance calls that are beyond the scope of DDD arrangements. The field experiment was devised and conducted by the New York Company. The article also describes some of the features of a proposed standard plan for handling special toll calls in all parts of the Bell System.

Initial studies of the general problem showed that it is practical to devise equipment to allow customers to dial and control most special toll calls with a minimum of operator assistance. Equipment for doing this would be economically attractive only if a large percentage of such calls were dialed by customers. Early studies also showed that only relatively large traffic volumes can justify the expense of such equipment.

A logical second step in the exploratory study was to try to determine the probable extent to which customers would accept the new service as pleasing and fast, and to evaluate more precisely the amount of operator work the new service would require. These two factors could be gauged reliably only by a service trial of the new arrangement, with customers originating the special toll calls at will. Such an experiment would also serve as a test on which sound engineering appraisals could be based.

During 1956 and 1957, when arrangements for this test had to be made, development engineers at Bell Laboratories were committed to other Bell System projects or to essential National Defense projects. Since the New York Telephone Company had a special interest in this project, it agreed to cooperate with the Laboratories in providing both manpower and equipment for a trial of the new services.

Central office equipment and central office circuit and equipment designs of the New York Company were used in the test. Laboratories engineers were available as consultants, and were responsible for the changes in AMA equipment. The A.T.&T. Company furnished guidance, including advice and counsel on operating methods and features and service requirements. Specifically, the trial was designed to determine the feasibility and economic value of the new services, with local central office equipment modified as necessary to provide the required features. The test was not of an optimum switching system for general application throughout the Bell System.

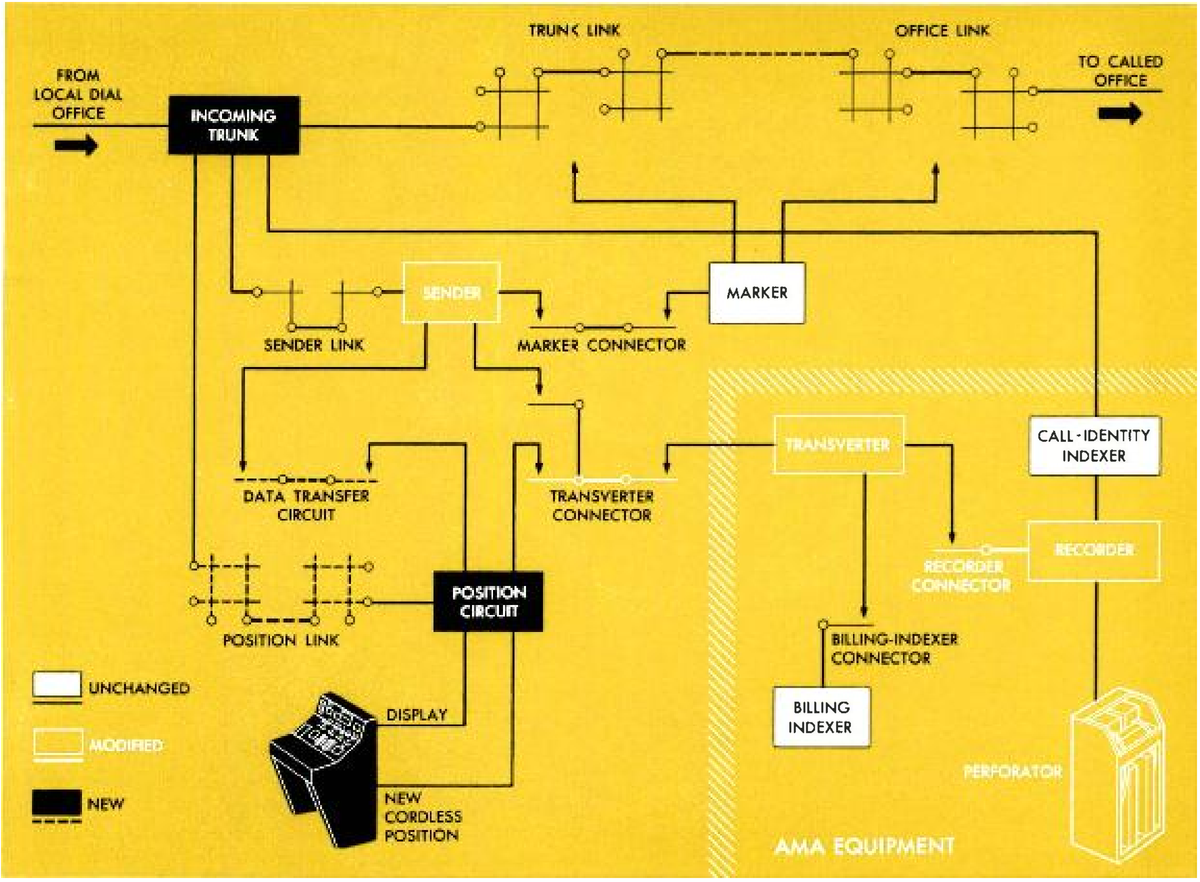
The New York Telephone Company selected the YU 8 office in Manhattan—a No. 5 crossbar local office—as the initial location for introducing trial service. Business customers who were known to originate many person-to-person and collect toll calls were invited to participate in the experiment. Many of these customers have private branch exchanges.

Somewhat later, a second trial location was established in Poughkeepsie, N. Y., for testing the proposed service in a smaller, more residential area. Customers in both areas were informed when the services would be inaugurated, and were instructed how to complete special toll calls. Included in the instructions was the reminder that dialing special toll calls would be faster because each call is being completed while the customer is giving the operator the necessary remaining details.

How Person-to-Person DDD Works

Dialing a person-to-person toll call is very similar to dialing a regular DDD call. The main difference, in the trial arrangement, is that you dial a zero first, then the three-digit area code, when required, and finally the complete (seven-digit) number of the telephone you wish to reach. Another important difference is that when an operator is connected you give her the additional details of your call; for example, "I wish to speak to Mr. John Smith."

On a collect call, you tell the operator that the call is collect, give her your name, and tell her whether you wish to speak with a particular person. On a credit-card call, you give your credit-card number to the operator and tell her whether you wish to speak with a particular person. A charge-to-third-telephone-number call is, of course, similar to a credit-card call except that



Block diagram of the standard plan for modifying crossbar tandem system to handle special toll calls. Automatic accounting equipment shown at the lower right would be located in the CAMA center.

the third telephone number is given to the operator rather than a credit-card number.

As mentioned earlier, one of the goals of the study program was to originate a standard plan for handling special long-distance calls. Such a plan would of course have to work in all areas of the Bell System and with all types of local and toll switching systems and accounting procedures. The specific requirements for the standard plan have recently been established.

With this plan, the local office, whether it be panel, crossbar, or step-by-step must be modified to recognize the zero prefix and route the special toll call to a central switching point where operators are available to assist in completing it. This modification involves changing the senders or registers (equipment units which transmit and receive dialed information) that handle calls in common-control offices, and designing new outgoing trunk circuits that handle calls with the zero digit prefix.

The block diagram above shows the proposed standard switching and accounting facilities for handling the new services, and indicates which of these facilities are new or modified. The diagram is predicated on the use of Centralized Automatic Message Accounting (CAMA) at a crossbar tandem switching center, rather than AMA at the local exchange, as is the case at YU 8 and Poughkeepsie. Local dial offices which are equipped for automatic number identification (ANI) (RECORD, *May*, 1958; *June*, 1960) will be arranged to send the calling numbers to the CAMA point by multifrequency pulsing.

To handle special toll calls, the crossbar tandem or other toll switching center must be modified to connect an operator to the dialed connection and to display the called number. In the standard plan, the calling number can also be displayed on special toll calls originated in local offices equipped with ANI. If the local office does not have ANI, the operator ascertains the calling number from the customer when she is connected, and keys it into the CAMA equipment.

