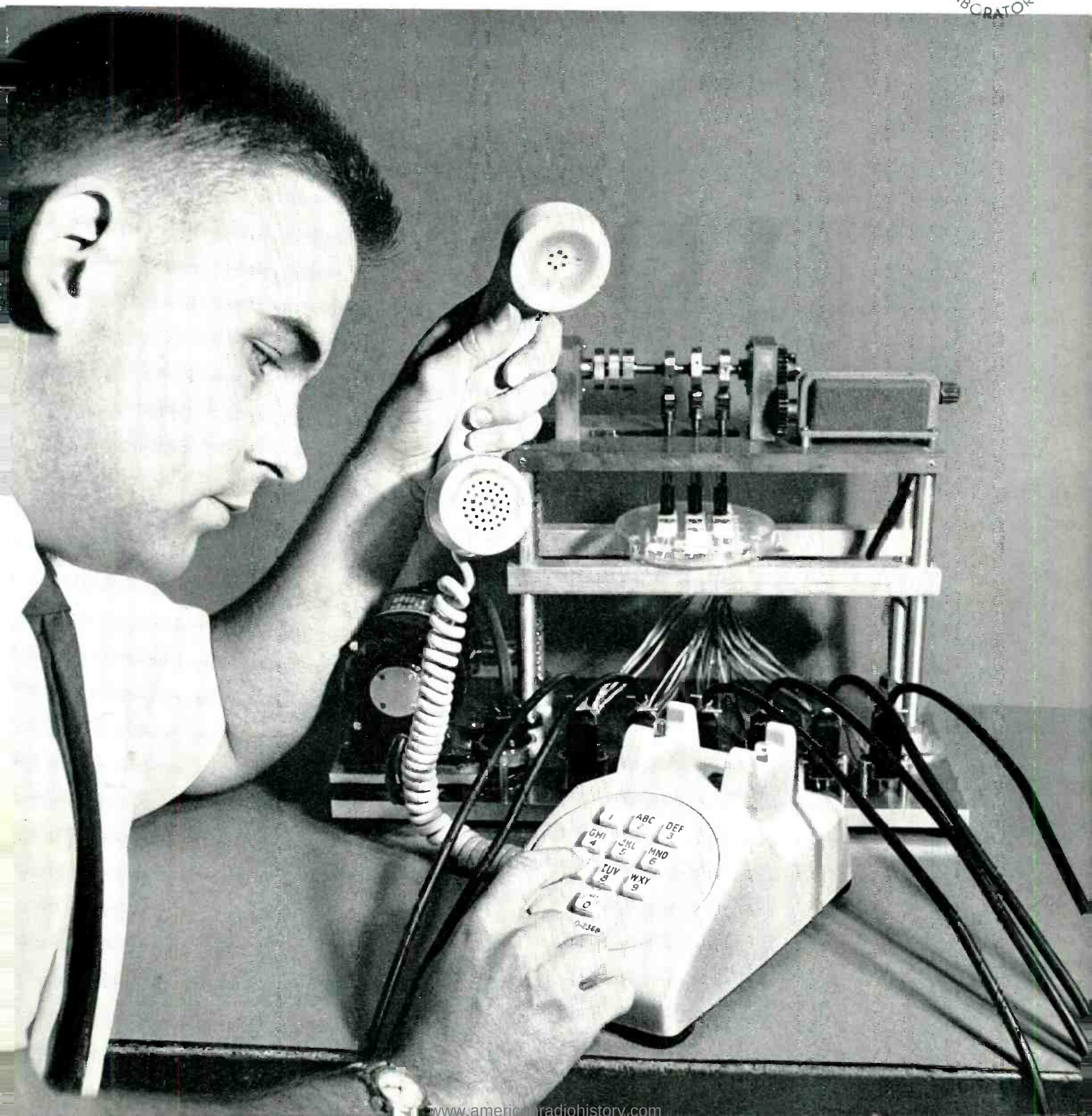
August 1959

Bell Laboratories RECORD

The Fine Art of Measurement
Colored Plastics for Wire and Cable
Simulation with Digital Computers
Microwave Radio-Relay Towers
Power for the AFMTC Cable



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Bell Laboratories **RECORD**

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Cover

New experimental model of a push-button telephone being tested by D. G. Tweed. Previous model was recently placed on trial (see story on p. 313).

Some of the most accurate and sensitive measurements of sound performed at Bell Telephone Laboratories are made in this large anechoic chamber. Echo-free, this chamber offers an almost ideal environment for the measurement of transducers such as microphones and loudspeakers.

"I have no faith in anything short of actual measurement . . ."

Charles Darwin

". . . probably more nonsense is talked about measurement than about any other part of physics."

N. R. Campbell

K. E. Gould

The Fine Art of Measurement

Measurement has a range of significance almost as great as that of Love. This is at least suggested by the fact that it encompasses the operations involved in: (1) assuring that screens will fit office windows, (2) choosing appropriate transmission levels in telephone circuits, and (3) determining customer preferences in proposed services.

The first example represents the simplest kind of physical measurement, and there is little uncertainty as to its significance. The third example is basically a matter of psychological measurements.

The second example is an intermediate case between physical and psychological measurements. It involves both relatively manageable factors, such as cable attenuation and amplifier gains, and less tractable elements like the speech characteristics of all telephone customers and even their habits in holding a telephone handset.

This article attempts, at most, to convey some sense of the rational objectives for a fairly wide variety of measurements and of some of the more interesting tools available, with examples of interest to the Bell System in particular. Although measurement is important in reaching an understanding of natural processes and in using them for the benefit of mankind, generalities related to this fact must be set down with some qualms, as one of the quotations above implies.

Objectives of Measurement

The objectives of measurement are varied. Some gifted people are merely inwardly impelled to devise a more elegant yardstick. The more usual motivation for developing a new measuring tool or refining an existing one, however, is to attain an objective otherwise beyond reach. Measurements are generally directed toward: (1) deductions as to fundamental structure, (2) determination of parameters, (3) evaluation of design procedures and (4) routine measurements, or testing.

Principal frequency standard for the Bell System is this elaborately instrumented equipment at the Murray Hill, N. J., location of Bell Laboratories. Accuracy of this standard depends on the very precise vibrations of piezoelectric crystals.

Perhaps the most exciting of these categories is the first. This is true in both the physical sciences and in psychophysics. The Michelson-Morley measurement which established the unchanging velocity of light is a familiar, classical case in the physical sciences. Almost equally well known are the measurements of electron diffraction in crystals, made by C. J. Davisson and L. H. Germer at Bell Laboratories, which showed that electrons behave like waves.

In psychophysics, H. S. Fletcher's measurements of hearing, at the Laboratories, led to a much fuller understanding of the physiological factors involved. As another illustration, measurements of the rates at which the human mind forgets have been made with the objective of deducing the structural properties of the central nervous system.

The use of measurements to determine parameters — the second general objective — in a sense bridges the transition between "research" and "development." Measurements of the transmission characteristics of multimode waveguides, for example, contribute to a fundamental understanding of the underlying physics. They also establish the attenuation and other parameters required to design a particular waveguide system. Since an excellent mathematical theory is available, this case illustrates the very common practice of corroborating theoretical development by actual measurement.

Measurement is often chosen in preference to computation of parameters, because it is easier. Not infrequently, mathematical techniques are deficient in certain respects and one resorts to measurement, with a mildly apologetic explanation that existing mathematical theories involve approximations not sufficiently close to reality.

But these difficulties are as nothing compared with measurement problems involving human beings. For example, it is only because familiarity breeds contempt, or at least indifference, that speech-volume distributions of telephone users become cold statistics. In the development of the hands-free telephone, the Speakerphone, design engineers discovered that these are living statistics and that the user behaves differently when he shifts from a handset to a microphone. Many essential parameters of communication systems depend on various aspects of hearing and visual perception, and these have been measured extensively.

A somewhat newer subject is "human engineering," or the consideration of man's abilities and comfort as system parameters. This is important not only to the telephone customer, but also to the Bell System employee who operates or maintains telephone equipment.

Finally, there is the measurement of human attitude, preference, or sense of values — often critical factors in system design. Suffice it to say here that quantitative measurements in this area are exceedingly difficult.

Evaluation of Design Procedures

To the development engineer, the use of measurements as a design tool is so universal that its other applications are dwarfed by comparison. Perhaps the most straightforward measurements here are those which confirm a theoretical design. This idyllic state occurs less frequently, however, than that in which measurements disclose unexpectedly critical factors. These may have been deemed too unimportant or too obscure to be included in the theoretical design, but must in fact be taken into account.

The truly universal application of measurement to design evaluation is in the introduction of a design change where it is important to know what effect this change will have on system performance. Here, it is of little significance whether or not the over-all observed characteristics have had the benefit of analytical explanation. Sufficiently precise measurements, with all other variables adequately controlled (no mean qualifications), can tell the designer to what extent he has modified system performance. They may also permit him to confirm this analytically.

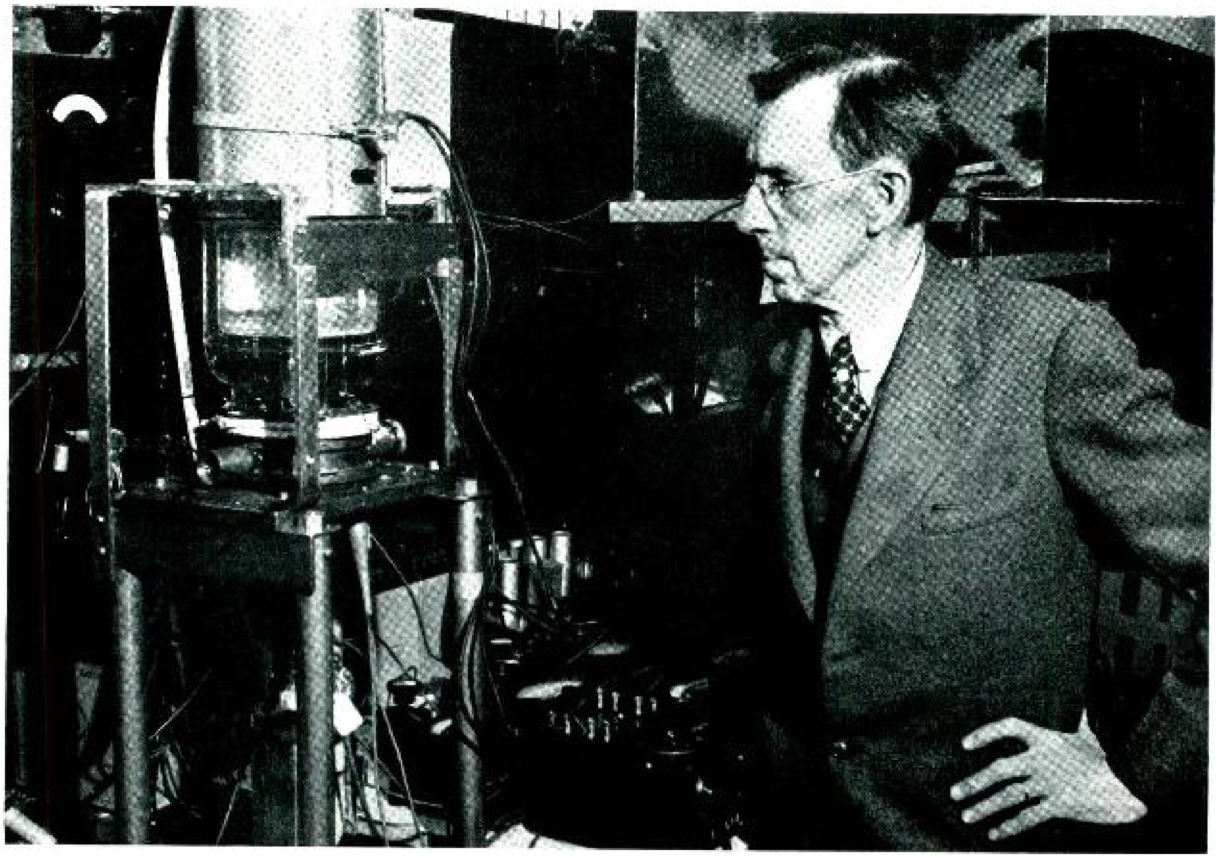
Most of us are familiar with the fourth general objective of measurement — testing — because we are aware that the successful operation of any system demands effective routine measurements. In many cases, today's routine measurement was yesterday's pioneering step in the laboratory. The differential gain and phase measurements regularly made on the broadband channels used for color TV transmission offer a good example. It is only a few years since the first successful measurements of this kind were made, with equipment that only the designers could operate.

One might think offhand that little fine art is involved in routine measurements. But test equipment which is stable, reliable, expeditious and not too demanding technically is a design accomplishment of which any engineer may be justly proud.

Factory testing involves these same principles, and is apt to be characterized by requirements of higher accuracy and speed, especially in repetitive measurements. Such measurements are greatly facilitated by visual presentation in which "sweeper" techniques have supplanted the "point-by-point" methods of earlier art. These refined methods take advantage of the powerful tool of direct substitution—that is, measuring the difference between the characteristic of the unit under test and that of a reference standard.

Repetitive measurements on resistors, capacitors, or dry-reed relays, for example, and life tests of electron tubes, generally do not require extreme accuracy, but must be done automatically to be economical. The story of the amazingly complex measurements that are performed automatically deserves an article in itself, as does the trend toward processing and recording measurement data in digital form.

Any description of specific measuring techniques is beyond the scope of this survey, but at least one general principle should be discussed:

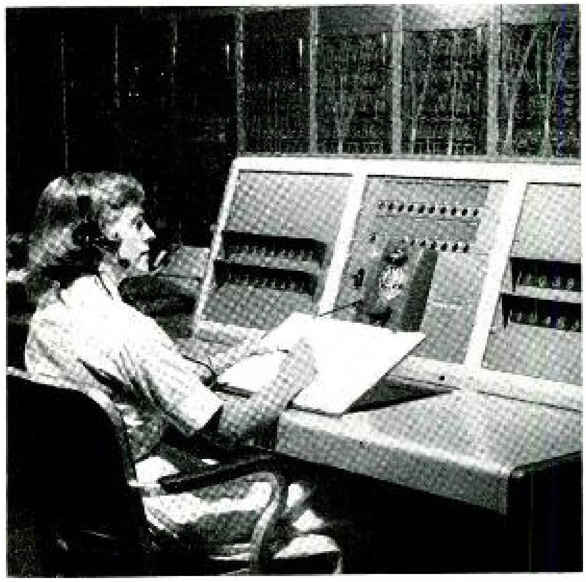


C. J. Davisson with some of the equipment used in his historic measurements of electron diffractions in crystals, made at Bell Laboratories with L. H. Germer. Davisson shared the 1937 Nobel Prize in Physics for this work, which firmly established the wave nature of matter.

the direct measurement of a physical quantity is a rarity rather than a rule. A simple illustration of this indirection is the measurement of small differences in linear dimensions by determining the change in capacitance between a pair of plates spaced in proportion to the dimension of interest.