In the Poughkeepsie trial, the toll operators serve as both assistance operators on special toll calls and calling-number identifiers on routine, station-to-station DDD calls made from non-ANI telephones. And in some cases they can be both simultaneously. If, for example, an operator is waiting for a called PBX extension to become idle on a person-to-person call, she can operate a switch and handle a station DDD call that requires only calling-number identification. Normally, this is a matter of receiving the calling number, saying, "thank you," and punching the keys at her position that record it in the CAMA equipment—about a 7-second operation.

The special DDD operators at both trial sites are located at cordless switchboards. Cordless boards can be used because it is not necessary for the operator to complete connections manually, as it is at conventional toll switchboards. An overall view of the operator positions at the Poughkeepsie trial is shown on page 300.

The turrets atop these switchboards have facilities for displaying called numbers. All of the customers participating in the Poughkeepsie experiment have local ANI, but a keyset is also furnished to key calling numbers on CAMA calls from other customers in the area.

In the standard plan, the crossbar tandem switching center, or CAMA center, must be further modified to link its AMA equipment to the trunk used for completing the special toll call. This arrangement is shown in lower right-hand corner of the diagram. The trunk circuit is designed to withhold any start-of-conversation signal to the AMA equipment for timing purposes until the operator presses a START-TIMING key. She does this when the particular person requested by the calling party is reached and conversation starts. Generally, no AMA record is made of a call that does not result in a chargeable conversation.

The new operator position being designed for the standard plan is also equipped with other pushbuttons, which the operator uses to indicate to the AMA equipment the kind of call being handled, or for other control purposes. These buttons can be seen in the close-up view of the experimental operator position shown in the color photograph on the cover.

Operators remain connected on a person-to-person call only long enough to be certain that the desired person is reached. On a collect call, they stay on only long enough to assure that a desired or authorized person, who agrees to accept charges, is reached. The operator must also record the credit-card number or the number of a third telephone on a mark-sensed switchboard ticket when she handles such calls. This ticket is eventually associated with the AMA record to complete the billing data for the call.

The standard plan will also call for other modifications in the AMA facilities at the crossbar tandem office and at the accounting center. These facilities must be arranged to: (1) register additional call indices (classification codes) for the subsequent application of proper rates on person-to-person calls; (2) to apply the proper identity on credit-card and charge-to-third-telephone calls; and (3) to designate other kinds of collect calls. Information on collect calls, including credit-card and charge-to-third-telephone calls, is eventually sorted out automatically at the accounting center and delivered to the proper billing center.

One important aspect of the YU 8 and Poughkeepsie tests has been the opportunity to experiment with various traffic operating methods and techniques in search of the combination that will give the best service with the least operator effort. Observations indicate a gratifyingly high percentage of use, which is after all the true measure of customer acceptance.

Some Important Results

These experiments have several significant results. First, and perhaps most important, it now appears feasible to ease, for some years, any possible problem arising from an acute shortage of toll operators. Second, the speed and convenience of direct distance dialing can now be extended to person-to-person, collect and other types of special toll calls.

A third important result of the YU 8 and Poughkeepsie trials has been the development of an entirely new toll switchboard for handling many types of long-haul toll calls and dial-assistance calls. This switchboard represents a large step toward the ideal of an attractive, general-purpose cordless position to handle, eventually, all types of switchboard traffic, except auxiliary services like intercept and information.

To the Operating Telephone Companies, these results mean more and better ways to attract and serve long-distance customers. To the customers, the ultimate judge of all Bell System services or equipment, improvements in operator-assisted DDD calls will mean speedier, more convenient and more reliable service, available at the least possible cost.

J. W. Emmons, of the New Jersey Bell Telephone Company checks voltages on equipment in lineup of "outgoing" cabinets. Equipment can be easily added or removed according to needs of the office.

The efficiency and reliability of a communications system depend directly on how its circuits work. Thus Laboratories engineers spent much effort in preparing the circuits for the 82B1 Teletypewriter Switching System. As a result, the 82B1, designed for military applications, can be counted on to route teletypewriter messages rapidly and accurately.

F. B. Crowson and R. R. MacLaughlin

Circuit Design of an Improved Teletypewriter Switching System

A new and improved automatic teletypewriter switching system has been developed by Bell Laboratories. Its first application is, under lease, in the U. S. Navy communication network. Known as the 82B1, this system improves both the speed and accuracy of teletypewriter message switching. In addition to fulfilling Navy requirements, this equipment is compatible with that of the other military services. Thus it will be able to switch interservice traffic.

The 82B1 switching system receives messages from an originating station, temporarily stores them and then relays them to outgoing lines leading to the destinations. These functions are carried out automatically and under circumstances that place no limit on the number of destinations. Major pieces of equipment, uniquely designed for the new system, are the incoming and outgoing cabinets. Within these cabinets are the important switching units, including the director and the bid receiver. It is this equipment and the connecting circuits that will be described in this article.

The incoming cabinet is essentially a junction between the incoming lines and all the rest of the equipment in the switching office. The circuitry of the cabinet is briefly as follows. Two "reperforator-transmitters" and their associated control circuits terminate two incoming lines and perforate incoming messages on tape. Decoding circuitry effectively "reads" these messages by automatically translating the various combinations of perforations into "control" characters.

Incoming messages arrive at speeds of either 60, 75 or 100 WPM (words per minute). Since these teletypewriter units transmit at 200 WPM, the reperforator-transmitter stores the tape until it receives either a complete message or an indication of a "high-priority" message. Then, the control equipment requests the services of a director—the circuit that is essentially the "brains" of the switching system.

As soon as the director connects to the incoming line, it receives at 200 WPM the portion of the preamble, or introductory signal common to all addresses, which it stores as perforated tape in its own reperforator-transmitter. An important feature of this director is its practically unlimited storage capacity.

During transmission of the introductory signals, which normally take less than one second, the equipment automatically decodes and checks the precedence prosign—characters signifying the priority of the message.

After this check, the director begins to process the routing indicators on the incoming message. The first routing indicator is "read" into routing fans (relay trees) and pulse-storage relays of the director. Simultaneously, the director checks the validity of each character, and then checks the entire group, including the space at its end, to ensure that the combination is a valid code.

Tape Perforations

After all items have checked correctly, the fan relays close a path to a route relay and simultaneously perforate in the director tape a cross-office outlet identifier consisting of two characters. This is followed by the perforations for the routing indicator.

The director then reads, stores and checks a second indicator, selects a route relay and perforates in its tape the two-character code and the second routing indicator. If the director detects an error, processing stops and the message is automatically sent to a service position—called miscellaneous intercept—where it appears on a page printer and as a typed, perforated tape. Suitable alarms announce its arrival.

If a destination point is closed, a copy of the message, together with the routing indicator, will be transmitted to an "intentional-intercept" position. Traffic from this position can be automatically re-introduced into the system at any time—for example, when the intercepted station reopens.

When all routing indicators have been checked, processed and stored in the director tape, and the "end-of-addresses" code has been read, the director then requests permission from a sequence circuit to "bid" for the desired outlets. Basically, this circuit prevents two directors from seizing a particular outlet simultaneously.

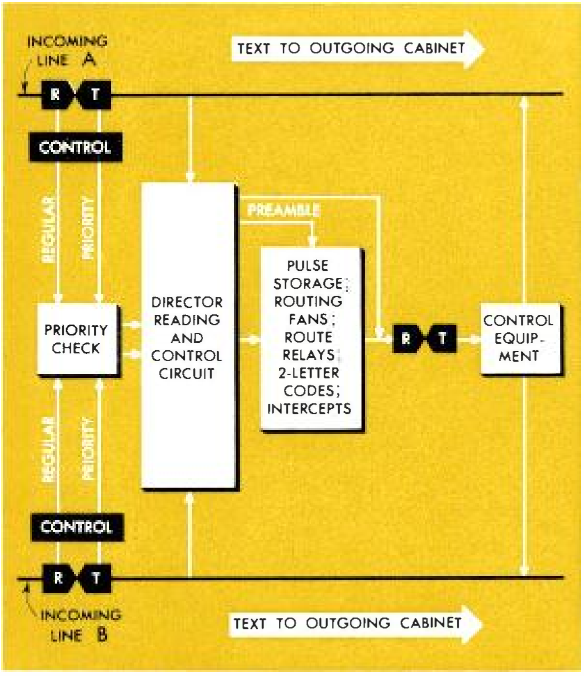
As soon as the sequence circuit attaches (normally a few milliseconds later), the director checks leads to ascertain whether the desired outlets are busy or idle. If they are idle, the director makes a bid for each of them and tells them the identity of the incoming line and order of precedence of the message. Each desired outlet, or bid receiver, checks this information before accepting a bid. The bid receiver will be discussed later in detail.

When all bid receivers have accepted the bid, the director "unblinds"—that is, it closes the transmission path—to all of them and sends the common portion of the preamble. If more than one channel number appears in the message, the director automatically deletes all but the first channel number. This, of course, saves line and switching time at any further points in the system.

After the director has decoded the space following the precedence prosign, it again "blinds" all outlets. Without pausing, the director reads the first two-character, cross-office identifier previously inserted, unblinds the appropriate outlet and sends the first routing indicator. The space following this indicator causes the director to again blind this outlet.

The director then reads the next two-character code, unblinds the second outlet and transmits the second routing indicator. In this manner each routing indicator is sent to only one outlet at a time. At the 200 WPM rate, each indicator is transmitted in less than ½ second.

Decoding and control equipment at each bid receiver checks that the first letter of the routing indicator has been correctly received in all outgoing machines. Unless the director receives notice of this within 70 milliseconds of transmission, it stops and gives suitable audible and visual alarms. These include a glow-lamp display of the outlet number involved. The bid receiver also gives an alarm indicating which machine received



Incoming cabinet. Two lines terminated in this one piece of equipment submit their introductory information, and routing instructions, to processing equipment located within this single cabinet.

the error. The combination of these alarms effectively speeds up trouble location and clearance.

The 82B1 has the highest speed of cross-office transmission of any Bell System teletypewriter network, but design engineers had to overcome many problems before this speed could be realized. One of their most difficult problems arose because in teletypewriter operation the sensing, or decoding, of a transmitted character occurs only during its transmission. This, of course, is too late to prevent its being sent to the outlet. Therefore, some device was needed to tell what a character would be even before it was transmitted.

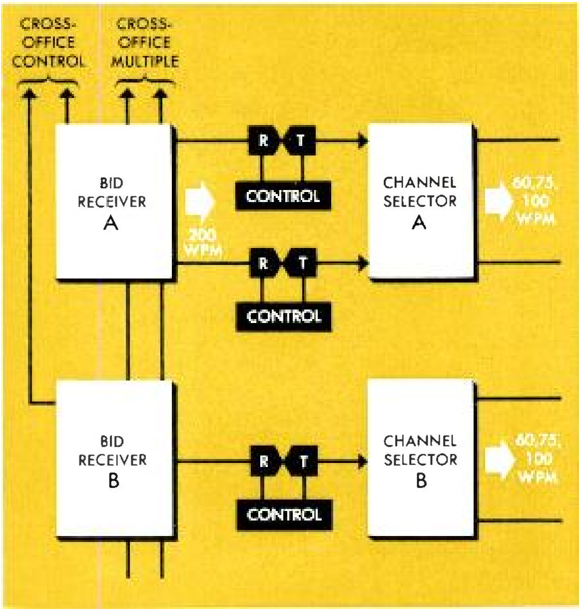
Such a device is now included in the system. This "anticipator" is a two-stage shift register which reads, decodes and stores one character while the previous character is being transmitted across the office. Coupled with very high speed circuitry, this device can decode and then blind or unblind the desired outlets during the few-millisecond interval between characters at 200-WPM operation.

The transmitting side of the director includes a decoder, a two-letter fan to establish the cross-office paths, the two-stage shift register, a circuit for inserting and deleting the space and carriage-return, and a channel-number suppression circuit for deleting unwanted channel numbers.

After sending all indicators to the required outlets, the director decoder reads the end-of-addresses code and unblinds all associated bid receivers. The director then releases the bid receivers and restores control to the incoming line. This allows the incoming-line machine to send the text of the message over the previously established paths directly to the same machines but without tying up either the director or any of the bid receivers. Thus, the control functions of the bid receivers are only used for a few seconds for any one message.

On the other side of the 82B1 switching office is the outgoing cabinet. Essentially, the outgoing cabinet circuitry and equipment receives messages addressed to the destinations it serves and relays them to the associated line channels. It is not an integrated unit, but an assembly of "patchable" components which may be grouped in many different ways.

The outgoing cabinet goes to work when a director, having processed a message and determined the outlets wanted, is "gated" by the sequence circuit. This simultaneously alerts the proper bid receivers over individual leads to which all directors are multipled. Ten coding leads common to all directors permit the incoming-line number to be indicated to all desired bid receivers. Engineers arranged the 100 incoming lines (for crossbar-switch operation) in 16 groups of six units and one of four.



Outgoing cabinet. Here, the bid receiver maintains order on the line. It acts with the director of the incoming cabinet to control the flow of messages in the teletypewriter switching center.

Each group is coded on a three-out-of-six basis and each unit on a two-out-of-four. Accordingly, each bid receiver looks for these combinations as a requirement for registration of a bid. On receiving them, the bid receiver signals that it will accept the message, whereupon the director releases the sequence circuit and the common-coding leads. The precedence of the message is indicated in a similar manner over two other common-coding leads.

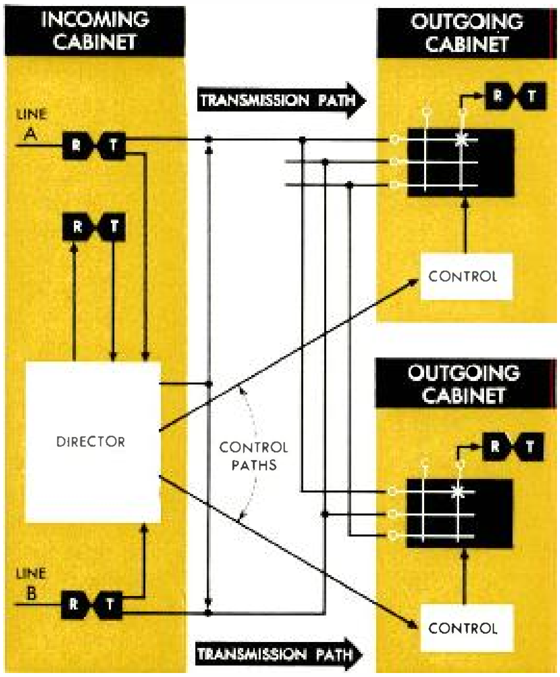
In the next step, each designated bid receiver assigns an idle teletypewriter machine to the proper incoming line. For this purpose, each bid receiver has two 6-wire, 10-by-10 crossbar switches arranged one above the other to form one switch of ten verticals and twenty horizontals. Jacks associated with each vertical permit one bid receiver to serve as many as ten machines.

The first seventeen horizontals are for transmission paths and the remaining three for translation purposes. Operation of appropriate horizontal-select and vertical-hold magnets associates an idle machine in each outlet with the incoming line. For multi-station operation, an electronic "distributor" inserts a number sequence for any or all of the five stations that may have been selected by the director. These number-group sequences have the dual function of maintaining the serial sequence of messages to each station and activating the stations intended to receive the messages.

When all bid receivers have signaled clearance to the director, it begins to transmit the preamble. At this stage, the director is in complete control because the path from the link-switch crosspoint to the machine is routed via relays in the bid receiver. These relays respond to control potentials that the director applies to the bid leads. As indicated previously, the control circuit of this machine contains reading circuits. Thus, failure to sense the carriage-return or the line-feed signal prior to that of the precedence prosign or the routing indicator is signaled back to the director. In this event, both cabinets are alarmed and action is halted so an operator can attend to the trouble.

When the director has completed transmission of all routing indicators, it relinquishes control of the cross-office path to the incoming line circuit which then transmits the text of the message. In retiring, the director releases the bid receiver which, in turn, gives over control to the machine-control circuit. At this point, both the director and bid receivers are free for further service on other messages.