This procedure is especially useful if the dimension is changing rapidly; say, varying rapidly about some mean value. Alternatively, the motion might be used to displace a coil of wire suspended in a magnetic field, inducing a voltage proportional to the time derivative of the displacement. The displacement can then be obtained through integration. If velocity happens to be the quantity of interest, so much the better, since it is given by the voltage across the coil.

Two other examples illustrate how the simple dimension of length can be determined, indirectly, by the use of interference phenomena. Precision measurements of small (but larger than atomic) dimensions commonly use observations of the interference patterns with monochromatic light (RECORD, *January*, 1957). Measurements of interatomic distances are generally made using the diffraction patterns of electrons or x-rays.



To test customer preferences, it is frequently necessary to simulate proposed services. This room full of equipment, called SIBYL, simulates various proposed services and automatically records data pertinent to "customer" reactions.

Natural Transducers

Assuming that these illustrations provide some notion of the great variety of physical effects which can be used to create a refined measuring technique, we can now consider some of the "transducers" which nature offers, in a sense, ready made. Transducer here means any phenomenon that, subjected to one kind of "stimulus," reacts with a quite different kind of physical manifestation which varies in a well-defined way with the magnitude of the stimulus.

Perhaps the most familiar natural transducer is the variation of electrical resistance with temperature. This method of measuring temperature is not only convenient, but is also very accurate because the techniques for measuring resistance, particularly differences in resistance, are highly developed.

Metallic resistance can also be used as a transducer in the measurement of very small displacements, as in the steel girders of a bridge. The resistance of wires firmly attached to these girders will exhibit measurable changes with changes in tension. Similarly, the resistance of a metallic wire under extremely high pressure is an excellent measure of the pressure itself.

The resistance of certain metals also varies with the strength of the magnetic field to which they are subjected, and this variation can be used to measure the intensity of such fields. Bismuth at liquid-helium temperatures provides a startling illustration. A field strength of 100,000 gauss increases the resistance by a factor of about 24 million.

Some of the most useful transducers known to the art of measurement are based on the piezoelectric properties of certain crystals. As tools, these might be considered double-ended wrenches. The dimensions of such a crystal change when a voltage is applied; and conversely, if the crystal is subjected to pressure, a voltage appears across it. Thus, the powerful tools available for measuring electrical quantities can be brought to bear in the measurement of displacements or pressures.

Certain junctions of dissimiliar materials generate thermoelectric electromotive forces due to temperature differences. This principle is often used for temperature measurements where great accuracy is not needed and simplicity of instrumentation is important. In a more specialized application of this principle, a number of such junctions, built with very small heat capacities and thermally isolated in a vacuum, are used for the measurement of infrared radiation.

Another natural transducer, the photoelectric effect, is used to measure light. Instruments of this type take two general forms, and both have electrical outputs. In one case, a voltage gradient is created at an emitting surface, and the change in electron emission is the quantity measured. The other is based on the "internal" photoelectric effect at a junction in semiconductors.

The Doppler effect — the change in wavelength of any kind of wave propagation due to rate of change of the path length — is a convenient tool for the measurement of velocity. Applications of this principle extend all the way from police surveillance of automobile speed to measurements of the apparent rate of expansion of the universe.

Hall, Faraday and Kerr Effects

Several other physical effects could also be considered natural transducers useful in measurement. The Hall effect, in which a conductor in a magnetic field exhibits a potential difference perpendicular to the plane through the current and field directions, is relatively large in certain semiconductors. This effect has been used to measure the strength of magnetic fields with an accuracy of perhaps one per cent at 10,000 gauss, under conditions where the available space is too small to permit the use of most other techniques.

The Faraday effect — rotation of the plane of polarization of electromagnetic radiation in a magnetic field — could hardly be considered a common basis for a transducer, but one could imagine an instrumentation problem for which it would offer a solution. A similar statement applies to the Kerr effect: double refraction of electromagnetic propagation in such materials as nitrobenzene, produced by an electric field. These two effects are mentioned primarily for those with unfettered imaginations.

Measurements of many physical phenomena yield information about the structure of the atom. Two examples are measurements of nuclear magnetic resonances and magnetic-resonance effects associated with electron spin. These latter effects have distinguishing characteristics that depend upon their observance in ferromagnetic, paramagnetic, or ferrimagnetic materials.

In the study of the band structure of metals, cyclotron resonances involving the charge associated with the electron have been used effectively. These resonance measurements are all made by superimposing a microwave field on a steady magnetic field, and many of them take advantage of advanced microwave techniques at millimeter wavelengths.

The Faraday effect has also yielded clues to atomic structure, and this points up an important distinction. In the earlier reference, the Faraday effect constituted a "black box," unimportant except for its capabilities as a transducer. In the present case, our interest is in why the black box behaves as it does. Thus, these tools for atomic and subatomic research are perhaps more in the nature of direct observations of what goes on inside the atom than applications of transducers. Quite aside from their important objectives, measurements of this kind also pose extremely challenging problems in instrumentation.

To this point, we have been concerned primarily with the general objectives of measurement and with some of the more interesting "natural" tools used in achieving these objectives. But in any survey of measurement, a few words are needed regarding scales, particularly certain distinctions between the scales used in the physical sciences and those used in psychophysics. In measurements of inanimate things, the steps of the scale are generally quantitatively defined, either as equal in magnitude or as fixed ratios. The zero is usually as unambiguous as the end of a yardstick.

In the two familiar thermometer scales — Fahrenheit and Centigrade — the fact that the steps differ in the ratio of 5 to 9, and that the zeros differ by 32°F, is no more than a nuisance. A number of physical relationships are more simply expressed in terms of "absolute temperatures," obtainable from the Fahrenheit or Centigrade scales by adding a suitable constant. "Absolute zero" is believed unrealizable, but this does not decrease the utility of absolute temperature scales in certain measurements.

Hall-effect apparatus. R. A. Logan adds liquid nitrogen to super-cool sample in an experiment for measuring the properties of semiconductors.

Making subjective measurements of TV "sharpness." Machine projects red, green and blue portions of simulated color TV picture on screen. Subject on the left then decides which test picture is the sharpest. Operator changes sharpness by varying proportions of red, green and blue. Tests show how much of total transmission band should be devoted to each primary color.

In the measurement of sensory perceptions. the "input" (stimulus) is some physical quantity for which a thoroughly satisfactory scale is generally available. Measuring "output" (response) with a quantitative scale begins to present difficulties, however. Consider attempts to measure impairments of different kinds in a television picture, for instance. It is not too difficult to establish an order of merit for a series of stimuli representing a range of such impairments. It is very difficult, however, to establish that one impairment is twice as great as another. At least one eminent experimental psychologist has gone so far as to say that well established ratio scales exist only for loudness and pitch.

One common method of establishing a scale for the measurement of human attitude goes something like this. (1) Some stimulus which lends itself to quantitative description — the weight of a telephone handset or the magnitude of an interfering tone—is chosen as the independent variable. (2) A reasonably well defined criterion, such as "acceptable," is adopted as one point on the attitude scale. (3) With a large number of subjects, the independent variable is adjusted for each subject until the criterion is just met. In this way, the distribution among these subjects is determined. (4) A response scale is then adopted in which the units have been adjusted so that the measurements result in a "normal" distribution.

While the assumption that this procedure yields a scale with equal intervals may be open to question, the method does yield illuminating and useful results. Indeed, one can often get significant results with a scale in which only the sequence of things, like order of merit, is meaningful. In such cases, the investigator would do well to overcome his reluctance to abandon the more refined scales.

Along with scales, we must also consider standards. There are two widely different meanings of the word as used here. One has to do with physical units such as mass, length and time. These involve choosing, as standards, objects or phenomena which are as stable as possible and which lend themselves to precise comparison with similar objects or phenomena.

The other involves the establishment of a significant relationship between a well defined quantity such as a meter reading, and some more elusive quantity like the subjective loudness of speech. Since loudness is a function of many variable qualities of speech, typified by the characteristic differences between male and female voices, these factors must be weighed properly. Such standards are of far lower accuracy than the standards of precise physical measurement. The reasons for this will be pointed out after we discuss physical standards.

The Primary Standards

In most of our measurements, accuracies comparable to those represented by the primary International Standards are not involved, and we use a wide variety of more convenient secondary standards. From a philosophical standpoint, the standards for mass, length and time occupy a special position; time perhaps more than the others. The standard for mass is a particular cylinder of platinum-iridium. Interestingly, the choice of this material proved a happy one, since it is remarkably free of radioactive elements that would have gradually degraded the standard. Thus, a danger was avoided which was unknown when the standard was established.

Until recent years, the standard for length has been a physical property of a specific object —a rod of platinum-iridium. Now, atomic phenomena have come into increasing favor as a more manageable standard of length. The red line in the spectrum of cadmium is highly regarded in this respect.

A similar situation exists with respect to time. The older view looked upon the movement of the celestial bodies as the most precise and invariant time standard. Observations of the earth's rotation, properly corrected, provided an unparalleled timepiece. Both pendulum clocks and oscillators controlled by quartz crystals permitted interpolations, or short-time measurements, but the celestial bodies constituted the primary standard.

Lately, however, such atomic phenomena as the electromagnetic absorption peaks in ammonia gas have shown promise as the ultimate refinement in frequency standards, and thus in time standards. An elaborate theory has been constructed to demonstrate that in about 20,000 years, gravitational and atomic clocks will be out of synchronism by one second per day.

No more intriguing speculation can be imagined that the reason for the time invariance of atomic phenomena, if such invariance is a fact. There is a school of thought which subscribes to the thesis that the properties of numbers are intimately associated with the structure of the universe, and the writer confesses to a fascination with such metaphysical considerations. For example, in one of his classical papers on wave mechanics. the German physicist E. Schrödinger says, "this half-integralness (of quantum levels), which is spectroscopically so significant, is thus connected with the 'oddness' of the number of dimensions of space." The British astronomer Eddington started out from a simple concept of this kind and derived what he firmly believed to be the precise values of several universal constants, including the number of indivisible particles in the universe. In his view, measurement should merely confirm his derivations. Pythagoras is quoted as saying, "All things are numbers."

Several paragraphs ago, we mentioned the great difference in accuracy between measurements in the physical sciences and those in subjective areas. There are at least two reasons for this disparity. In the physical sciences, the ultimate limitation on accuracy is represented by Heisenberg's uncertainty principle, and in any macroscopic measurement fantastic accuracy is realizable. In x-ray measurements of crystal lattices, for example, the dimensions may be of the order of one hundred-millionth of an inch. Here, the uncertainty principle may limit the accuracy to a few parts in a million. By contrast, it is a rare measurement in psychophysics which can be made to one part in a hundred.

Standards to Replace Judgments

The second, and perhaps most important, factor which complicates the establishment of precise standards to replace subjective judgments is the impracticality of correcting for all variations. A precise loudness measurement, for example, necessitates high-fidelity recording, an analysis of spectral-energy distribution, application of weighting factors over many narrow bands of frequency, and summation of these bits and pieces into one final answer. In contrast, a very simple circuit will provide a loudness measurement which is good enough for most practical purposes, and is a great improvement on subjective judgment.

Frequency-weighting factors to be applied in measuring a combination of interfering effects in television present similar problems. While the relationship between the quantity measured and the subjective effect is not precise, random television interferences can be measured with a power meter having appropriate frequency weighting, and the results will be accurate enough to be valuable in the design or maintenance of television transmission circuits.

This discussion of accuracy leads to another important aspect of measurement, the distinction between accuracy and sensitivity. The definition of sensitivity—the smallest quantity which can be measured—is deceptively simple. In the presence of what? We measure signal in the presence of noise, for instance, and threshold of hearing varies widely with the environment. On the other hand, the smallest difference between two light intensities or two sound levels that can be detected by normal eyes and ears is close to a fixed ratio over a wide range of intensities. Thus, sensitivity should be carefully defined in a given context.

In many cases, sensitivity, not accuracy, is the interesting aspect of a measuring technique. For example, impurity concentrations in semiconductors of one part in 10 million have been measured by mass spectrography with semi-quantitative accuracy, as have surface contaminations of the order of 1/10th of a molecular layer. Furthermore, there are impurities which affect certain properties of semiconductors to such a degree that concentrations of one part in many billions can be detected.

Again, sound pressures as low as 0.00006 microbar (6×10^{-11} dynes/cm^2) can be detected—a sensitivity far greater than that of the human ear. In achieving this sensitivity, the great discrimination of filters which pass only very narrow bands of frequencies was an invaluable tool, as it has been in many other fields.

Absolute and Relative Accuracy

Accuracy has two important facets which must be distinguished clearly—absolute accuracy and relative accuracy. Actually, measurements in which absolute accuracy is of first importance are rather rare, at least in technology. The situation is usually somewhat like that of buying water which is fit to drink. The exact amount of water is far less critical than any increment that might be due to arsenic. Thus, an uncertainty of one part in ten in the magnitude of a television signal is hardly significant, but certain ripples of very small magnitude in its transmission-frequency characteristic will perceptibly impair the television picture.

An outstanding example of refined relative accuracy is the attainment, in transmission measurement, of an accuracy of the order of one hundred-thousandth of a decibel over quite wide ranges of frequency. This represents the ability to distinguish between two received powers that differ by about one part in 500,000.

It is natural to look upon measuring techniques of high precision as somehow of greater scientific worth than those which yield more qualitative results. As a matter of fact, a scientist of great renown once said that future discoveries must come from measurements correct to the sixth decimal place. Many profound deductions have come from such measurements, but much of our basic knowledge, as in the case of cosmic rays, also comes from measurements of low accuracy.

There is an interesting class of measurements in which neither the sensitivity nor the accuracy is particularly impressive—those that have necessitated significant advances in instrumentation. In many cases, these challenges arise from making measurements "on the run," as in measuring the diameter of a wire during high-speed drawing, or the dynamic friction of a bearing.

In other cases, the frontiers of an existing art simply need to be extended. The measurement of one milliwatt of power at a wavelength of a few millimeters with an accuracy of ¼ db falls in this category. One might also mention the measurement of the effective resistance of conductors in 9000-mc fields to an accuracy of one per cent, and the elastic modulus of a crystal of tenth-inch dimensions to an accuracy of at least ½ per cent.

Many measuring techniques in this same class are further characterized by the peculiarly qualitative nature of their results. A case in point is the use of extremely short pulses of microwave energy to determine "dispersion" by the observation of unwanted images, displaced in time. Pulses as short as one millimicrosecond have been used for this purpose (RECORD, *December*, 1954). Similar pulses have even been circulated repeatedly through the same amplifier to show the cumulative distortion of the original pulse.

The examples in this article are not intended to define the present state of the fine art of measurement, and if they did, they would soon be out of date. One can only hope to suggest the scope over which the imagination of engineers and scientists, at the Laboratories and elsewhere, is free to roam in the search for a measuring tool.

At least twenty departments in the Laboratories, through a much larger number of individuals, have contributed to the present article, not only with regard to specific techniques but also with ideas on presentation. These contributions are hereby gratefully acknowledged.

Looking as new as tomorrow in its garb of colored plastic, insulated wire is still the work horse of communications. This is one reason why the Bell System is now consuming plastics at the unprecedented rate of nearly 70 million pounds a year.

J. B. Howard and V. T. Wallder

COLORED PLASTICS FOR WIRE AND CABLE

During the last decade, engineers have made great advances in the art and science of communications. For example, developments in coaxial cable, microwave radio-relay, and over-the-horizon scatter propagation have increased the number of conversations possible over a single transmission medium. However, even with the increase from a few dozen conversations on carrier lines to many hundreds on coaxial systems, or with the possible tens of thousands for circular wave-guides, use has not decreased for that work horse of communications, the simple insulated wire.

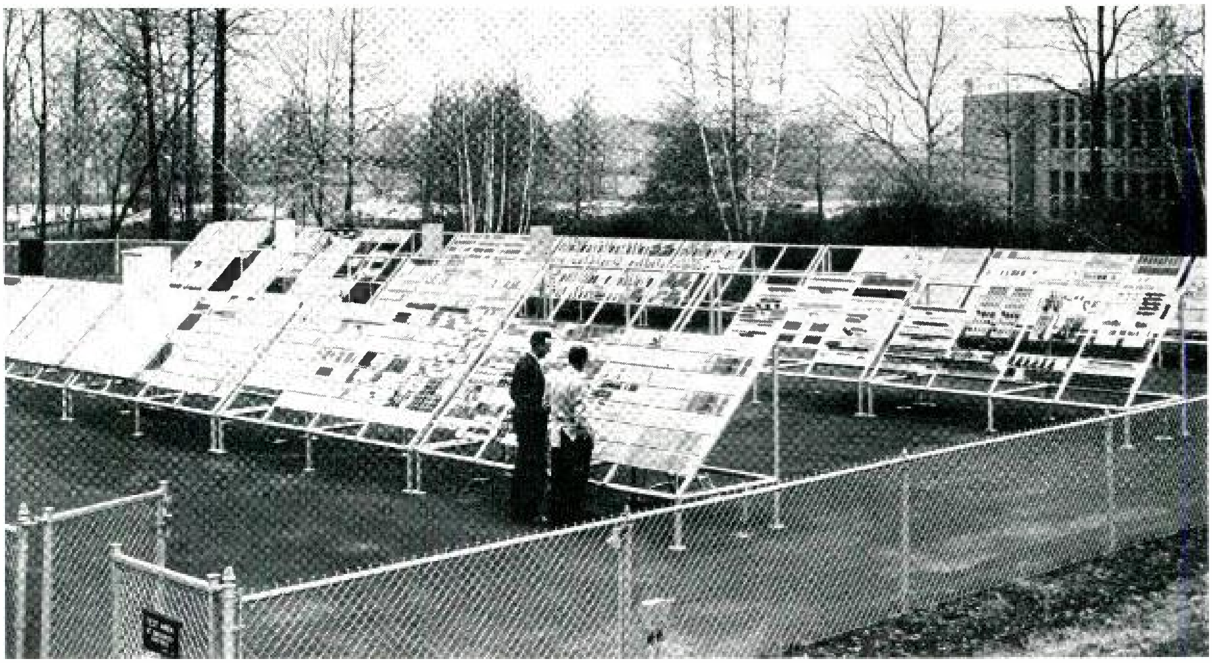
Cable Covers

In 1950, the Bell System used 33 million pounds of various materials for covering wire and protecting cable. Included among these were paper; textiles such as nylon, cellulose acetate rayon, and cotton; synthetic rubbers such as neoprene and GRS (a general purpose synthetic rubber); and plastics such as polyethylene and polyvinyl chloride. Consumption was about equally divided among plastics, rubbers, and textiles.

In 1956, the Bell System used nearly 75 million pounds of insulating and sheathing materials. By this time plastics had increased to over 50 per cent of the total, paper and textiles held steady at 35 per cent, while rubbers decreased to 15 per cent. Polyethylene and polyvinyl chloride accounted for the major increase, jumping to about 40 million pounds.

One reason for this large increase in the use of plastics is the growing demand in rural and urban areas for unsheathed cables exposed directly to the weather. For such rural or urban wire to be broadly useful in the field, Laboratories chemists had to develop weather-resistant insulation that could be color-coded.

Examples of the successful solution of this problem are the weather-resistant colored vinyl jacket over a primary insulation of polyethylene on B-Rural Wire (RECORD, *July*, 1956; *May*, 1954) and the combined insulation-jacket on B-Urban Wire (RECORD, *October*, 1956). Urban and rural



Exposure plot at the Laboratories Murray Hill location. This area is used to weather-test all types of materials and equipment intended for use outdoors. Over 4000 samples are now under test.

wires are similar in that they consist of twisted pairs of insulated conductors cabled loosely around a central steel supporting strand, which is cushioned by a jacket of weather-resistant polyethylene. They differ in the number and gauge of conductor pairs, and in the dielectric quality of their insulations. Rural wire, used for greater distances between telephones and the central office, has larger conductors and polyethylene insulation under the vinyl conductor jacket.

Chemists developed these colored vinyl compositions so that they would remain serviceable, with colors easily distinguishable, for not less than fifteen years. This development followed and benefited from work on light-colored polyvinyl chloride, whose outdoor aging tests began at the Murray Hill location of the Laboratories prior to 1950.

A prime necessity in a weather-resistant, nonblack vinyl is an effective light screen or opacifier. This screen limits the destructive effects of ultraviolet radiation to the outermost few mils of the plastic. Bell System requirements have proved too severe for the usual organic light-screens. But among the opaque screens, a zinc-treated rutile grade of titanium dioxide has been outstandingly effective as a protection against deterioration initiated by light.

A satisfactory stabilizer to resist thermal degradation is also needed in weather-resistant vinyl compositions. And for this, dibasic lead phosphite appears to be almost unique. This substance is not only reasonably opaque to ultraviolet light, but it also "weathers" well. That is, it can withstand the assaults of sun and storms.

Protection for Colors

The real challenge, however, is in providing effective protection for color compositions other than black or white. The great majority of commonly used colorants for plastics fade rather quickly on exposure to sunlight. For example, in a series of vinyl films covering the color spectrum, only blue and green phthalocyanines and iron-oxide pigments were found to retain their original colors after exposure to the weather for nine years. These limit the chemist to a narrow, muted range of colors.

A fundamentally important constituent in a vinyl plastic is the plasticizer. Plasticizers are generally liquids with high boiling points which are added to plastics to make them softer, more flexible, and better able to withstand low temperatures without cracking. Bell Laboratories chemists have used dioctyl phthalate for this purpose, but one other promising material with which they have had much experience—n-octyl n-decyl phthalate—has only recently been available in commercial quantities. Highly satisfactory experience with dioctyl phthalate is the present basis for the Laboratories estimate of service-life expectancy.

The basic colored vinyl compositions now in use are three: (1) white, (2) black, and (3) a type that serves as a base for red, brown, yellow, blue, and green compositions. Iron and phthalocyanine pigments are in themselves good enough radiation screens that the titanium dioxide content of compounds in which they are used can safely be reduced.

Growing interest in color for telephone sets has created another important application for colored plastics—spring cords which match the colored instruments. The Western Electric Company now manufactures these cords in ten colors: ivory, green, red, yellow, grey, white, blue, pink, beige and brown. Because the springiness of the cords is due primarily to the elastic "memory" of the vinyl jacket, a compound for this application must exhibit a rapid rate of retraction. In addition, it must resist stiffening and be harmless to common furniture finishes.

Lacquer-marring tendencies are rated qualitatively by placing flat samples cut from molded sheet on standard lacquered panels. These specimens are kept under light pressure for two weeks at room temperature, after which their surfaces are visually inspected.

Chemists at the Laboratories compared retraction speeds of plastics containing various plasticizers by measuring the recovery time of small, standardized heat-set helices after their controlled extension. Stiffness in flexure before and after immersion for twenty-four hours in lard oil or kerosene furnishes a measure of resistance to extraction of the plasticizers.

Compromise Plasticizers

In general, low-temperature plasticizers such as tri-octyl phosphate make cords retract the fastest, but unfortunately these are most active in their attack on furniture finishes and are among those most readily extracted. On the other hand, lowest extraction and least finish attack are exhibited by polymeric plasticizers, which in general, are quite sluggish in retraction. In the compromise obviously necessary, a careful balance of selected monomeric and polymeric plasticizers has led to a composition with a satisfactory retraction time. This composition stiffens less than 25 per cent after immersion for twenty-four hours in oil. It also does not attack furniture finishes.

For exposed locations, there is no novelty in the use of properly compounded black polyethylene stocks as long-life wire jackets and cable sheath. In fact, the oldest sample of weathered polyethylene is still in sound condition after nearly eighteen years of Florida sunshine. The brittle temperature for this sample has been virtually constant at −25°C for ten years, and the wire is expected to remain serviceable for many years more.

Currently the Laboratories is using a polyethylene with a higher molecular weight protected with about three times as much carbon black. This cable-sheath material, adequately protected as it is against photo-degradation, should enjoy a very long life indeed.

J. B. Howard and V. T. Wallder examine operation of extruding machine. Wire from rear passes through device to receive its "coat" of insulation. It then goes into cooling trough, foreground.

A large proportion of simulation of engineering projects is carried out on this IBM 704 digital computer. P. M. Pelly, left, attends the master control board while E. V. Scott loads cards.

to the state of the system at discrete intervals of time. However, engineers can obtain great accuracy by choosing sufficiently small time intervals. Guided-missile studies, for example, where small miss distances at the end of long flights must be estimated, are problems for which digital simulation of this type is well suited. Such studies have played an important part in the design of guided-missile systems at the Laboratories.

Simulating Digital Systems

A powerful use of digital simulation is the study of systems that are themselves digital and therefore difficult to simulate by analog methods. Many devices or systems are of a digital nature, apart from digital computers. Telephone switching systems can be thought of as digital in nature; for example, one telephone switching system receives dialed numbers and steps through switches to make connections. Also, many problems such as handling traffic, controlling supplies or making strategic decisions, involve digital quantities. Therefore, systems designed to carry out these functions must be digital.

Sometimes a special digital simulator is constructed to help design a digital system. Much of the No. 5 crossbar equipment used in the Bell System was studied this way (BSTJ, *March*, 1953). Usually, however, simulation of digital systems is done on a general-purpose digital computer. This article will describe the process.

To see how engineers carry out simulation of a digital system, we must understand a little of how a digital computer works. Essentially, it consists of a storage unit, an arithmetic unit, a control unit, and input-output devices. The storage unit, or memory, is divided into a large number of cells. Each cell stores an item of information and each has an "address" to identify it. The information either may be a unit of the data being processed by the computer, or an instruction forming part of the program the computer is to follow.

The arithmetic unit does the mathematical operations called for by the instructions; the control unit does the logical functions—it makes decisions. The control unit also "steps" the computer through the program by selecting the successive instructions from its memory. To do this it has some special memory cells, called registers, that carry both a copy of the current instruction being executed and the address of the next instruction. Where necessary, instructions cause data to be read into or out of the computer through the input-output devices.

Information stored in the memory cells is basically in the form of numbers, but different meanings are attached to the numbers according to their function. In the instructions, for example, numbers indicate the operations and the addresses of the operands. In the data, on the other hand, the numbers may be figures occurring in a calculation or they may be codes representing whatever type of information is called for in the problem being solved.

Suppose, for example, the computer is to simulate a telephone switching system. For this, some of the memory cells will hold computer instructions that form the simulation program. Others will represent the telephone number that has been dialed and the state of each switch involved in the call. Systems designers can then make the simulation program read the dialed number and proceed to change the contents of the memory cells representing the switches in exactly the same way as the telephone system will alter the switches in making the connection. Information showing the values of the numbers in the memory can be written out at any time. Thus, the state of the system can be followed.

At the Laboratories, simulation of this type has been used to a large degree in the design of an experimental electronic switching system aimed at using digital, computer-like devices in telephone central offices of the future (RECORD, *October*, 1958). Some other examples of digital systems that have been simulated on computers at the Laboratories include data-transmission equipment, pulse-code modulation systems, and line concentrators—devices for sharing a number of telephone lines among customers.

A very striking example of the versatility of digital simulation is the use of one digital computer to simulate the execution of a program on another digital computer. Why would anyone want to do that? There are several reasons.

Simulation may be used to make one computer behave exactly like another, existing computer. A person who uses the computer can then take advantage of programs written for other computers without rewriting them for his own. Or, if a user is changing from one computer to another, he can prepare and test programs for the new computer long before he gets it.

In other cases, the computer being simulated is fictitious. Most digital computers are general-purpose ones with a fixed set of basic operations. Engineers might conceive of a different computer with special arrangements or new operations more suitable for a particular problem. By writing a simulation program, they can make a general purpose computer behave like the desired computer. In effect, they will provide a new computer without actually building it or modifying the existing one. However, the simulation program will solve the problem more slowly than the special computer would have done.

People can then write programs for solving problems on the special computer without knowing or caring how to program for the general purpose computer, or even knowing that the general purpose computer is used. Laboratories engineers developed one such simulation program to make an IBM 650 computer behave like a machine suited for certain mathematical calculations.

Another important type of computer simulation occurs where the simulated computer is one being designed or rebuilt. Simulation can then be used to test out new ideas and check that the proposed machine will be adequate. A large project at the Laboratories used simulation of computers in this way to study the mechanization of accounting procedures in the Bell System.

One Computer for Another

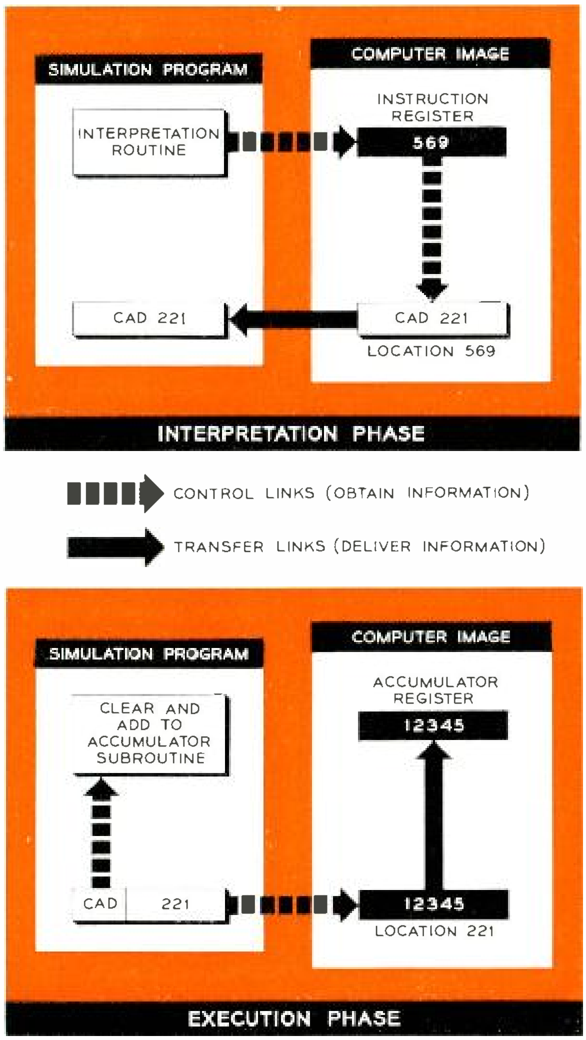
Simulating one digital computer on another is a particularly good example of the methods of programming used in digital simulation. Suppose a computer, A, is to be simulated on another computer, B. The memory of Computer B must carry information about the contents of each memory cell of Computer A. In this way, Computer B holds a complete *image* of Computer A and the image includes a copy of the program that Computer A is to follow, because the program would be stored in the memory of Computer A.