In transmitting the text, the incoming-line circuit exercises control and supervisory functions over the transmission lead. Upon completion of transmission of a message, this circuit releases the link switch and takes down the cross-office connection. The incoming line can then notify its director that it is ready to handle the next message, and the control circuit of the outgoing machine is again available to its bid receiver.



Cross-office paths between incoming and outgoing cabinets serve two functions. One—the control path—keeps order in the switching operations. The other path then is free to transmit messages.

After the message has been transmitted to the outgoing cabinet, it comes under control of selectors on the outgoing line channel. To expedite the flow of cross-office traffic and to handle priority messages, there are usually more machines assigned than line channels required. Two or three machines sharing one line channel is a common arrangement, but five to ten machines sharing two to four channels would not be unusual for some trunk arrangements.

The patching is highly flexible as is the case between machine-control circuits and bid receivers.Each patch consists of one three-conductor cord to carry the one transmission lead and the two control leads. Except for multi-station-line applications, the bid receiver, machine-control circuit, and channel selector may be assigned to separate cabinets and interconnected via multiple circuits made up of three-conductor intercabinet trunks.

A stepping selector circuit serves each of the four line channels. These have access to all the control circuits of assigned machines. The presence of perforated tape in a machine alerts the selectors, but they are sequenced so that only one, then idle, will "home" on a machine circuit seeking a line channel. As soon as this is done, the polarity of the potential on the selector terminal is changed to avoid double connections.

For trunk operation the electronic distributor transmits a number sequence directly to the line channel. The selector circuit then activates the machine to transmit the message. During transmission, a reading circuit watches for the end-of-message sequence. When this is encountered, transmission ceases and the line channel releases, permitting the selector to step to any other machine that has tape available for transmission.

In a totally automatic system such as the 82B1, operating personnel in a switching center never "handle" a message unless it is intentionally intercepted or it encounters trouble. This is why so many safeguards are necessary to ensure that all traffic is processed correctly and that in case of trouble the condition is noticed immediately. As additional safeguards, the design engineers incorporated circuitry to quickly set up an alarm for line or machine troubles. These features are in keeping with the requirements of accuracy and assurance for teletypewriter switching systems.

Personnel with little or no training in photography must periodically replace photographic plates used for storing digital information in the semipermanent memory of an experimental electronic central office. To simplify this precise operation, Bell Laboratories engineers have designed an Automatic Plate Processor (APP).

R. K. Eisenhart and R. F. Glore

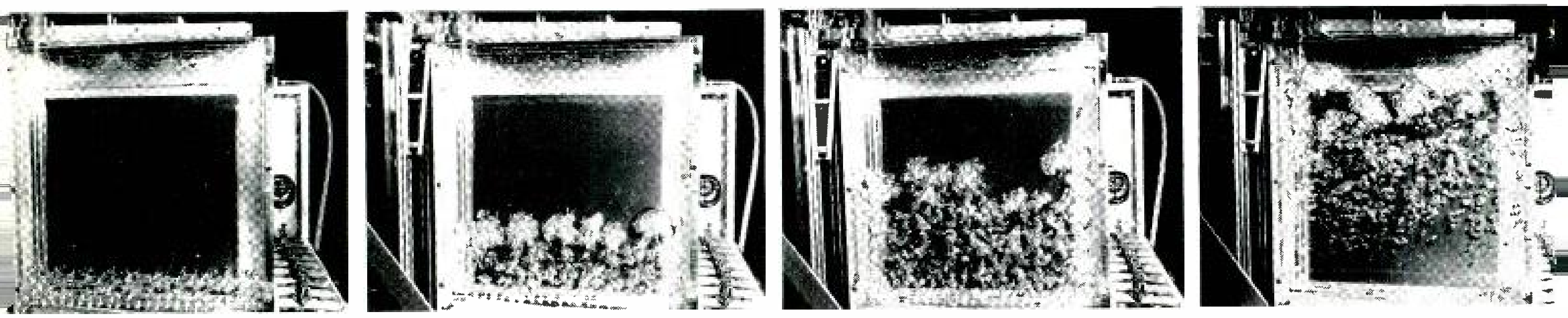
Automatic Processing Of Code Plates for Data Storage

The trial electronic switching system presently installed in Morris, Illinois utilizes a number of new switching system components. Among these is the semipermanent memory—the "flying-spot store"—which stores a very large amount of information used to control the operation of the electronic central office (ECO). One-quarter of the contents of this memory is information the ECO must have about each customer line to process each call properly. This information changes with changes in customer service and requires periodic revision of the memory.

The flying-spot store (RECORD, *October*, 1958) uses photographic plates on which data is encoded in the form of tiny clear and opaque areas corresponding to binary "ones" and "zeros," respectively. Though this information is "semipermanent" in the sense that it cannot be erased or changed electronically (as in the temporary memory), it is nevertheless necessary that plates with new or changed information can be prepared conveniently. Also, the plates are to be prepared by personnel with little or no background in electronics or photography.

Unexposed photographic plates are inserted into the flying-spot store, where each area to be made a binary "one" is exposed by the projected image of the spot on the cathode-ray tube; the latter is programmed to pause for a controlled fraction of a millisecond at each address for which a "one" is to be written. A system of shutters permits each of a number of channels to be exposed independently, one after the other. The plates are then removed from the "store" in light-tight plate holders and are carried to the Automatic Plate Processor (APP) where they are chemically processed and dried.

An initial model of the APP, suitable for laboratory use without a darkroom, is shown on page 311. This machine processes one plate at a time, or two plates simultaneously. The glass plates are 10 by 12½ inches in size, and each contains a number of encoded areas. A carriage frame does the processing; it receives



Left to right, air bursts start from source in bottom of tank and rise to surface of solution. Each air burst produces a random agitation of chemical solution needed for uniform processing. Continuous bubbling would set up repetitive swirl patterns, causing uneven development.

the plates and carries them from one to another of a series of processing tanks according to a preset program — which effects individual timing of the period of dwell in each tank. Though there are as many as fifteen steps in a typical reversal processing cycle, the machine is simple to use and actually has few external controls.

Plate Processing

To insert a plate the technician clamps the cassette, or plate holder, with a light-tight seal to one of the loading stations. The machine is prepared to receive the plate by directing the carriage to the appropriate LOAD station by the "select" knob on the control panel. A plastic bar on top of the cassette is then drawn backward, withdrawing steel tapes which seal the front of the cassette and the entrance slot of the APP; this allows the technician to inject the plate into the processor with a handle on the side of the cassette. Processing then starts and continues automatically until completion, which is signaled by a lamp.

It takes 26 minutes to process a single plate or two plates simultaneously. In general, only one plate will be changed in each of two flying-spot stores, making it possible to use only one processing cycle.

A cam on the carriage operates a series of microswitches, and these indicate approximate alignment with the various tanks. To position a plate precisely over each tank a half-nut from the lead screw is disengaged, whereupon a sliding nylon fork engages an accurately located pin. This avoids any need for stopping the motor-driven screw at any precise position — which would be difficult because of inertial effects.

The chemicals are mixed with an automatic stirrer — usually in a gallon-size, wide-mouth plastic bottle. The chemicals are then brought to the proper temperature (76°F) by one of the following methods: storing them in a temperature controlled cabinet, placing them in a water bath, or storing them at room temperature — provided the room is held to about 76°F. They are placed into the plastic tanks of the machine by hand with a funnel. Experience has shown that the chemicals remain at about the same temperature for several hours with only a one- or two-degree change. This eliminates any need for temperature control of the processing solution inside the processor. The processing tanks are made of plastic (methylmethacrylate) for corrosion resistance, and they hold one-half gallon of chemical solution each; there are eleven tanks for chemicals. Plates can be inserted into ten of these, but the eleventh is short and is used to hold the "A" solution of the reducer needed for step 9. This must be mixed with the "B" solution in tank No. 10 just before use because of the short life of the mixture. To do this, an automatically actuated solenoid valve allows the "A" solution to flow into tank No. 10 at the appropriate time in the process. The conveyor supports the plates 0.4 inch apart with the emulsion sides facing each other, and the tanks are just wide enough to receive this assembly with minimum clearance between the sides of the tank and uncoated glass surfaces.