To carry out the simulation, a programmer would write for Computer B a program divided into two parts. The first part, called the interpretation phase, is concerned only with following in the image a program that would be running in Computer A. The second part, called the execution phase, is concerned with changing this image in a way corresponding to an instruction coming from Computer A.

The simulation proceeds as follows. First, the simulation program goes to the image of Computer A to find the instruction of the Computer A program that is to be carried out. It can do this because the image includes a copy of the Computer A register holding the address of the next instruction. The simulation program then changes the *image* of Computer A in exactly the same way as the instruction it has found would change the *memory* of Computer A. To make these changes, the execution phase of the simulation program has a separate section corresponding to each instruction of Computer A. The interpretation phase of the program "switches" to the appropriate section.

After executing the changes, the interpretation phase acquires the next instruction of the Computer A program and repeats the action until the program of Computer A is finished. The whole process is illustrated in the sketches below which show how the memory of the simulating computer is organized. These drawings demonstrate the sequence of events when an instruction calls for an item of information to be taken out of the store and put into the accumulator register in preparation for a mathematical operation.

Because of its versatility, digital simulation has, in addition to helping solve engineering problems, become a useful tool in many research problems. At Bell Laboratories, for example, great interest is being shown in such problems as mechanically recognizing writing (RECORD, *January*, 1958), understanding speech (RECORD, *August*, 1957), and recognizing and tracking objects in television pictures.



Organization of the memory of a simulating computer. Top panel shows simulation computer finding the location of and acquiring an instruction in the simulated computer. This instruction will select the subroutine to execute the action—a change in the image of the computer being simulated. This action reflects the change the same instruction would cause in the actual computer. (Term CAD refers to "clear and add" process.)

Solutions to these problems would permit engineers to design more efficient ways to transmit information. Or, they could arrange machines to act upon input data in new ways without human intervention.

Perhaps engineers may wish to test different systems for their usefulness as recognition schemes. The essentially analog signals involved in recognition—seeing and hearing—can be converted into digital data by appropriate equipment. Then, digital computers can be programmed to simulate the particular scheme engineers wish to study.

As far as possible, these recognition schemes are based on the characteristics of the human senses. However, the processes involved in human perception are not yet fully understood, and as a result, the methods employed in recognition studies are largely experimental. Under these circumstances, simulation is a particularly valuable technique because it can save building special processing equipment for carrying out the studies at least until a clearer idea is obtained of the most suitable equipment needed.

Recognition studies can do more than just provide useful design data for engineers. Such studies also uncover the essential elements of visual and acoustical information and give us some insight into actual working methods of the brain.

For example, scientists have shown that nerve cells—the basic elements of the brain—have certain digital properties. However, these nerve cells, or neurons, are considerably more complex than the simple binary elements used in digital computers. Moreover, digital processes alone are not sufficient to explain their action.

It is not feasible to construct on a computer, therefore, models of the brain that are biologically accurate. Nevertheless, digital simulation enables scientists to construct and test logical models that help them gain a better understanding of how the brain processes data received through its senses.

These examples of research and design problems illustrate the great versatility of digital simulation. This versatility is responsible for simulation's importance in science and engineering. Through it, designers and scientists have an inexpensive, yet rapid, method of testing and evaluating their ideas.

Towers for microwave radio-relay routes represent a significant part of the total system investment. For this reason, the Outside Plant Development Department at Bell Laboratories has devoted considerable effort in achieving tower designs that meet all strength and transmission requirements, yet are economical to fabricate and install.

H. A. Wells

Microwave Radio-Relay Towers

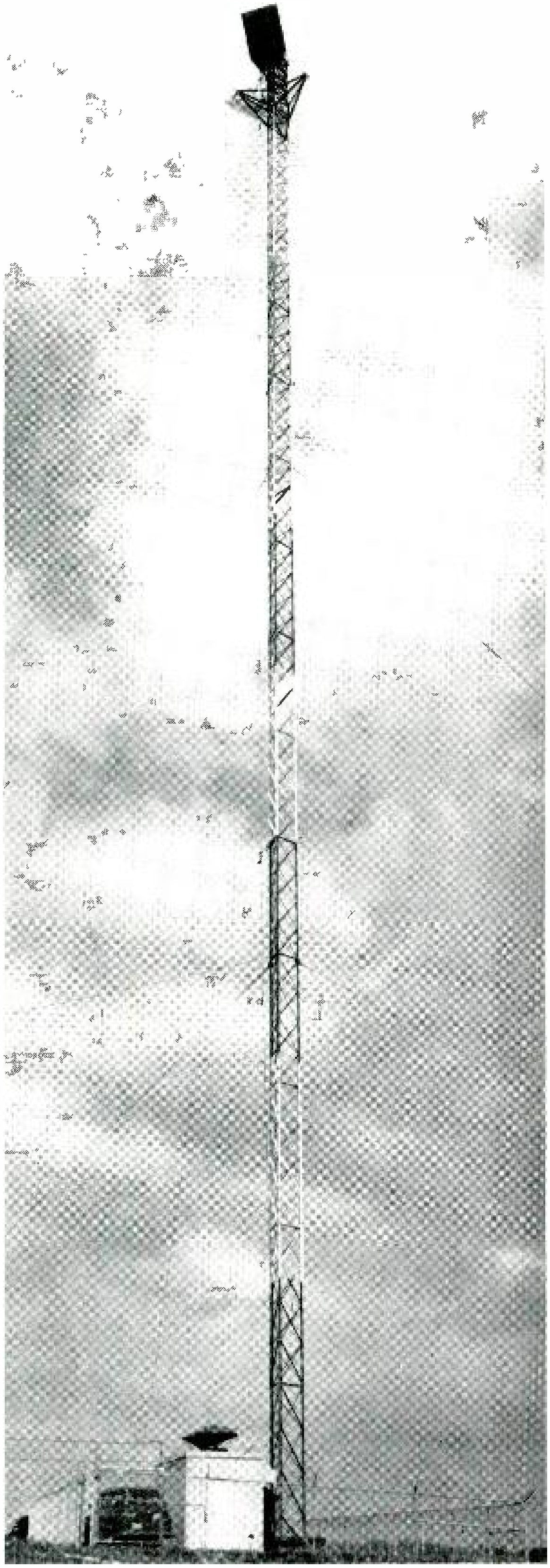
Microwave radio-relay towers have become a familiar part of the contemporary landscape. Most of us, while driving along open highways, have seen these tall, slender structures with antennas or passive reflectors at the top. Associated with each tower is radio equipment, and typically such an installation represents a repeater point. Here the microwave radio beam is received, amplified and transmitted to the next repeater along the radio-relay route. Because microwave radio beams tend to travel in straight lines, a line-of-sight path is established between stations. And, to avoid the expense of a great many, closely spaced repeaters, there is an obvious advantage in raising the radio beam high off the ground.

In mountainous regions, it is often possible to use short structures and transmit from ridge to ridge. Height can also be gained by installing short structures or small towers on top of telephone buildings. But for the most part, it is necessary to erect towers which are particularly suited to the topography between adjacent stations. Some of the tallest are used for transmission over water or very flat land to eliminate or reduce the effect of surface reflections.

Associated radio equipment is most often housed at the base of the tower or, when the tower or other structure is atop a building, within the building itself. In either case, the radio signal must be transmitted vertically to the top, then horizontally to the next station. This may be accomplished by means of a waveguide to an antenna at the top, from which the signal is transmitted horizontally, or the transmitting antenna may be placed near the radio equipment and aimed upward. In this second case, the radio beam travels upward to the top of the tower and there strikes a passive reflector. Such a reflector acts as an "electrical mirror" for the signal, which bounces off in the required horizontal direction. It is termed "passive" because, unlike an antenna, it does not radiate energy but merely reflects that which it receives.

Both of these arrangements are used with the new TJ Radio Relay System — a "short haul" system operating in the 11,000 mc region (RECORD, *April*, 1959). And, in the course of the TJ development program at Bell Laboratories, the Outside Plant Development Department was asked to prepare the necessary tower designs to accommodate these arrangements.

Obviously, "ground rules" or requirements are needed before such design work can be undertaken.



For example, what maximum height should be made available, and what increments of height should be provided? How many reflectors and antennas should the towers be able to support, and how much can they bend or twist under what wind conditions? With the radio system in development, immediate answers to some of these questions were difficult to obtain.

A canvass of the Operating Companies indicated that for TJ installations, both self-supporting and guyed towers would be required, ranging up to a height of 300 feet in increments of 20 feet. A minimum height of 40 feet seemed desirable for self-supporting towers, and a minimum of 80 feet for the guyed type.

Types of Towers

The canvass also showed a preference for the use of guyed towers, due probably to their lesser cost. Guyed towers are inherently less expensive than self-supporting towers of the same heights because they require considerably less material to accomplish similar results. However, guyed towers need relatively large property areas to accommodate the guying arrangements, and where large land plots are not available, self-supporting towers will be required. The use of a self-supporting tower is also usually indicated when an existing building is not tall enough and a tower must be erected on its roof.

Several proposed TJ routes and existing short-haul radio-relay systems were analyzed to determine how many antennas and reflectors the towers should be able to support. With cross polarization of the radio signals, so that one antenna may both transmit and receive, a TJ terminal needs only one antenna or reflector; a repeater needs two; a point at which one route branches into two needs three; and a point at which two routes cross needs four. In a short-haul system, repeaters account for the largest number of installations, with terminals second. But for future growth, so that any repeater might become a branching point, it was decided that the minimum number of antennas and reflectors which the towers must support should be three. This was a most appropriate decision for guyed towers, since they are generally triangular in cross-section and therefore lend themselves to this number. Self-supporting towers, on the other hand, are generally square in cross-section.

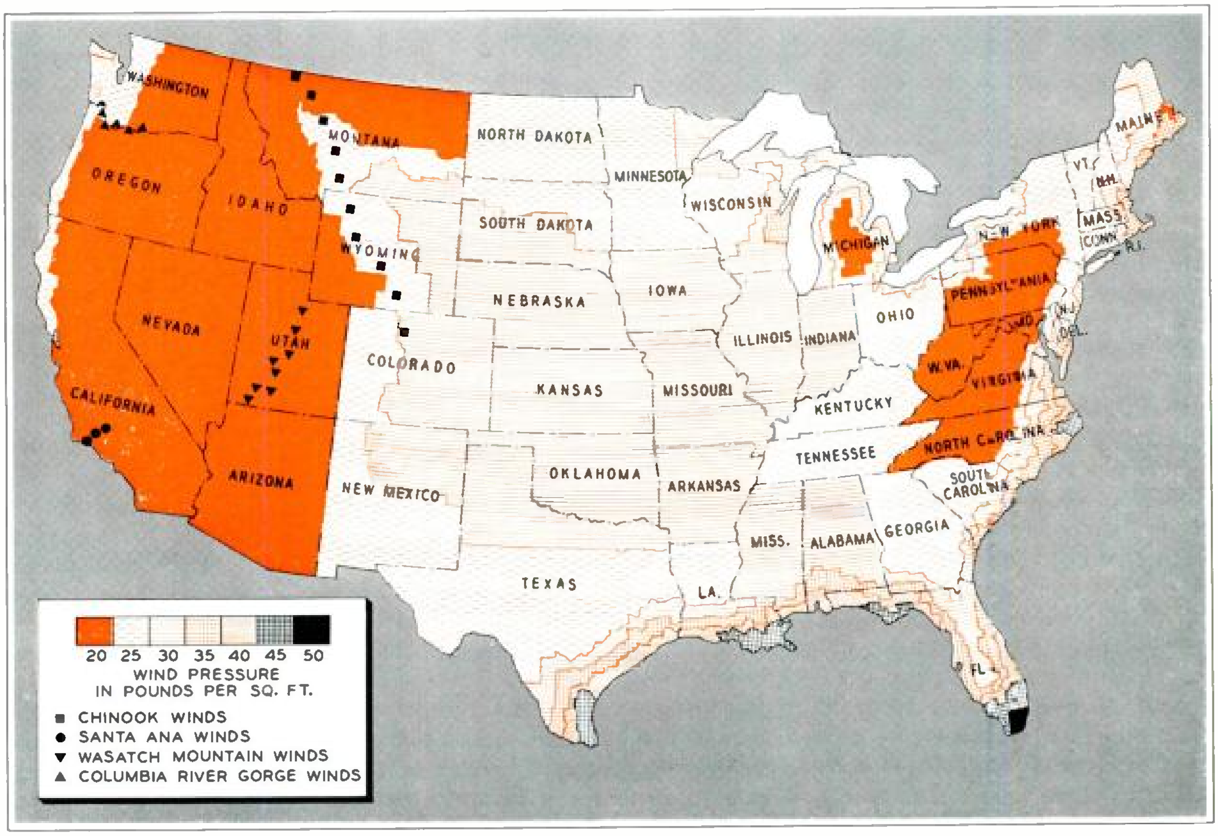
The B Guyed Tower for the TJ radio-relay system. Guyed towers use less steel, but they require more real estate than self-supporting structures.

a configuration more suitable for four antennas or reflectors.

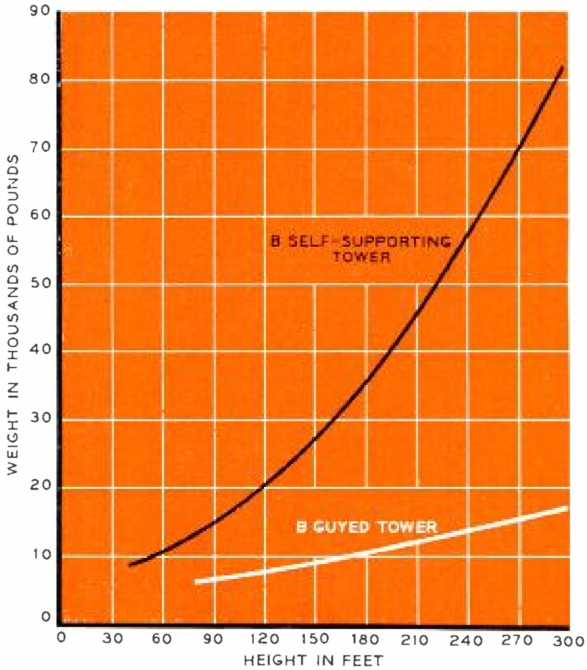
The establishment of bend and twist limitations for towers — factors which affect the deflection of the radio beam — is extremely important because these limitations are frequently controlling in the design. In the TJ System, the beam width, or angle from half-power point to half-power point, is in the neighborhood of one degree for both passive and radiating elements. It is highly desirable to restrict the allowable deflection of the radio beam to half this value, so that under normal operating conditions, the signal received at the next station is not below the half-power level. A tolerance of plus or minus ½ degree was therefore indicated, nominally in all directions. However, where a reflector is employed, optical reflection laws pertain, which means that if the reflecting surface is rotated in the plane of the incident and reflected beams, the reflected beam is displaced through an angle twice that of the reflector rotation. This implies that the towers should not tilt more than plus or minus ¼ degree, while the tolerance for twist remains at plus or minus ½ degree. In general, the twist deflection of guyed towers is more difficult to control, while with self-supporting towers twisting is little or no problem once the tilt requirement is met.

Accommodating Wind Forces

A study of expected maximum wind conditions in the United States indicated that loading of 20 pounds per square foot (PSF) occurs in all areas *(see map on this page)*. This resulted in the decision to design these towers to remain within deflection limits in this environment, which is approximately equivalent to wind velocities of 70 miles per hour. The strength requirement, of course, is more rigid — 40 PSF, or wind velocities of about 100 mph. Thus, these towers represent a compromise design which is not too costly for use in areas of lesser wind loading and can be used over the great majority of the country. In hurricane areas, encompassing much of the Gulf Coast and Atlantic Seaboard, wind loadings in excess of 40 PSF can be expected, and special tower designs are necessary. Wind velocities of about 600 mph may exist near the eyes of tornadoes, and they will



Wind-loading map of the U. S. The new towers can be used wherever wind loading is not expected to exceed 40 PSF. (By courtesy of the American Standards Association, Std. A58.1-1955, p. 11).



Weights of two towers for various heights. Curves show savings in material with guyed towers.

produce a loading of almost three-quarters of a ton per square ft. The effect of tornadoes is therefore rarely considered in the design of structures, and a calculated risk is taken whenever they are installed in areas where tornadoes occur.

In the course of the development of these towers, a rather complete specification or design code was prepared, and will soon be available to the Operating Companies. This code specifies such design parameters as allowable stresses, how wind forces on surfaces shall be determined, and how stress calculations should be made. It does not specify the number of antennas, deflection requirements or other factors peculiar to a particular tower and therefore may be used to govern the design of any steel tower.

Because TJ is a light-route system, economy is a particularly important factor, and much effort was expended to ensure that economical tower designs would result. Consideration was given to the weight of steel to be fabricated and shipped, the number of parts to be erected and the number of field-bolted connections to be made. With TJ, it is expected that many towers of similar design will be used, and these considerations assume great importance. In other situations, where only one or two towers of a type are to be installed, they are engineered to meet the provisions of the applicable code or specification, and little is done to minimize weight, member sizes or field connections. The cost of a detailed design procedure for this purpose would more than offset the savings in material and erection cost which might result.

Guyed Tower Design

The family of guyed towers, as mentioned earlier, is triangular in cross-section, and the width of its face is uniform from bottom to top. Structurally, a guyed tower may be considered as a continuous beam, carrying both axial and transverse loads, and supported at several points — namely, the ground and the guy-attachment points. By the judicious selection of the spacing of guy-attachment points, a constant spacing of leg members may be used over the full height. Fundamentally, therefore, the problem was to choose a face width (that is, the dimensions of the cross-section) and the diagonal spacing (that is, the locations along each leg at which diagonal members should be attached) to provide minimum weight. This meant that many different face widths and diagonal spacings had to be tried. Before the weight of any particular configuration could be considered meaningful, the tower design virtually had to be completed to determine that it met requirements for strength and deflection. Effectively, the tower was designed many times over and the final design was selected on the basis of the data obtained.

The total weights of material for these designs were calculated and plotted, so that a smooth curve connecting all points might be drawn. This analysis indicated that, for the specified strength and deflection requirements, a minimum weight was achieved with a face width between 3 feet, 9 inches, and 4 feet, combined with a diagonal facing of 5 feet. A 4-foot face width was selected for simplicity in detailing. These dimensions, of course, apply only to the standard B Guyed tower. If the number of antennas, wind loading, maximum height or provisions of the design code are changed, a new design might be necessary.

The family of self-supporting towers was designed with much the same investigative approach. This type of structure is a cantilevered beam anchored at the ground, so that the bending moment caused by imposed loads increases from top to bottom, reaching a maximum at the ground. To permit the tower to resist an increasing bending moment without unduly increasing the sizes of the leg members, the sides of the tower are generally sloped or "battered" so that the tower has a large cross-section at the bottom and a small cross-section at the top. Sloping the leg members also aids in limiting the tilt deflection of a self-supporting tower.

The first variable determined was the batter of the tower faces. Here there are a number of possibilities, the simplest of which is a single batter or uniform slope of the tower sides. Or the batter can be changed once, twice or more times to make the leg members more divergent at the base. Carried further, the slope can be changed continuously by using curved members or straight members with a different slope beginning at every "bent" or level of horizontal bracing. The Eiffel Tower is an excellent example of this type of construction.

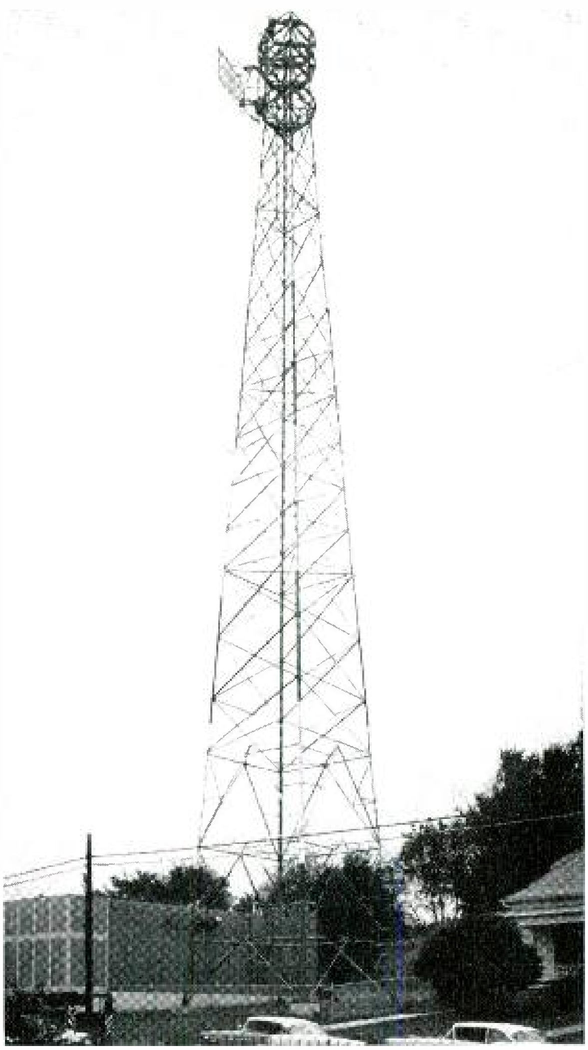
In conventional tower design, it is the usual practice to consider only single, double and sometimes triple batter. The use of many different leg batters, while resulting in a tower which may be aesthetically pleasing, is expensive. Also, if carried too far, the diverging base will require long horizontal members to span between legs, and the result may be greater weight than if a uniform batter is used.

After consideration of all these factors, a uniform or single face batter was selected as the most economical for the TJ application. The actual angle of this batter was based upon consideration of several factors, the most important being tower weight. As with the guyed tower, this required the preparation of several designs, at least to the point of determining sizes of the various structural numbers, so that a fairly accurate total weight could be determined.

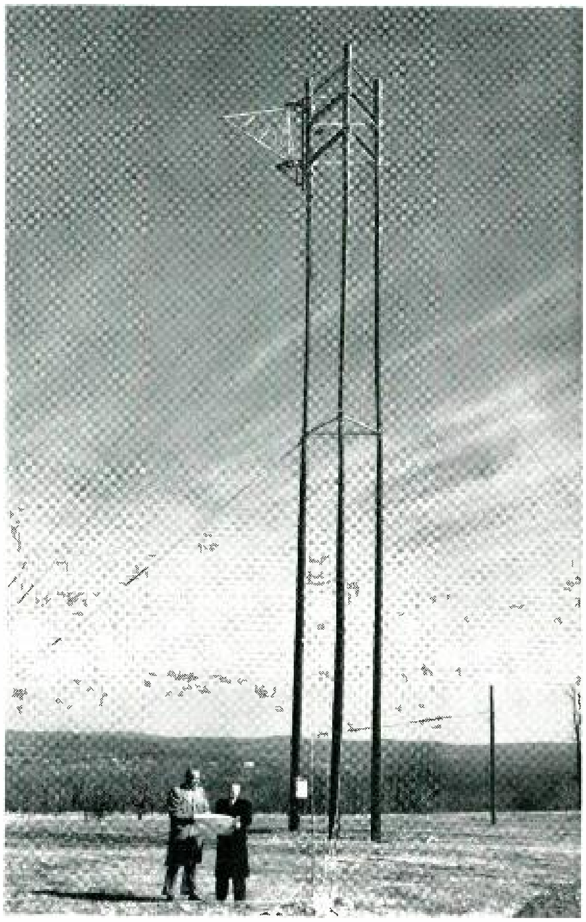
The minimum cross-section at the top of the self-supporting tower was another important design variable. This was established with consideration given mainly to the mounting of four antennas or reflectors and providing room for their adjustment. Then with top size and batter selected, a complete design was prepared with consideration given primarily to the strength of the structure.

For the range of tower heights under study, it was found that no significant over-design for strength resulted from removing lower portions of the 300-foot tower to form progressively shorter towers. This method of attaining multiple heights from a single design is extremely desirable from the standpoint of economy in detailing and fabricating common parts, and in the subsequent stocking of tower parts. Calculations indicated, however, that with this initial design, the three tallest towers would tilt too much to meet TJ requirements. An alternative was to design a heavier tower, either larger in cross-section throughout, or with increased batter so that it would become larger at the base. This was unattractive because statistically, the taller towers should be used much less frequently than those of intermediate heights, and all tower heights would then be burdened with extra weight needed in only a few cases.

The answer was found in the analyses of the deflection curves, under load, for the various heights of tower. The 240-foot tower (which is really the upper 240 feet of the 300-foot tower) was within limits for tilt and twist deflections required for TJ. It was also determined that the 300, 280 and 260-foot towers would bend most, per unit of length, in the region just below the level at which the antennas and reflectors are



The B Self-supporting Tower for the TJ system. Important design parameters were dimensions at the top, and the "batter" of the side members.



The author and N. K. Jorstad checking plans for wood-pole tower at Chester, N. J., Laboratory.

mounted. With a small amount of excess tilt deflection available in the 240-foot design, the taller towers could be brought within limits if they could be stiffened in some manner. The solution was to use larger leg members only in the region of maximum deflection per unit length, to pull the tops of the taller towers "back into line". The heavier leg numbers are not needed at the tops of towers 240 feet and less in height, and of course are not used.

It is evident that the 240-foot self-supporting tower is the optimum design, and is of minimum weight to meet requirements. It is a balanced design as opposed to the taller towers, which are heavier than needed to meet strength requirements, and the shorter towers, which are heavier than needed to meet deflection requirements. (Since a short self-supporting tower is merely the upper portion of a taller tower, alone it will not deflect under load more than the amount it contributes to the deflection of the taller tower.)

It is possible, of course, to prepare balanced designs for each height of tower, utilizing in each the full allowance for strength and deflection. With this approach, all towers would likely differ in batter and size of members, precluding the economy, mentioned before, inherent in the "single design."

The graph on page 302 shows how the weights of the guyed and self-supporting towers vary with height. For towers of the same height, these curves may be used for estimating fairly accurately the relative manufacturing costs, and they demonstrate very well the economy of using guyed towers where possible, especially where taller towers are required. Many other factors enter into the over-all cost of a tower in place, however. In addition to the fabrication, shipping and erection costs mentioned earlier, other items of expense include the foundations, electrical grounding and aircraft obstruction painting and lighting.

A final economic consideration deserves a comment. This is the fact, perhaps not readily apparent, that per foot of tower, shorter towers cost more per pound to fabricate. The shorter towers can be made of relatively light members, but each must be handled, cut, coped, punched, stamped and galvanized as with heavier members. For the most of these operations, fabrication cost does not decrease in direct proportion with weight. (Incidentally, the raw material accounts for less than half the cost of finished structural steel.) Also, each tower, regardless of height, must have its complement of antenna and base fittings which require expensive fabrication operations, such as forming, drilling and welding in addition to those mentioned above for simple structural parts.

In brief, the cost of a short tower includes a higher percentage of fabrication and handling charges, which are more costly than the material itself. For this reason, the Outside Plant Development Department is investigating the possibility of using wood poles in radio relay applications. Presently under consideration are guyed wood-pole structures in heights up to 120 feet for use with TJ. It is hoped that economies may be realized which will make them attractive in comparison to steel towers *(see photograph on this page)*. The photograph shows a 100-ft. wood-pole structure with one passive reflector at the top. This reflector was installed prior to erecting the upper half of the tower.

Reducing electrical noise in transmission lines is a continuous problem for the cable engineer. Before he can attack this problem, however, he must ascertain the causes of noise. To help do this, the Laboratories has developed a device capable of measuring and comparing the noise levels caused by flexing cables insulated with various materials.

R. A. Rasmussen

Flexural Noise in Cables

Whenever an insulated conductor undergoes some violent motion, such as a vigorous shaking, spurious voltages will appear across its terminations. Although small, these voltages may be large enough to determine the signal-to-noise ratio of transmission lines carrying low-level signals. This is most troublesome where the cable is shaken at the same frequency as that of the signal passing through it.

Undersea cables are particularly affected by this problem. Not only do breakers at shore lines buffet the cable, but also movements of water on the ocean beds disturb it. Because the Bell System is vitally interested in the proper operation of telephone cables, the Laboratories has devised test equipment for "characterizing" different types of cable with respect to electrical noise.

Cable engineers generally believe that noise voltages resulting from a flexing cable are caused by the transfer of electrical charges between the conductor and its insulation. These transfers may occur whenever the insulating jackets are separated from the conductors — which may happen when the cable is flexed. As a result of this separation, a "displacement" current flows in the metallic circuit, neutralizing the charge on the conductors and producing a voltage across the terminal load.

The cross-sectional drawing (*bottom of next page*) shows a pair of insulated conductors terminated in a load or output resistance R. The insulator has separated from the upper conductor and is charged negatively over the area of separation. We can assume that the length of the conductor pair is sufficiently small to justify lumping or accumulating the cable capacitance to one value, C_0, across R.