During processing, the solutions are agitated by a "gaseous burst" method in which bursts of air bubbles are allowed to stream upward between the plates. The duration of the bursts and the intervals between bursts are adjustable and are controlled by an electric timer. Typical values would be a 1.2-second burst on 12-second intervals. These intervals allow the bubbles from one burst to rise to the surface, and allow associated currents in the liquid to become quiescent before the succeeding burst arrives. Above is an illustration of this controlled bubble activity. Such regulation is necessary to achieve randomness in the liquid agitation. If randomness is not achieved, circulating current patterns may be established that would result in non-uniform processing of the plates.

The feasibility of the gaseous-burst method of agitation as applied to the code plates of the flying-spot store was first explored with an early model of the processor. This machine is not enclosed and does not include facilities for automatic loading of the code plates, but it does transport the plates from tank to tank by an air cylinder and motor-driven lead screw. The model was used to establish the suitability of 0.4-inch spacing plates — with air bubbles rising between — as a technique for agitation. The air is supplied to each tank through a plastic tube in the bottom, with a series of small holes along the lower side of each tube. To prevent inflow of chemicals, light air pressure is maintained inside the tubes, even during the interval between bursts. A novel feature of the new machine is that the air bursts for all tanks are supplied from a single stainless steel tube (which also supports the plates); this tube is transported from tank to tank with the plates being processed. It has been found that compressed air fed into each end of the tube assures a consistently more uniform burst pattern.

R. F. Glore attaching a cassette containing an exposed code plate to one of two loading stations of the trial Automatic Plate Processor (APP).

Compressed-Air Bursts

Air can be used for the gaseous bursts because of the limited number of plates — seldom more than four — that will be processed in a given period. Fresh chemicals are used for each occasion that new plates are to be made. It is therefore not necessary to use nitrogen, or other non-oxidizing gases. Chances of the undesirable oxidation of chemicals are lessened if air bursts occur only where the plate is immersed.

A small diaphragm-type air compressor supplies compressed air for the bursts. This type was chosen to eliminate the possibility of injecting oil and other impurities into the filtered air. The air flow for the bursts is controlled by an intermittently operated solenoid valve in series with a small pressure-reducing valve. When in the "down" position, the carriage is linked to the air supply by a stainless steel tube that engages a nylon cylinder with a ring seal. A small check valve rides with the carriage to prevent reversal of air flow and consequent chemical contamination of the tube from which the bursts are emitted. The compressor also supplies air for the main cylinder which raises and lowers the plates, and for a second cylinder which removes the half-nut and drives the tapered fork into engagement with the horizontal-positioning pins. Compressor noise is reduced to a low value by vibration mounting and by use of a muffler in series with the intake.

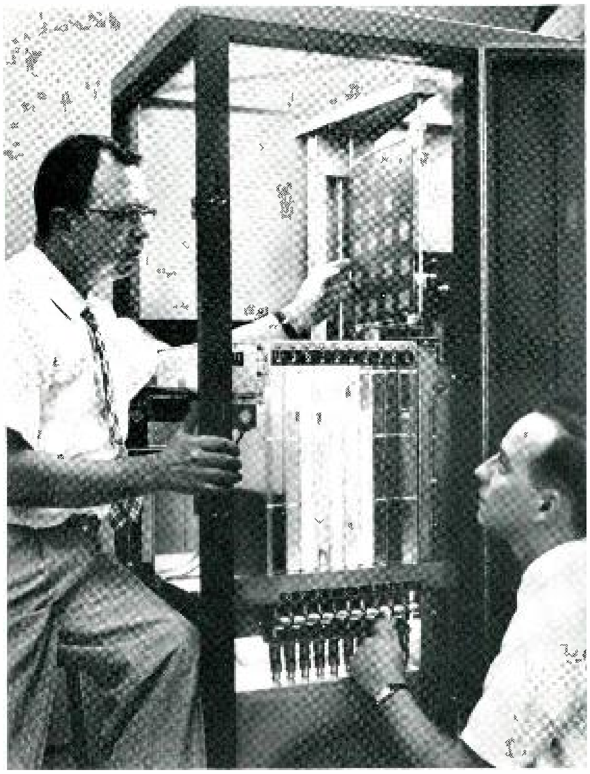
The plates are dried by rinsing in a mild detergent — which minimizes formation of droplets — and by circulating filtered, warm air past the plates in a drying chamber adjacent to tank No. 1. Air is blown downward past the plates to help carry away droplets which naturally run downward by gravity. This minimizes spotting caused by drying of droplets within the image areas. To shorten the drying period, the electric heaters and circulating blowers are automatically turned on prior to arrival of the slides. Thus, the equilibrium temperature will be reached before drying starts.

The processor contains a versatile program panel from which the steps and timing of almost any desired process may be easily set up or changed. The tank or position to which the machine is directed — and the precise time it will remain there — is determined by inserting goldplated control pins in the appropriate holes. Other pins may be inserted to establish the time at which solutions are mixed (tanks 10 and 11), when lights are turned on in the processor for exposure during processing, and when the blower and heater are turned on for drying. To simplify the circuitry, pins must also be inserted to indicate whether the desired tank location is to the left or right of the present location. The timing circuit uses relays and selector switches to count revolutions of a shaft which is rotated at the rate of once every six seconds by a synchronous motor. The counter and shaft start from a zero position when the carriage is lowered, so that the transit time of the carriage does not affect the dwell time, and adjustment of the time interval for one step of the process does not change the timing for any other step.

Need for Cleanliness

The very small size of the clear areas on the processed plate requires that the plates be essentially free from dust or other particles before exposure, and that this cleanliness be maintained through all subsequent handling and processing. After initial cleaning, the plates are never exposed to room air, but are continuously enclosed by the dust-tight cassette, the flying-spot store, or in the processor itself. The latter is maintained essentially dust-free with special air filters in the bottom. As long as the door is closed, virtually all air entering the machine passes through these filters—including air used for the gaseous bursts, for operating the air cylinder, and for drying. The filters are of a pleated glass-asbestos type, which are more than 99 per cent efficient in removing dust particles larger than 0.3 microns in size (wavelength near that of ultraviolet light). Though occasional particles 100 times this size would probably not be objectionable on the code slides, the finer filtration creates margins against flocculation (forming large particles from aggregates of smaller ones) within the processor.

The APP and cassette contain a number of interlocks and other safety features to protect the mechanism in the event of malfunction or improper handling. Mechanical interlocks prevent closing the light-tight steel tapes preparatory to starting the cycle, unless the plate is fully inserted into the machine, and also prevent removal of the cassette if the door is open. Limit switches at the ends of the normal travel for the plate carriage disable the screw drive in the event that this normal range of motion should be exceeded for any reason. The vertical carriage drive is not permitted to lower the carriage at any station until the closing of a switch indicates that the pin for precise horizontal positioning has been fully engaged. Once the process cycle is started, all external controls are disabled until the cycle is completed — with the exception that the depressing of an emergency HOME button will return the carriage at once to one of the LOAD stations. Design of the processing tanks with sump and drain pump make cleaning easy, thereby minimizing opportunities for contamination because of accumulated chemical deposits. Regular cleaning of the processing tanks is required after each day's use and consists of scrubbing the tanks with a brush and water.



R. F. Glore, left, inspects encoding plate as R. K. Eisenhart adjusts chemical level in tanks. Color-coded solutions indicate mixture in each tank.

The experimental model of the APP described in this article has been used on many occasions for processing plates of the type shown in the photograph, above. It appears to meet the objectives of a more uniform and more reliable processing than can be achieved readily by hand methods, and it does this easily, without a darkroom, and under control of personnel with little or no background in photographic techniques.

". . . to take that one-billionth of a millionth of a watt reflected from a big balloon a thousand miles up in the sky, and play tricks with it so that you will have the illusion of talking with someone else at the other end of a six-foot cable—this takes a lot of doing. . . ."