C_1 is the capacitance of the air chamber formed when the insulation separates from the conductor, and C_2 is the total capacitance coupling the lower conductor to the charge on the insulation. If we assume that the separation occurs instantaneously, and if we neglect leakage resistance

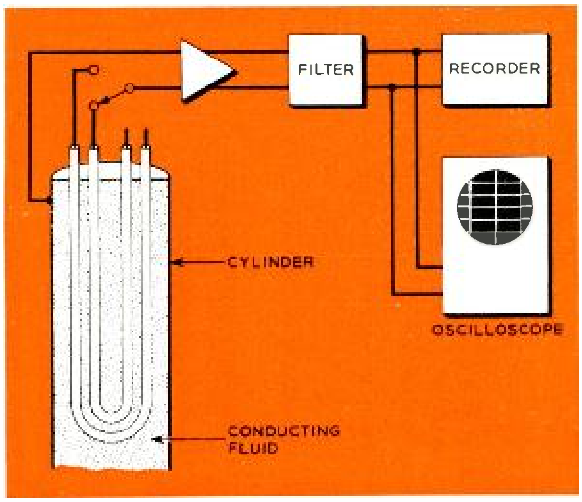


Diagram of testing equipment. Although two samples can be inserted in cylinder, amplifier must be alternately switched during measurements.

across C_1 and any inductance in the circuit, we can express the voltage appearing across the termination by the equation appearing in the illustration. In this equation, Q is the total charge caused by the separation of insulation and wire.

Improvement by Bonding

Measurements have shown that an improvement in the degree of contact, or bonding between the insulation and the conductor, reduces noise caused by cable flexure. Applying a conductive coating to the inner surface of the insulation has a similar effect. In this case, the conducting material acts as a low-resistance path between the conductor and the inner surface of the insulation. This path rapidly neutralizes the charges following separation, because the low resistance effectively shunts capacitance C_1 of the equation.

No consistent theory is available to explain the origin of the charges, but certainly friction between dielectrics and conductors can cause them to become electrified. Also, impact or simply close contact between dielectrics and conductors may result in their electrification. Moreover, both amorphous and crystalline dielectrics can become charged as the result of compression. While further research is required before a better understanding of these charging effects and the relationships between them can be achieved, cable specialists recognize that all or part of these effects may be present in an insulated conductor sometimes subjected to shock and vibration.

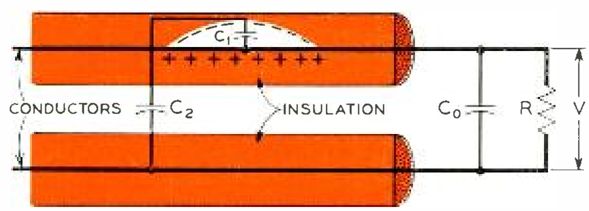
Previous attempts to design an experiment to permit the measurement of noise caused by flexure indicated that reliable results could be obtained only by accepting two basic criteria. First, the agitation should be applied uniformly over a reasonably long sample. This is necessary because the physical and chemical properties of the insulation, and the degree of contact between insulation and conductor, may vary along a length of the sample. Furthermore, uniform agitation permits an integrated value to be measured, reflecting contributions of agitation from all parts of the sample.

The second criterion requires that the source of agitation will not produce charges on the outer surface of the insulation. This assures that charges transferring between the agitator and the cable insulation do not contribute to the measured noise voltages.

Bell Laboratories engineers designed the testing apparatus to fulfill these requirements. In this device, shown in the photograph on page 308 one end of a brass cylinder is fitted with a piston whose displacement is controlled by a rotating cam. The other end of the cylinder is fitted with watertight packing glands. A loop of the cable sample to be tested is placed in the cylinder, and the cable ends are brought out through the packing glands. The cylinder then is completely filled with a saturated salt solution through fittings on the top.

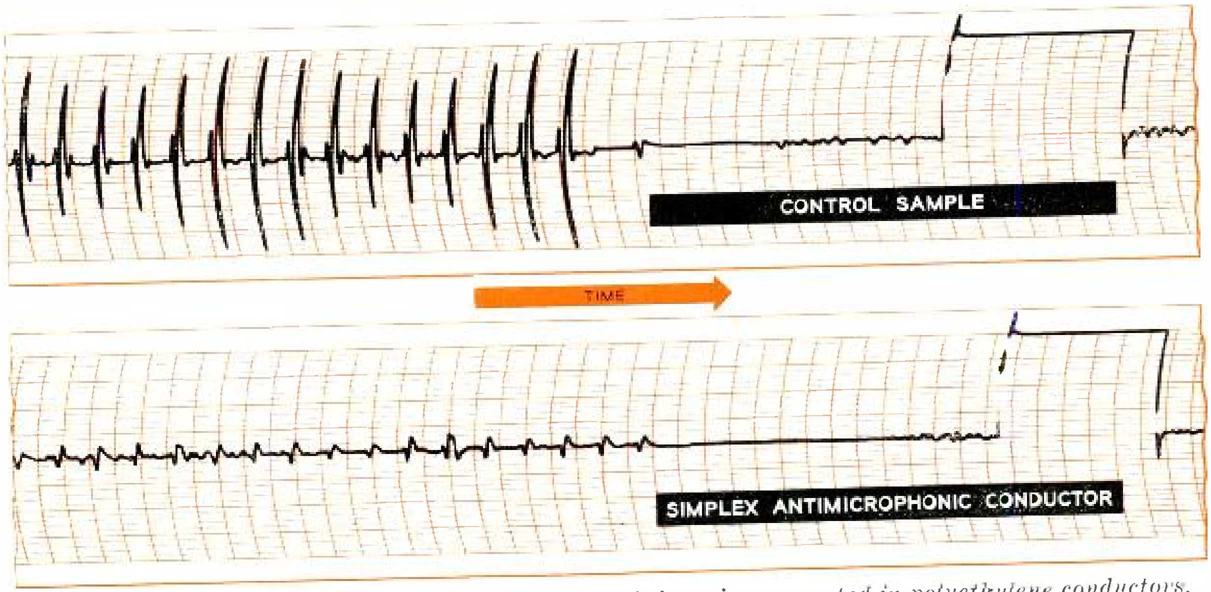
The piston shaft is coupled to a ball-bearing cam follower through a spring. Adjusting the compression of the spring permits maximum piston displacement to produce the desired maximum fluid pressure. This is indicated by the gauge extending from the side of the cylinder. The cam is shaped so that its rotation results in a gradual increase in the fluid pressure followed by a sudden decrease to the pressure that existed at the beginning of the cycle.

Fluctuations in fluid pressure during opera-



$$V = \frac{Q\,C_1}{C_0(C_1 + C_2)}\, e^{\frac{-t}{RC_0}}$$

Pair of insulated conductors showing how "loose" insulation forms a capacitor with the metal conductor when an insulated cable is flexed.



A typical record, from the measurement system, of the noise generated in polyethylene conductors.

tion cause the insulation alternately to be pressed tightly against the conductor and then to be released abruptly. It is during the pressure fluctuations that separation occurs between the insulator and the conductor. Resultant displacement currents flow through a load resistor connected between one end of the conductor and the cylinder wall, producing a voltage drop that can be readily measured. It is interesting to note that the conducting solution within the cylinder and insulated conductor form a coaxial cable; the solution corresponds to the lower conductor in the cross-sectional drawing.

Four packing glands permit the simultaneous introduction of two samples to which the measurement equipment may be connected alternately during one test period (*see drawing at top of previous page*). A filter with a relatively narrow pass-band ensures an adequately low level of background noise for the test.

A typical record obtained with this equipment (*above*) shows the noise level resulting from the separation charge indicated by the height of the spikes. The rate at which the spikes recur is controlled by the frequency at which the piston is operated although, within broad limits, this is unimportant. For the observations recorded in this illustration the pressure was varied at a rate of 3.2 cps.

The experimenters first made measurements to determine the relationship of noise voltage to pressure amplitude and the degree of uniformity between samples of one type of insulated conductor. They made these measurements on six 20-inch long samples of a polyethylene compound called "P-3". The samples were subjected to pressure variations ranging from 5 to 30 psi. The data recorded are typical of polyethylene insulation types especially with respect to the range of the noise voltages found among samples of any one type.

Sample Variation

Pairs of samples were tested simultaneously. Cable engineers attributed the differences in noise voltage to variations among the samples rather than to variations in the test facilities. This view was supported by the narrow range of values noted between pairs over the entire variation of pressure.

The relationship between noise voltage and pressure variation, determined with 20-inch long samples of the various cable types, in general shows that noise increases linearly with pressure. This important observation agrees with the theory when the areas of separation are assumed to be evenly distributed along the length of the sample. From the results of testing several types of cable insulation, we can draw several conclusions.

For example, after a relatively low pressure, butyl rubber showed little increase in noise at higher pressures. This may be attributed to the high compliance or "bendability of this type of insulation. In this case, only a small pressure appears to be needed to press the insulation into firm contact with the conductor. Further increase of pressure apparently does not increase the contact area significantly, and thus the noise voltage remains essentially constant.

Another conclusion
that

Drawing shows island-to-island route of the Bell System-designed Cape Canaveral cable pathway.

along the submarine cable, the power facility at the attended station must provide approximately 500 volts dc. This operating voltage therefore was substantially greater than that provided by the standard battery plant. We may note, for instance, the 250 volts used at TD-2 microwave repeater stations.

Summarizing then, we can say that the submarine-cable power plant must supply up to 2.4 amperes at a voltage in the order of 500 volts. Voltage varies for each station because of different cable voltage drops to the remote stations. The further requirement that cable power interruptions cannot be tolerated during missile shoots made mandatory a high-voltage battery for reserve power during emergencies.

The 500-volt plant consists of a newly developed battery unit superimposed upon the 130-volt installation already required at the attended station. This latter unit will be described later, but we may note that this arrangement is clearly in the interests of economy and simplicity. By this technique, the new battery plant of 117 to 201 cells, with the necessary charging and regulating equipment added to the 130-volt plant, can furnish the proper voltage for the remote unattended repeaters. The exact number of cells is dependent on the voltage actually applied to the cable.

This new plant includes two basic circuits as shown in the last schematic: a charge circuit and a power-supply circuit. The charge circuit includes a rectifier and control features for supplying the repeaters and floating and recharging the superimposed battery. A metallic rectifier (400 volt, 3 amperes) automatically regulated to maintain the battery voltage at plus or minus 1 per cent, was developed for this application. After an ac power failure, during which the battery alone must supply the cable load, the rectifier furnishes current for recharging the battery in addition to supplying the normal cable current. Voltmeters are used to read both the total battery voltage to ground and the voltage of the superimposed battery. Voltmeter relays monitor this battery and transmit an alarm if the voltage deviates plus or minus 2 per cent from its normal value because of any trouble condition. The charge-circuit equipment is assembled in an enclosed-type cabinet similar to cabinets used in the TD-2 power plants. This cabinet houses the charge-control equipment in its upper sections, and the remainder of the cabinet is occupied by the several component assemblies of the rectifier.

Power Supply Circuits

Within the new plant, standard protective devices such as covers, sleeving and warning plates protect personnel from hazardous voltages. Additional precautions are taken for the battery, which is mounted in two cabinets equipped with front and rear doors. The cabinets are furnished with key interlocks to permit access to the battery only after it has been taken out of service; locks are located at the front switch panel and at the front and rear doors of the battery cabinet.

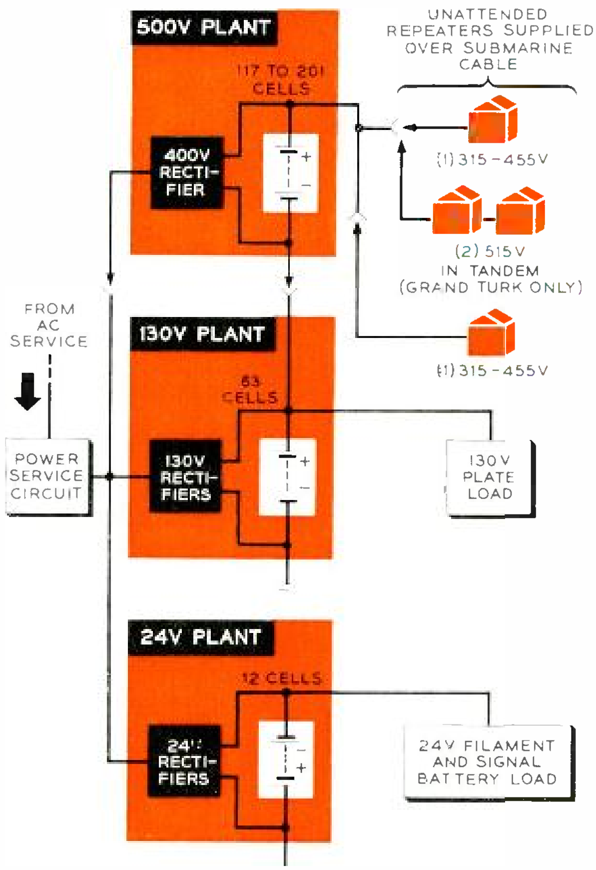
Remote repeaters, as noted before, are essentially constant-current loads. The power-supply circuit regulates the output of the charge circuit to meet this requirement. Essential features of this circuit were drawn from standard Bell System power-plant techniques. The constant-current feature is accomplished by a motor-driven rheostat which adds or removes resistance in series with the cable so as to maintain the current constant within plus or minus 1½ per cent. Two voltmeter relays are used as the sensing devices in what is basically a relay-controlled servomechanism. The relays monitor the current being supplied to the cable, and through telephone and power-type relay circuitry actuate the motor. One relay is set at plus or minus 1½ per cent limits, and the other at plus or minus 2 per cent to serve as an additional precaution against failure of the first relay to maintain adequate regulation. For maintenance or adjustment purposes, it is possible to control manually the operation of the motor-driven rheostat. If power should fail, the power-supply circuit will maintain minus 1½ per cent regulation by removing resistance as the battery-plant voltage decreases.

The reserve built into the battery plant is sufficient for a period of eight hours with an additional eight-hours reserve available until the emergency voltage of the repeater (minus 10 per cent) is reached. During emergency conditions, one or two constant-current circuits, depending on whether the plant will supply unattended repeaters over one or two submarine cables, regulate the plant output to the repeaters.

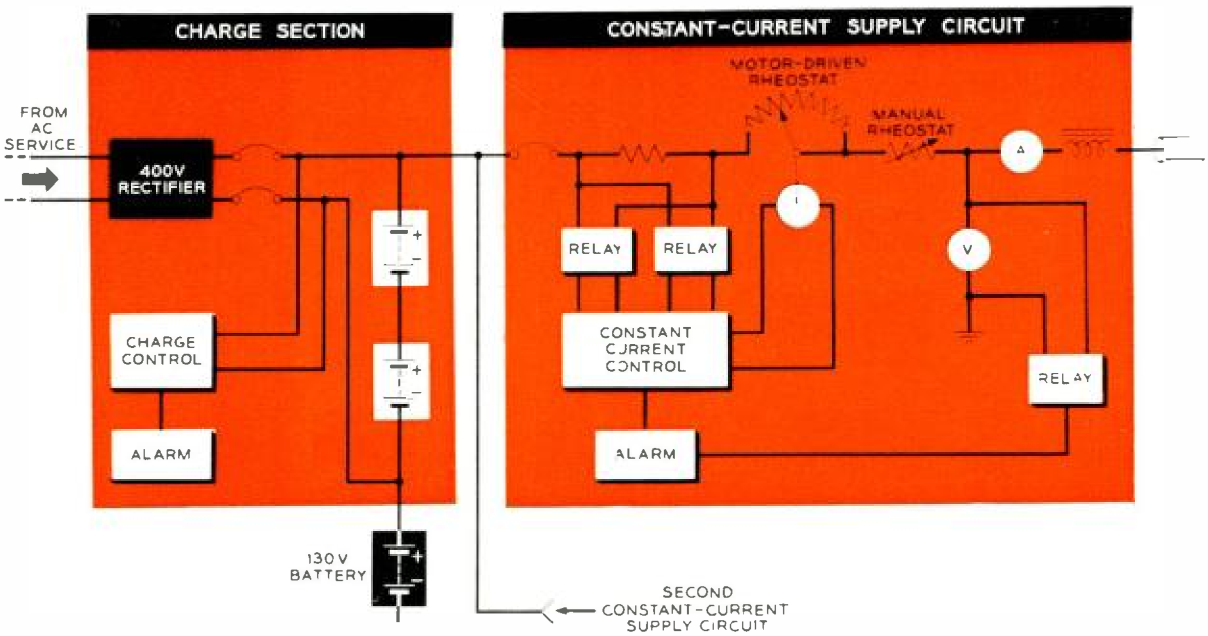
At Point Jupiter, Florida, and Mayaguez, Puerto Rico, only one such circuit is required. At Goldrock Creek, Eleuthera Island, San Salvador and Abraham Bay — all in the Bahamas Island group — two constant-current supply circuits are needed. Grand Turk Island is unique in that a single cable is used to power two repeaters in tandem so that only one circuit is required. Where the two power-supply circuits are used, manual rheostats enable the plant to use one battery voltage to supply two cables of different lengths by reducing the voltage to the shorter cable.

The equipment of the power-supply circuit is in a cabinet identical to the charge-equipment cabinet; two power-supply circuits are located in a right-hand cabinet. Each of the control panels in the center of the cabinet is associated with one cable. The motor-driven rheostats and relay apparatus are under enclosing covers.

There is a total absence of fuses both in the



Block schematic of power supplies for submarine cable-linked missile observation stations. Power for the attended stations is indicated as is the power source for unattended remote repeaters.



Schematic drawing of the 500-volt power plant. Circuit contains a 400-volt (3 ampere) metallic rectifier developed to charge the battery to within plus or minus one per cent at constant load.

power-supply cabinet and charge cabinet, and a complete reliance on circuit breakers for circuit protection and switching. Circuit breakers, with poles in series to break the dc voltages, were selected because of the high dc voltages and importance of personnel protection.

Attended Stations

For the attended-station filament and signal battery load, a new 24-volt battery plant was adapted from standard plants, with the major change being the omission of counter E.M.F. cells in the discharge circuit. Two 30-ampere metallic rectifiers supply the load and charge and maintain a 12-cell (420 ampere-hour) battery. Control circuits automatically connect or disconnect the second rectifier as load conditions require. The two rectifiers, the filters, the control equipment and the distribution fuses are mounted in one enclosed-type framework. Sealed jar batteries are mounted on standard open-type battery racks.

The 130-volt equipment at the attended stations furnishes a regulated and filtered plate supply for the station equipment and also gives part of the voltage for the 500-volt power supply as previously mentioned. This equipment includes a 63-cell (50 ampere-hour) battery which is maintained and charged by two tube-type rectifiers which are 8-ampere regulated. One rectifier will cover the load, the second serves as a spare. These rectifiers maintain battery-voltage limits of plus or minus 1 per cent except during ac-power failures when the battery is unregulated. After an ac-power failure, both rectifiers are put in service to recharge the battery. A relay circuit, which functions as a monitor for the battery voltage, automatically turns off the second rectifier when the battery reaches the desired voltage.

This 130-volt plant is contained in a bay on the right side of the cabinet. Here the operating rectifier is mounted at the bottom of the bay with the spare rectifier above it. All fuses are mounted at the top of the bay in dead front-type fuse holders so as to prevent exposure to the plate voltages. In addition, all exposed terminals in the discharge circuit have been protected further by use of insulated sleeving or covers. The batteries are mounted on standard open-type battery stands very similar to those used for the 24-volt battery.

All of the power facilities have standard alarm features to indicate abnormal conditions such as fuse failure, rectifier failure, and high- and low-voltage alarms — all of which are connected to the office alarm systems. These alarms, in some cases, have time delays to distinguish false alarms from troubles which clear themselves in a short time.

NEWS

Dr. Fisk to Serve on Guggenheim Foundation And M.I.T. Corporation

Dr. J. B. Fisk was recently elected a member and trustee of the John Simon Guggenheim Memorial Foundation. Established in 1925 to improve quality of education, foster research, and enhance better international understanding, the Foundation offers fellowships to further the development of scholars and artists by assisting them in their research in any field of knowledge.

Dr. Fisk has also been elected an alumni member of the Massachusetts Institute of Technology Corporation. The term of the election is five years.

Experimental Set Using Push Buttons Placed on Trial

One of the important links in telephone communications is the connection between the customer's telephone set and his central office. Over this connection, the customer not only talks but also sends the digits of the number he is calling. With automatic equipment, he does so with successive turns of his rotary dial; the dial mechanism sends trains of d.c. electrical pulses representing the digits.

Another way to send called-number digits is to generate tone pulses with push buttons. To find out whether customers would like to have this type of service, and whether they would benefit from faster calling, the Laboratories has designed an experimental push-button telephone. Some 400 preliminary models were recently placed on trial in Hamden, Connecticut, and in Elgin, Illinois. Installed temporarily in offices and homes at these locations, the sets are being used to obtain field data as a valuable addition to the preliminary results of laboratory tests.

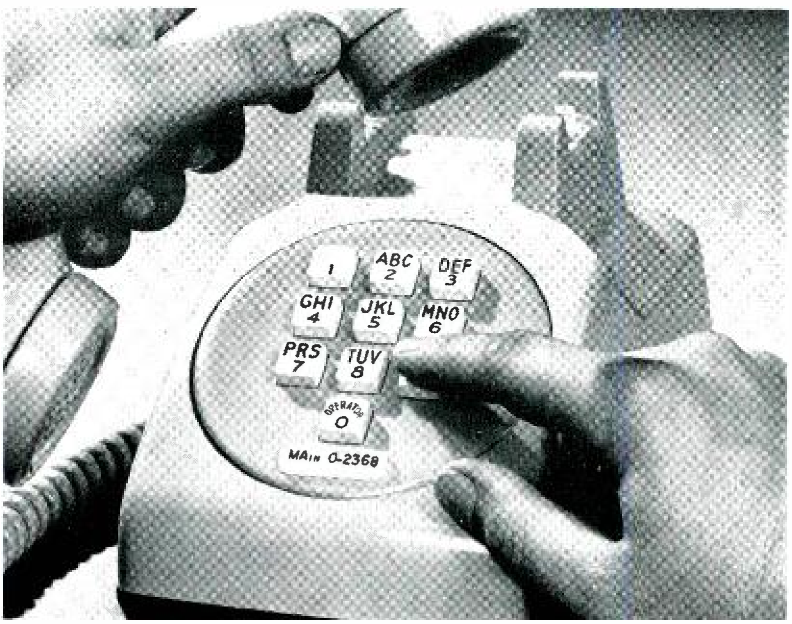
Transistor Oscillator

The push-button unit was designed to fit into the same shell that now houses the standard instrument. It contains a transistor oscillator that, when a push button is depressed, produces two simultaneous tones. These are coded so that a different combination of tones identifies each of the digits. Users hear the tones at a reduced level in the receiver of the telephone set.

The use of tones creates, in effect, a new electrical "language" to be interpreted by the central office. Thus, special translators have been designed to adapt existing offices for receiving numbers from push-button telephones.

Tests at Bell Laboratories have indicated that with push buttons, some people can key a seven-digit number in less than two seconds, although the average time is about five seconds. The corresponding average time for rotary dialing is about nine seconds. After the number has been keyed, the time for a push-button call to go through would depend on the type of switching equipment in the local office. With crossbar switching, the time is reduced nearly in proportion to the faster keying by the customer. When the office has step-by-step switching equipment, the call would go through at a slightly better speed than with rotary dialing.

Considerable attention is being given to the design of the push-button unit so that new models will incorporate improvements. Among the studies are investigations of the size, shape and arrangement of the push buttons, and also of their action or "feel." It has been found, for example,



Laboratories experimental push-button set (also see cover). Push-button unit here includes changes made subsequent to trial model.

that a "snap" action did not produce any greater accuracy than other types. In human-factors tests at the Laboratories, most people preferred a smooth button action with a definite stop, but slightly cushioned.

Laboratory human-factors tests also indicated that there is an optimum size and spacing for the push buttons. When they are closely spaced, the individual buttons are difficult to strike without depressing others at the same time. With large buttons, the entire group cannot easily be taken in at one glance. The tests indicate that the buttons should be about one-half inch square, separated about one-quarter inch.

Many different arrangements of buttons have been tried — various rectangular arrays, circles, triangles, and a "cross." Among the many resulting possibilities, several gave approximately equal performance, and four were about equally well liked — two circular arrays, a rectangular array of two horizontal rows, and a three-by-three array with the "zero-operator" button centered in a fourth row. This last arrangement was selected since it uses the available space efficiently and permits a simplified design in the initial application.

Laboratory tests indicated that most users are enthusiastic about push-button operation, and preliminary data from the Connecticut and Illinois field trials support the laboratory findings. The encouraging results obtained so far indicate that the push-button set could be an important new convenience to telephone customers.

W. C. Tinus Appointed to Scientific Advisory Board

At the invitation of General Thomas D. White, Chief of Staff of the Department of the Air Force, W. C. Tinus, Vice President — Military Development Programs, has become a member of the Scientific Advisory Board of the Air Force for the year 1959.

FIELD TEST OF NEW DATAPHONE

Western Electric Co. engineer prepares to send business items through the compact card reader of the new Dataphone system.

A new experimental form of Dataphone service for sending the supply orders of an Operating Company to a Western Electric distributing house is being tried out by the New York Telephone Co. and the Illinois Bell Telephone Co. The new service is designed to convert Operating Company "shopping lists" into electronic form so they may be transmitted at high speed over regular telephone circuits.

Developed by a team of Western Electric Co. and Bell Laboratories Engineers, the system is expected to reduce greatly the amount of paperwork and time now required in manual processing of supply orders — more than 20,000 of which pour into Western Electric's distributing houses daily. Orders will be transmitted to the distributing house within minutes after they are compiled, and clerical work at both ends will be speeded and simplified by data processing machines.

Made up of card-reading, transmitting, and receiving units, the new device converts punched-card information into electrical impulses that are transmitted over a regular telephone line. Supplies are requisitioned by establishing a telephone connection and fitting pre-punched cards, representing items wanted, into the card reader. The receiving unit at the distributing house activates a key-punch to produce a duplicate set of cards bearing the Operating Company's order. These cards are transferred to a computer that automatically tells the warehouse which items to send.

This low-cost, easy-to-operate form of Dataphone service should yield substantial savings for the Bell System.

PAPERS

Following is a list of authors, titles, and places of publication of recent papers published by members of the Laboratories.

Amron, I., see Koontz, D. E.

Anderson, E. W., see McCall, D. W.

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Kleinman, D. A., see Logan, R. A.

Koontz, D. E., and Amron, I., *An Ultrasonic Washing System for Eliminating Physical Contaminants from Electron Devices,* Symposium, Proc. on Cleaning of Electronic Device Components and Materials, S.T.P. 246, pp. 22-31, Mar., 1959.

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Zuk, P., *Ultrasonic Grinder Forms Mesa Diodes*, Electronics, 32, pp. 112-113, May 29, 1959.

TALKS

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

SIGNAL CORPS FREQUENCY CONTROL SYMPOSIUM, Asbury Park, N. J.

Atalla, M. M., Bray, A. R., and Lindner, R., *Stability of Thermally Oxidized Silicon Junctions.*

Bray, A. R., see Atalla, M. M.

Griffin, J. P., *High Temperature Crystal Units Employing Thermo-Compression Techniques.*

King, J. C., *Dislocation and Impurity-Induced Defects in Quartz.*

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

Smith, W. L., See Warner, A. W.

Warner, A. W., and Smith, W. L., *Highly Stable Crystal Oscillators for Missile Applications.*

White, L. D., *Ammonia Maser Work at Bell Telephone Laboratories.*

INTERNATIONAL CONFERENCE ON TRANSISTORS, London, England.

Brattain, W. H., *Historical Development of Concepts Basic to the Understanding of Semiconductors.*

Ebers, J. J., and Sparks, M., *Characterization and Properties of Transistors*, (Presented by M. Sparks).

Felker, J. H., *Transistors in Data Processing Machines.*

Pudvin, J. F., *Environmental and Device Cleanness and Purity Standards.*

Sparks, M., see Ebers, J. J.

A.S.Q.C. NATIONAL CONVENTION, Cleveland, Ohio.

Jones, A. W., *Solution by Simulation of Problems Involving Chance Variables.*

Paterson, E. G. D., *Quality Control Engineering in Product Evaluation.*

Roberts, S. W., *Early Detection of Relatively Small Shifts in Process Average.*

SYMPOSIUM ON MOLECULAR STRUCTURE AND SPECTROSCOPY, Columbus, Ohio.

Clogston, A. M., see Wood, D. L.

Dodd, Miss D. M., *The Infrared Absorption Characteristics of Ferroelectric Triglycine Sulfate.*

Liehr, A. D., *Spectro- and Magneto-chemistry of Au(II) and W(V) Complexes and Their Homologues.*

Schawlow, A. L., see Wood, D. L.

Wood, D. L., Schawlow, A. L., and Clogston, A. M., *Electronic Spectra in Crystals.*

AMERICAN PHYSICAL SOCIETY, Milwaukee, Wisconsin.

Collins, R. J., and Hopfield, J. J., *Polarization of the Edge Emission in CdS.*

Hopfield, J. J., see Collins, R. J.

Kisliuk, P. P., *Calorimetric Heat of Adsorption-Nitrogen on Tungsten.*

Kunzler, J. E., *Oscillatory Dependence of Temperature with Magnetic Field.*

Miller, R. C., *Some Studies of Domain Dynamics in Barium Titanate.*

Thomas, D. G., *Excitons in Zinc Oxide and Cadmium Sulphide.*

I.R.E.-A.I.E.E. SOLID-STATE DEVICE RESEARCH CONFERENCE, Ithaca, N. Y.

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

Baker, A. N., Goldey, J. M., and Ross, I. M., *Dynamic Breakdown in P-N-P-N Diodes.*

Batdorf, R. L., *An Esaki-Type Diode in InSb.*

Bray, A. R., see Lindner, R.

D'Asaro, L. A., *A Stepping Transistor Element.*

Goldey, J. M., see Baer, A. N.