F. R. Kappel

Communications in the Space Age

News from the Bell System

Telephone scientists' research in space communications is aimed at creating thousands of high-quality voice channels, and ultimately, TV channels, that would interconnect all parts of the globe by way of satellites, A.T.&T. President Frederick R. Kappel said recently. Discussing the possibilities and problems of "Communications in the Space Age" at the University of California at Los Angeles, Mr. Kappel said "that by whatever means will serve the public most efficiently, we shall succeed in providing the requisites for a new era in world communications."

If, he said, the telephone industry can make satellite systems work, "as we believe we can, they will help us increase the number of intercontinental voiceways many times over. We start with the idea of getting perhaps 500 to 1,000 out of a single system, and hopefully, later on, a great many more than that. Moreover, if by using a number of satellites we can span one ocean, then using these same satellites plus a few more, we can span others as well. We can create several systems interconnecting different points, instead of just one." This type of system, he added, also offers a "most hopeful possibility" for world-wide television, although he cautioned that live TV transmission via satellite is "still a distant prospect."

Mr. Kappel cited the Bell System's role in "Project Echo," currently being sponsored by the National Aeronautics and Space Administration, as a key step in space-communications research. The object of Echo is to get a 100-foot diameter balloon satellite into orbit and then "bounce" voice signals off it between Holmdel, N. J., and Goldstone, Calif.

Immediate aims of the project, Mr. Kappel said, are: to determine whether speech can be transmitted; to get data on radio waves; to test communication system components; and to check the balloon itself—whether it will work as anticipated, keep its shape and also how meteorites will affect it.

Other frontiers in space communications include building more efficient antennas, receivers and higher powered transmitters; improving long-life power supplies; and finding methods for adjusting the positions of satellites and the direction of their antennas.

Some of the earlier research leading to the feasibility of Echo was related by Mr. Kappel. "One of our scientists (at Bell Laboratories), John R. Pierce, got to thinking seriously about using satellites for communications back in 1954—three years before the first artificial satellite even went into orbit. He studied various ways of doing the job, and in a technical paper published in 1955 he presented the very first concrete suggestions for satellite communications. Rocket technology still had to catch up. So did some of the electronics technology. As a result, Bell Laboratories people went promptly to work on the electronics end, and since that time they have developed certain devices that we believe will have tremendous value in the present experiments—notably a new form of receiving antenna and new types of amplifiers.

"At the same time, we are drawing on research done many years ago. Back in the early 1930's, for instance, when artificial earth satellites were unheard of, J. G. Chaffee, also of our Laboratories, jotted down in his journal a new idea that he thought might result in an extremely low noise radio receiver. It did just that, but the invention when applied to earth-bound communication systems was less economical than other methods that also produced excellent results. So for years Mr. Chaffee's invention, called a "demodulation feedback receiver," stayed on the shelf. Yet it turns out today to be the best thing available for receiving signals reflected from satellites. Past research often pays this sort of dividend."

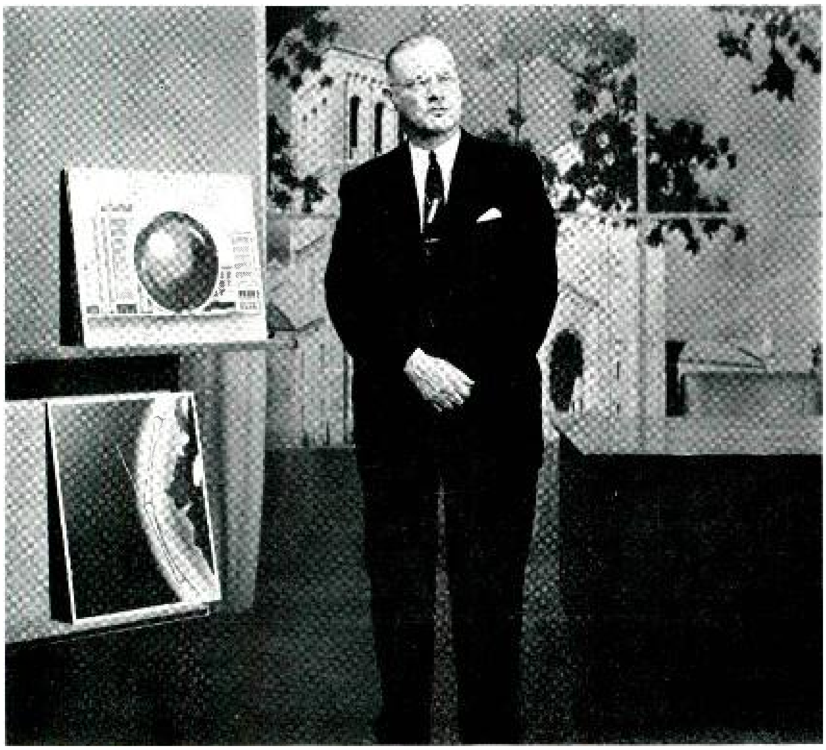
Mr. Kappel said an additional method of providing for growing world communications needs will be to increase the undersea telephone cable network. "There is room for an indefinite number of cables in the 'inner space' of the ocean depths," he said, and added that ocean telephone cables "are just hitting their stride."

He discussed also the limited range of frequencies suitable for space communications; the responsibility for setting up space systems for commercial use; and ownership of such systems.

"In the United States, for example," he said, "there are at present no frequencies specified for space uses in the frequency range most suitable for satellite communications—that is. the range above 890 megacycles. But there are any number of claimants who would like to use such frequencies for various purposes. Great care must be taken to make sure they are not wasted. It will be fruitless to create satellite communications systems, and at the same time create a shortage of the frequencies required."

Ownership, he said, should be shared, as are ocean-cable systems, by the telephone companies and administrations that provide the service, for "this puts full responsibility for the service right where it belongs." In the present stage of experiment and exploration, he said, it is natural for the government to take the lead in putting up satellites. "But," he added, "when we come to providing communication service, I think we in the Bell System should take all the responsibility we can for the job that is given us to do.

"We need only look at the record to know that private enterprise will also keep this country out in front in space communications, just as we have led the way on land and sea. It was the Bell System, I may remind you, that pioneered worldwide telephony, first by radio and later through cables. We want and intend to be pioneers tomorrow too. We are ready, willing and able to push ahead. All we need is the leeway, the freedom, to do our best."



In his speech, A.T.&T. President Kappel used visual aids of this type to describe satellite communications concepts.

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Suhl, H., see Clogston, A. M.

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Williams, A. J., see Nesbitt, E. A.

Winslow, F. H., see Hawkins, W. L.

Wood, D. L., see King, J. C.

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PATENTS

Following is a list of the inventors, titles and patent numbers of patents recently issued to members of the Laboratories.

Babcock, W. C. — *Urban Mobile Radio Telephone System*—2,941,201.

Bonner, A. L. and Donaldson, J. C. —*Subscriber Ringing in Carrier Telephone Systems*—2,939,919.

Brill, M. D.—*Wave Filter*—2,943,280.

Brown, A. B., Jr.—*Magnetic Core Counter Circuits*—2,941,089.

Budenbom, H. T. — *Compensated Hybrid Ring*—2,943,273.

Cook, J. S. — *Slalom Focusing Structures*—2,941,114.

Cutler, C. C. — *Magnetic Structures for Traveling-Wave Tubes* —2,942,141.

Danielson, W. E. — *Traveling-Wave Tube*—2,939,995.

DeLange, O. E. and Dietrich, A. F. —*Frequency Modulated Pulse Radar*—2,941,200.

DeLange, O. E.—*Variable Bandwidth Timing Circuit for Self-Timed Regenerative Pulse Repeaters*—2,942,196.

Dietrich, A. F., see DeLange, O. E.

Donaldson, J. C., see Bonner, A. L.

Flint, E. D.—*Visual Display for Complex Systems*—2,939,630.

Ham, J. H., Hershey, H. J., Hohmann, L. A., Jr. and Kinsman, F. W.—*Magnetic Drum Repertory Dialer*—2,941,043.

Hershey, H. J., see Ham, J. H.

Hohmann, L. A., Jr., see Ham, J. H.