Lindner, R., Bray, A. R., and Atalla, M. M., *Stability of Thermally Oxidized Silicon Junctions in Wet Ambients.*

Morgan, S. P., see Smits, F. M.

Ross, I. M., see Baker, A. N.

Smits, F. M., and Morgan, S. P., *Potential Distribution and Capacitance of a Graded P-N Junction.*

Smits, F. M., *Upper Limits for Pinch-Off Currents in Field-Effect Devices and a Modified Field-Effect Structure.*

I.R.E.-P.G.M.T.T. ANNUAL MEETING, Cambridge, Mass.

Buchsbaum, S. J., *Microwave Measurements of Electron Densities and Temperatures in a Gaseous Plasma.*

Engelbrecht, R. S., *Parametric Amplifiers: State of the Art.*

Harkless, E. T., and Hines, M. E., *A Transmission Line Backward Wave Filter.*

Hines, M. E., see Harkless, E. T.

Judkins, R. W., see Weiss, J. A.

Rowe, H. E., see Warters, W. D.

Seidel, H., *Some New Ferrite Device Forms.*

Von Aulock, W. H., *Use of Demagnetizing Fields to Minimize Temperature Effects in Ferrite Devices*

Warters, W. D., and Rowe, H. E., *TE_{01} Shuttle Pulse Measurements in Multi-Mode Circular Waveguide.*

Weiss, J. A., and Judkins, R. W., *A Double-Sweep Comparator for Microwave Ferrite Device Measurements.*

OTHER TALKS

Anderson, R. E. D., *Regulator Circuits: Tubes and Transistors*, Capital Radio Engineering Institute Alumni Assoc. Meeting, Mountainside, N. J.

Barns, R. L., *Examination of Electrical Contacts by the Plastic Replica Method*, Seminar on Electrical Contacts, Pennsylvania State University, Pa.

Beck, A. C., *Circular Electric Waveguides*, Northern New Jersey I.R.E.-P.G.M.T.T. Meeting, Arnold Auditorium, Murray Hill, N. J.

Becker, E. J., see Becker, J. A.

Becker, J. A., Becker, E. J., and Brandes, R. G., *Reactions of Oxygen with Pure Tungsten and Tungsten Containing Carbon*, Field Emission Symposium, Washington, D. C.

Bond, W. L., *Precise Lattice Constant Determination*, Conf. on Precision Lattice Constant Determination, Stockholm, Sweden.

Brandes, R. G., see Becker, J. A.

Egan, T. F., *Organic Deposits on Precious Metal Contacts*, Seminar on Electrical Contacts, Pennsylvania State University, University Park, Pa.

Engelbrecht, R. S., *Parametric Traveling-Wave Amplifiers*, Long Island Chapter, I.R.E., P.G.M.T.T., Mineola, N. Y.

Engelbrecht, R. S., and Mumford, W. W., *Parametric Amplifiers: Historical Background and Recent Results with U.H.F. Traveling-Wave Amplifiers Using Diodes*, Princeton I.R.E., N. J.

Flaschen, S. S., see Garn, P. D.

Garn, P. D., and Flaschen, S. S., *Electrically Insulating Flexible Inorganic Coatings on Metal Produced by Gaseous Fluorine Reactions*, Research Laboratories, General Chemical Division, Allied Chemical Company, Morristown, N. J.

Goldschmidt, K., *Transistors and the Electronic PBX*, A.I.E.E. Communications Disc. Group, Louisville, Ky.

Hannay, N. B., *Mass Spectroscopy of Solids*, American Petroleum Institute, New York.

Hawkins, W. L., Worthington, Mrs. M. A., and Winslow, F. H., *The Role of Carbon Black in the Thermal Oxidation of Polyolefins*, U. of Buffalo, N. Y.

Honaman, R. K., *Forward Look in Communications*, 37th Annual Conference of Utility Commission Engineers; and Pacific Tel. and Tel. Co., San Francisco, Calif.

Honaman, R. K., *Technology's Challenge for Public Relations*, Southern California Chapter, Public Relations Society of America, Los Angeles.

Highleyman, W. H., *A Generalized Scanner for Character and Pattern Recognition Studies*, A.I.E.E. Middle Eastern District Meeting, Baltimore, Md.

Javan, A., *Description of Some Experiments Using Gas Discharges*, U. of Michigan, Ann Arbor, Mich.

Kostkos, H. J., *Missiles and Messages*, Public Relations Group, Pacific Tel. and Tel. Co., San Francisco, Calif.; Telephone Employees Group, Seattle, Wash.; and Public Relations Dept., Pacific Tel. and Tel. Co., Los Angeles.

Knab, E. D., *Design of Fine-Pitch Worm and Helical Gear Combinations*, American Gear Mfg. Assoc., Hot Springs, Va.

Mumford, W. W., see Engelbrecht, R. S.

Mumford, W. W., see Weiss, M. M.

Raffone, J. J., *Company Publications*, Seventh Annual Technical Writers' Institute, Rensselaer, Troy, N. Y.

Rowe, H. E., *Waveguide as a Communication Medium*, Ithaca Section, I.R.E., Cornell University, Ithaca, N. Y.

Saal, F. A., *TASI: A Time-Assignment System*, Lehigh Valley Sub-Section, I.R.E., Western Electric Co., Allentown, Pa.

Schelkunoff, S. A., *Anatomy of "Surface Waves,"* U.R.S.I. Symposium on Electromagnetic Theory, U. of Toronto, Canada.

Spindler, G. P., *Techniques of Glass to Sapphire*, Annual Meeting of the American Scientific Glassblowers Society, Corning, N. Y.

Terry, M. E., *Types of Engineering Problems for Digital Computers*, Monmouth Subsection, I.R.E., Holmdel, N. J.

Vanderwal, N. C., *Transistors — Their Manufacture and Use*, Delaware-Lehigh Amateur Radio Club, Bethlehem, Pa.

Weiss, M. M., *Radiation and Communications*, Kiwanis Club, Nutley, N. J.

Weiss, M. M., and Mumford, W. W., *Microwave Radiation Hazards*, Health Physics Society Meeting, Gatlinburg, Tenn.

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

Winslow, F. H., *New Materials in Product Design*, W.E. Engineers and Supervisors Meeting, East Orange, N. J.

Worthington, Mrs. M. A., see Hawkins, W. L.

PATENTS

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

Abbott, G. F., Jr. — *Permanent Signal Alarm Circuit* — 2,892,895.

Bogert, B. P., and Kock, W. E. — *Narrow Band Transmission of Speech* — 2,890,285.

Bredehoft, H. A. — *Sound Output Control for Telephone Ringers* — 2,892,187.

Carbrey, R. L. — *Volume Compression and Expansion in Pulse Code Transmission* — 2,889,409.

Carmichael, R. L. — *Two Terminal Monostable Transistor Switch* — 2,889,510.

Clogston, A. M. — *Nonreciprocal Circuit Element* — 2,892,161.

Feiner, A. — *Electrical Information System* — 2,892,037.

Fox, A. G. — *Nonreciprocal Wave Transmission* — 2,890,328.

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Glore, R. F. Hovgaard, O. M., and Perreault, G. E. — *Relay* — 2,889,424.

Goldschmidt, K. — *Impulse Dial* — 2,890,287.

Ham, J. H., Jr. — *Signaling Device* — 2,893,001.

Hawkins, W. L., Lanza, V. L., and Winslow, F. H. — *Stabilized Straight Chain Hydrocarbons* — 2,889,306.

Heffner, H., and Kompfner, R. — *Backward Wave Tube* — 2,891,191.

Hogg, D. C. — *Antenna System Having a Directionally Variable Radiation Pattern* — 2,892,191.

Holdaway, V. L. — *Gaseous Discharge Device* — 2,891,188.

Hovgaard, O. M., see Glore, R. F.

James, R. T., and Ruppel, A. E. — *Digital System with Error Elimination* — 2,892,888.

Jenkins, R. T. — *Signaling System* — 2,889,550.

Joel, A. E., Jr., and Yostpille, J. J. — *Identification of Stored Information* — 2,892,184.

Kirkpatrick, W. E. — *Electron Discharge Device* — 2,892,122.

Kock, W. E., see Bogert, B. P.

Kohman, G. T., Mason, W. P., and McAfee, K. B., Jr. — *Separation of Gases by Diffusion* — 2,892,508.

Koliss, P. P. — *Combined Splice Closure and Cable Terminal for Plastic Sheathed Cable* — 2,891,101.

Kompfner, R., see Heffner, H.

Lanza, V. L., see Hawkins, W. L.

Manley, J. M., and Reiling, P. A. — *Voice-Operated Gain Adjusting Device* — 2,892,891.

Mason, W. P., see Kohman, G. T.

McAfee, K. B., Jr., see Kohman, G. T.

Meissner, C. R. — *Method for Making a Transposed Conductor Structure* — 2,889,239.

Muller, J. F. — *Automatic Core Winding Machine* — 2,891,735.

Pearsall, F. M., Jr. — *Identifier-Recorder* — 2,889,402.

Perreault, G. E., see Glore, R. F.

Pfann, W. G. — *Electromagnetic Stirring Method* — 2,890,940.

Rack, A. J. — *Vocoder Absorption Modulation System* — 2,892,892.

Reiling, P. A., see Manley, J. M.

Rieke, J. W. — *Instantaneous Signal Amplitude Clipper* — 2,892,081.

Rowen, J. H. — *Nonreciprocal Circuit Element* — 2,892,158.

Rowen, J. H. — *Nonreciprocal Circuit Element* — 2,892,160.

Ruppel, A. E., see James, R. T.

Schmitz, D. R. — *Miniature Inductive Assembly* — 2,889,524.

Stieritz, W. G. — *Gaseous Discharge Devices* — 2,889,481.

Turner, E. H. — *Nonreciprocal Circuit Element* — 2,892,159.

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

Yostpille, J. J., see Joel, A. E., Jr.

Zinn, M. K. — *Delay Network* — 2,890,333.

THE AUTHORS

King E. Gould

King E. Gould, author of "The Fine Art of Measurement," began his Bell System career with the Development and Research Department of the A.T.&T. Company in 1927, transferring to the Laboratories with the inductive coordination group in 1934. He has since worked in transmission development, transmission engineering, and military systems engineering. Prior to his appointment as Director of Station Development, he was responsible for power development and audio facilities. During World War II, he was assigned to the development of several of the early radar systems, both shipborne and airborne, and was project engineer on the APQ-13 radar, with which the B-29 was generally equipped. He served as consultant to the Air Force in the Marianas toward the end of the War, and subsequently, to the occupation forces in Japan. Mr. Gould was born in Illinois, and was educated at Oklahoma A&M and at M.I.T., from which he received the degrees of MS and ScD in Electrical Engineering in 1925 and 1927.

Geoffrey Gordon

Geoffrey Gordon was born in London, England. He studied at the University of London where he received the B.S. degree in Physics in 1945, the B.S. degree in Mathematics in 1950 and the M.S. degree in Mathematics in 1952. He worked on problems in high frequency heating at the Research Laboratories of the General Electric Company and later headed a department engaged in the theoretical study of guided missile systems. He came to the United States in December 1955, and in 1956 joined the Special Systems Engineering Department at Bell Laboratories, where he has been concerned with the application of digital computers to data processing and the study of switching systems. He is a member of the Association of Computing Machinery. Mr. Gordon is the author of the article "Simulation with Digital Computers" in this issue.

J. B. Howard was born in New Haven, Connecticut, and lived in that area until completing his formal education. He received a B.S. degree with Honors from the Sheffield Scientific School of Yale University in June 1936, and immediately joined Bell Laboratories, where he is now supervisor of the group responsible for thermoplastics on wire and cable. His work at Bell Laboratories has covered many phases of high polymer chemistry, including studies of the structure and properties of polyethylene, polyesters and polyamides; polymerization techniques for vinyl monomers as well as for polyesters and polyamides; development and application of rubber insulation and jacket compositions; and development of test methods and specifications for plastics and rubber. Mr. Howard is a member of the American Chemical Society, the Society of Plastics Engineers, Alpha Chi Sigma, and Committee D-20 of the American Society for Testing Materials. He is co-author of the article "Colored Plastics for Wire and Cable" in this issue.

J. B. Howard

V. T. Wallder has been a member of the Laboratories in the Chemical Research Department since 1936. Born in Belleville, N. J., he graduated from the University of Pennsylvania and has studied at Brooklyn Polytechnic Institute. He worked for several years developing improved abrasion resistance coatings for drop-wires and during World War II was concerned with the development of synthetic rubber compounds for military and Bell System wire and cable. Following the war, Mr. Wallder became responsible for a group handling thermoplastics for wire and cable and since 1954 has been in charge of the subdepartment responsible for

V. T. Wallder

the development and engineering applications of plastics to Bell System and military projects. Mr. Wallder is a member of the ASTM, the American Chemical Society, and is currently chairman of the Polymer Group of the North Jersey Section of the American Chemical Society. Mr. Wallder is co-author of the article "Colored Plastics for Wire and Cable" in this issue.

H. A. Wells is a native of New Jersey, and after service in the Air Force, received his Bachelor of Mechanical Engineering degree from Cooper Union in 1947. He then joined Bell Laboratories where he worked on improved plant maintenance methods, followed by work on wire development. Starting in 1951, he was concerned with phases of Nike Ajax development carried on by the Outside Plant Development Department. He received the M.S. in Mechanical Engineering from Newark College of Engineering in 1952, and later worked on the development of structures for the TD-2 and TH Radio Relay Systems. In 1955, Mr. Wells became the supervisor of a group responsible for the development of structures, and has worked on several radio-relay and military weapons systems. He is an associate member of the A.S.M.E. and is a Professional Engineer, licensed in New York State. In this issue he is author of the article on radio-relay towers.

H. A. Wells

R. A. Rasmussen

R. A. Rasmussen, a native of California, attended Los Angeles City College and the University of California from which he received the B.A. degree in Physics in 1950. He earned the M.A. degree in Physics from the University of Texas in 1952, and in 1953 joined Bell Laboratories as a member of the Underwater Systems Development Department. His work, until he left the Laboratories, was concerned with underwater acoustic devices including development of a compliant hydrophone suspension member. He studied problems encountered in holding suspended hydrophones in fixed angular orientation, and developed a small data-taking camera for these studies.

Samuel Mottel was born in New York City and received a B.S. degree in Mechanical Engineering from the College of the City of New York in 1950. After serving in the U. S. Army for two years in radar maintenance, he joined the Laboratories. He participated in the Communications Development Training Program and concurrently was engaged in the development of a power plant for the U. S. Army Signal Corps Alaska Communications System Submarine Cable. Since that time he has been involved in TD-2 power, Bell System submarine cable power plants, and in developing power equipments for the new TH and TJ microwave systems. He is currently concerned with power equipment for the BMEWS system and a new power plant for an extension of the Air Force cable system, described in the article "Power for the AFMTC Submarine Cable System" in this issue. Mr. Mottel is presently attending evening classes at Polytechnic Institute of Brooklyn for an M.S. in Mechanical Engineering. He is a member of Tau Beta Pi and Pi Tau Sigma.

Samuel Mottel