Irland, E. A. and Ruppel, A. E.—*Pulse Distribution Indicator*—2,943,149.

Joel, A. E., Jr.—*Simultaneous Direct-Current and Multifrequency Signaling System*—2,941,042.

Kinsman, F. W., see Ham, J. H.

Krantz, H. K.—*Centering Fixture*—2,940,764.

Lewis, W. D.—*High Speed Digital Data Processing Circuits*—2,942,192.

Lozier, J. C.—*Dynamic Transducer Accelerometer*—2,940,306.

Madsen, R. L. and Schell, A. C.—*Amplitude Limiting Circuit*—2,942,197.

Mason, W. P.—*Pre-Aging of Electrostrictive Ceramics*—2,940,158.

Mason, W. P.—*Variable Resistance Semiconductive Devices*—2,939,317.

Mattingly, R. L.—*Antenna with Means for Preventing Re-Radiation into Feed Guide*—2,942,266.

McGuigan, J. H.—*Magnetic Core Shift Register Circuits*—2,942,241.

Miller, S. E.—*Selective Mode Filters*—2,940,057.

Poole, K. M.—*Time Division Multiplex Communication Systems*—2,941,074.

Raisbeck, G.—*Transposed Layer Conductor*—2,942,211.

Rogers, S. C.—*Parallel Transistor Amplifiers*—2,941,154.

Ruppel, A. E., see Irland, E. A.

Saal, F. A.—*Traffic Simulation*—2,941,039.

Schell, A. C., see Madsen, R. L.

Schneider, H. A.—*Pulse Selector Circuits*—2,941,091.

Tryon, J. G.—*Redundant Logic Circuitry*—2,942,193.

TALKS

Following is a list of speakers, titles and places of presentation for recent talks presented by members of Bell Laboratories.

FIFTY-NINTH ACOUSTICAL SOCIETY MEETING, Brown University, Providence, R. I.

Crystal, T. H., see Schroeder, M. R.

David, E. E., Jr., see Kaiser, J. F.

Fitch, A. H., *A Dispersive Ultrasonic Delay Line.*

Flanagan, J. L., *Analog Measurements of Sound Radiation from the Mouth.*

Flanagan, J. L., *Models for Approximately Basilar Membrane Displacement.*

Foulkes, J. D., *An Attempt to Persuade the IBM 704 Computer to Identify Vowel Types.*

Foulkes, J. D., *A Spectographic Technique for Disconing Formant Frequencies.*

Kaiser, J. F., and David, E. E. Jr., *Reproducing the Cocktail Party Effect.*

Martel, H. C., *Further Results on the Detectability of Known Signals in Gaussian Noise.*

Meitzler, A. H., *Critical Frequencies Occurring in the Propagation of Elastic Pulses in Wires.*

Schroeder, M. R., and Crystal, T. H., *An Autocorrelation Vocoder.*

Sessler, G. M., *Sound Propagation in Gaseous Dissociating N_2O_4.*

I.R.E.-A.I.E.E. SOLID-STATE DEVICE RESEARCH CONFERENCE, Pittsburgh, Pa.

Atalla, M. M., see Kahng, D.

Atalla, M. M., see Lindner, R.

Goldey, J. M., Mackintosh, I. M., and Ross, I. M., *Turn-Off Gain in p-n-p-n Triodes.*

Gummel, H. K., and Mitchell, M. M., *1/f Noise In Diffused Base Germanium Transistors.*

Kahng, D., and Atalla, M. M., *Silicon-Silicon Dioxide Field Induced Surface Devices.*

Lindner, R., and Atalla, M. M. *Silicon-Silicon Dioxide Surface Varactor.*

Mackintosh, I. M., see Goldey, J. M.

Mitchell, M. M., see Gummel, H. K.

Ross, I. M., see Goldey, J. M.

OTHER TALKS

Anderson, P. W., and Morel, P., *Aligned Orbital Momentum in the Proposed Low-Temperature Phase of Liquid He_3*, International Conf. on Many-Body Problems, Utrecht, Netherlands.

Anderson, O. L., *The Determination of the Equation of State of Solids by Ultrasonic Methods*, Physics Symposium, Cornell University, Ithaca, N. Y.

Baker, R. G., *Coatings for Contact Surfaces*, Delaware Valley Electronic Study Gp., Philadelphia, Pa.

Baker, R. G., see Compton, K. G.

Banar, P. D., *Comparative Methods of Providing Information for Keypunching Aperture Cards*, National Microfilm Association Conv., N. Y. C.

Bowers, K. D., *Parametric Amplification*, Symposium on Recent Advances in Solid-State Devices, Marquette University, Milwaukee, Wis.

TALKS (CONTINUED)

Bozorth, R. M., *Magnetic Properties of Some Superconductors,* Moscow, 5/11; Leningrad, 5/13; Sverdlovsk, 5/19; Tiflis 5/23/60.

Brown, S. C., see Buchsbaum, S. J.

Buchsbaum, S. J., Mower, L., and Brown, S. C., *Interaction of a Bounded Microwave Field with a Cold Plasma in a Magnetic Field,* A.P.S. Meeting, Montreal, Canada.

Compton, K. G., and Baker, R. G., *The Use of Electroplated Metals in Static Contacts,* Engineering Seminar on Electrical Contacts, Pennsylvania State University, Philadelphia, Pa.

DeCoste, J. B., *Advances in ASTM Test Methods for Vinyl Plastics,* Soc. of Plastic Engrs., N. Y. C.

DeGrasse, R. W., *Solid-State Maser Amplifiers,* Symposium on Recent Advances in Solid-State Devices, Marquette University, Milwaukee, Wisc.

Fuller, C. S., *Donor Equilibria in the Ge-O System,* Electrochemical Soc. Meeting, Chicago, Ill.

Hanson, G. H., *A Survey of Recent Progress in the Development of High-Frequency Transistors,* Seventh Region Conf. of I.R.E. Seattle, Wash.

Hemmendinger, B. G., *Automatic Telephony,* St. Francis Academy, Joliet, Ill.

Jakes, W. C., Jr., *Bell Laboratories' Part in the Echo Experiment,* A.F.C.E.A. Conf. Washington, D. C.

Keister, W., *Electronic Logic for Automatic Control,* Alabama Section A.I.E.E., Birmingham, Ala., 5/9; Armed Forces Communications & Electronics Association, Montgomery, Ala., 5/14; A.I.E.E., Cincinnati, Ohio, 5/26/60.

King, J. C., *Acoustic Behavior of Modified Synthetic Quartz,* Fourteenth Annual Frequency Control Symposium, Atlantic City, N. J.

Leutritz, J. Jr., *The Toxicity of Creosote and Creosote Pentachlorophenol Mixtures in Cattle,* 1959 Annual Meeting American Wood-Preservers Association, Dallas, Tex.

Looney, D. H., *Memory,* Summit Association of Scientists, Summit, N. J.

Looney, D. H., *New Magnetic Devices for Digital Computers,* 1960 Electronic Components Conf, Washington, D. C., 5/11; Seventh Region Conf. I. R. E., Seattle, Washington, 5/25/60.

Lowry, W. K., *Some Functions, Interactions, and Problems of Communication,* Annual Conf. Special Libraries Association, Cleveland, Ohio.

Lumsden, G. Q., *Fortified Wood Preservatives,* Engineering Institute Meeting on Wood Utility Poles, University of Wisconsin Extension Division, Madison, Wisc.

Montesano, L., *Test Methods for Evaluating the Corrosion of Copper by Casting Resin Compounds,* Western Electric/Bell Telephone Laboratories Casting Resin Conf., Merrimack Valley, North Andover, Mass.

Moore, E. F., *Machine Models of Self-Reproduction,* Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia, Pa.

Morel, P., see Anderson, P. W.

Mower, L., see Buchsbaum, S. J.

Mumford, W. W., *The Technical Aspects of Microwave Radiation Hazards,* San Diego Section of I.R.E., Point Loma, Calif.

Myers, G. H., *Guidance Constraints on the Tiros I Orbit,* American Rocket Soc. Semi-Annual Meeting, Los Angeles, Calif.

Nelson, C. E., *Some Factors Affecting Readability and Reproducibility of Microfilm,* Soc. of Photographic Scientists and Engrs., Arnold Auditorium, Bell Telephone Laboratories, Murray Hill, N. J.

Nelson, L. S., *Heterogeneous Flash Heating,* DuPont Experimental Station, Wilmington, Del.

Nelson, L. S., *Spectra of Flash Heated Gases,* Soc. for Applied Spectroscopy, N. Y. Section, New Brunswick, N. J.

Paterson, E. G. D., *Management's Concepts of Quality Control Responsibilities,* Fourteenth Annual A.S.Q.C. Conv., San Francisco, Calif.

Pearson, A. D., *Glass Formation in the System Arsenic-Sulfur-Bromine,* Am. Ceramic Soc., Philadelphia, Pa.

Peck, D. S., *A Mesa Transistor Reliability Program,* Semiconductor Devices Panel of Aerospace Industries Association Meeting, Dallas, Tex.

Pierce, J. R., *Problems of Satellite Communication,* 1960 Conv. of Armed Forces Communications and Electronics Association, Washington, D. C.

Reiss, H., *Thermodiffusion in Semiconductors,* Texas Instruments Co., Dallas, Tex.

Sharpless, W. M., *Gallium Arsenide Point Contact Diodes,* 1960 Prof. Gp. on MTT National Symposium, Coronada, Calif., 5/9; Stanford University, Special Colloquium, Stanford, Calif., 5/23/60.

Traube, M. J., *The Nike-Hercules Guided Missile System,* 102 Artillery Brigade (AA) NYARNG, Brooklyn, N. Y.

Trumbore, F. A., *Vapor Pressure and EMF Measurements on Certain Zinc-Germanium Alloys,* Electrochemical Soc. Meeting, Chicago, Ill.

Wehe, H. G., *Electron Beam Recording,* Vacuum Metallizers Association, Bermuda.

THE AUTHORS

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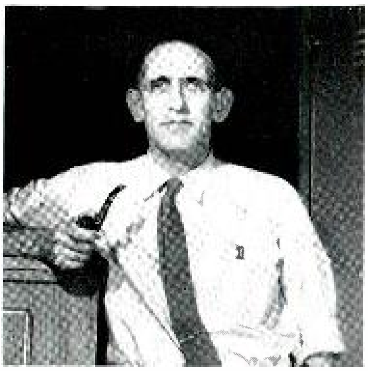
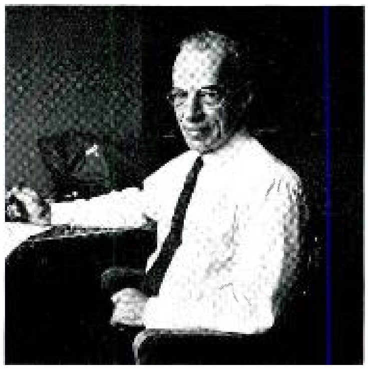
R. B. Murphy, a native of Springfield, Massachusetts, received the A.B. (1943), A.M. (1949), and Ph.D. (1951) degrees in mathematics from Princeton University. Following service in the U. S. Marine Corps, he was a graduate student and instructor at Princeton and an instructor and assistant professor of mathematics and statistics at the Carnegie Institute of Technology. He joined the Quality Assurance Department of Bell Laboratories in 1952, and since 1958 has been quality results engineer. At the Laboratories, he has specialized in the statistical aspects of quality assurance. He is the author of the article, “Reliability in Telephone Engineering”, in this issue. Mr. Murphy is a member of the American Mathematical Society, Institute of Mathematical Statistics, American Statistical Association, the Econometric Society, the American Society for Quality Control, Phi Beta Kappa, Sigma Xi, and Pi Mu Epsilon.



G. J. Levenbach

G. J. Levenbach (author of “The Use of Statistics in Device Development”) born in Philadelphia, Pa., got his M.E. degree from the Institute of Technology in Delft, Netherlands. For many years he worked as a Communications Engineer with Philips Telecommunications Industry in the Netherlands and with the Governmental Telephone Service in Indonesia. In 1953 he returned to the United States and joined Bell Laboratories. Since then as a member of the Device Development Department he has been engaged in statistical applications on design and development problems for items such as the L-3 transformer, a liquid dielectric tantalum capacitor, and various components for the submarine cable. This involves statistical design of experiments, problems in data reduction, and reliability studies. He is a member of several professional statistical societies here and abroad.



G. H. Peterson

George H. Peterson's early interest in electrical engineering stems from “being brought up in a powerhouse,” where his father was a stationary engineer and where he worked for several summers. After graduating from Tufts University in 1920 with a B.S. in E.E. degree, he joined the Development and Research Department of the A.T.&T. Company, and came to the Laboratories in 1934 with that group. During most of his 40 years with the Bell System, Mr. Peterson has been concerned with engineering-economic studies for the establishment of design requirements for manual and other switching systems. At present he is in charge of a group planning further mechanization of special toll calls, information bureaus and other switchboard operations. In this issue he is the author of “Current Experiments in Person-to-Person DDD.” He is a native of Somerville, Mass.

F. B. Crowson

F. B. Crowson, born in Goldsboro, North Carolina, received his B.S. in E.E. from North Carolina State in June, 1930 and promptly went to work for the Long Lines Department of the A.T.&T. Co. His assignments in Long Lines ranged from the construction forces to the general office. During the war years he was engaged in writing, conducting and supervising specialized training courses for the armed services. Following the war, his assignments were concerned with microwave, television, many types of carrier and

AUTHORS (CONTINUED)

R. R. MacLaughlin

other forms of electronic equipment. He transferred to the Laboratories in 1954 and is presently engaged in exploratory development in signaling and control systems. In this issue, he is co-author of "Circuit Design for an Improved Teletypewriter Switching System."

R. R. MacLaughlin, the other co-author of the teletypewriter circuits article, was born in Toledo, Ohio, and entered the Long Lines Department of the A.T.&T. Co. in 1929 upon graduation from Ohio State University, where he received the B.E.E. and M.Sc. degrees. Until World War II his work involved various aspects of the relationship between inductive coordination and foreign wires. He spent the war years on leave from the Bell System, with Columbia University's Division of War Research at New London, Connecticut on hydrophone development, and with M.I.T.'s Radiation Laboratory at Cambridge, Massachusetts, on airborne radar systems. After returning to Long Lines, he was assigned engineering of "L" carrier and private-line telegraph systems, and fundamental planning associated with the nationwide toll dialing program. Since joining the Laboratories in 1954 he has been engaged in private-line switching systems and automatic Data-Phone development.

R. K. Eisenhart was born in Topton, Pennsylvania. He studied at Pennsylvania State University, where he received a B.S. in Mechanical Engineering in 1957. He then joined the Laboratories and is participating in the Communications Development Training Program, through which he received a M.E.E. degree from New York University in 1959. Concurrently, as a member of the mechanical design group for the experimental electronic switching system, he was engaged in exploring methods for processing the photographic code plates used in the flying-spot store and the exploration of photographic plate handling techniques. He is a member of Pi Tau Sigma and Tau Beta Pi. Mr. Eisenhart is co-author of the article, "Automatic Processing of Code Plates for Data Storage" in this issue.

R. K. Eisenhart

R. F. Glore

R. F. Glore was born in Kansas City, Kansas, and received the B.S. degree in mechanical engineering from the University of Kansas in 1932. He was employed by the Southwestern Bell Telephone Company in various departments, including the Division Plant Engineering office, and was resident telephone engineer for the Lake City Ordnance Plant and Olathe Naval Aviation Base. In 1942 he was on loan to the Laboratories for military work on mine mechanisms. At the end of the war, a permanent transfer was effected, and he was assigned to the Switching Apparatus Development Department. In various groups of this department he has worked on U and Y relays, assisted in the development of the wire-spring relay and collaborated in the design of a new type dry-reed relay. At the present time he is concerned with the mechanical design of the experimental electronic central office. Mr. Glore is co-author of the article on automatic processing of code plates. He is a member of Tau Beta Pi.