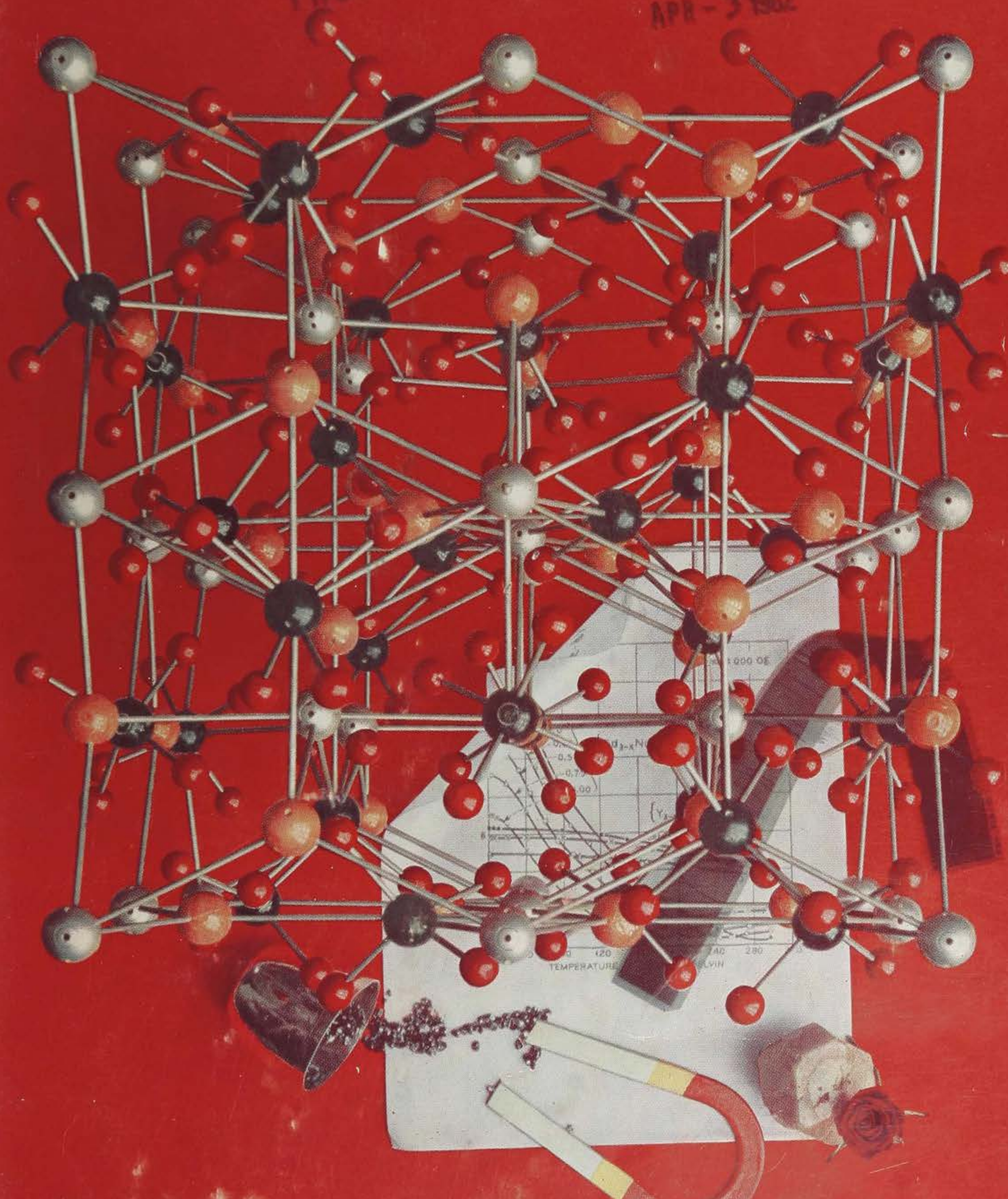
March 1962

Bell Laboratories

RECORD

Low-Speed Data Transmission
The Structure of Crystals
Laboratory for Ocean Cable
Compatibility in Communications
TELSTAR—Satellite Tests



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Cover *Magnetic yttrium iron garnet crystals spill out of platinum crucible in which they were synthesized. X-ray photographs yield film strips from which graphs and structural models can be made. Natural garnet in foreground serves as pedestal for Garnet Rose.* *(See story on page 81)*

A LOW-SPEED DATA SET FO

R. Sokoler

One of the frontiers of communication is the transfer of symbolic language or code through the voice telephone network. Such information transfer is made possible by the Bell System's DATA-PHONE service which incorporates a variety of data-transmission systems. Some of these systems carry information between business machines in digital form, such as coded alphabetic or numeric characters. Other systems handle information in continuous, or analog, form. Most of the data sets may be used as ordinary telephones when they are not handling data. Transmission speeds vary from more than 2000 bits (binary digits) per second to less than 100 bits per second.

The 401 data set described here transmits data at relatively low speeds—about 80 bits per second. Why not a high-speed data set for high-speed business? In designing any equipment, there must be a middle ground between features such as high speed and economy. The data sets in the 401 family are designed primarily for those businesses and industries which originate relatively short messages at outlying stations and collect data at a centralized receiver. Because many business machines deliver their information in parallel form, direct transmission by parallel

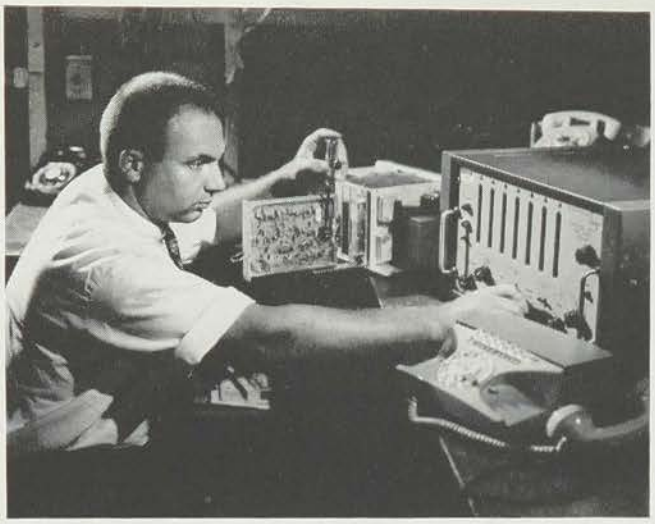
IGH-SPEED BUSINESS

techniques affords greater simplicity and economy. With a 401 data set transmitter, a customer can send information from his business machine, one character at a time by transmitting several frequencies simultaneously. With these data sets, all organizations large and small can transmit information to any point in the United States.

The use of the existing voice telephone network eliminates the necessity of leasing private lines and makes the system economically attractive and highly flexible. To set up a data connection, a customer dials a number just as for a regular telephone call. The receiving terminal, unlike a standard telephone, may not ring, but may answer the call automatically and transfer the line to the data portion of the receiver. The customer's equipment, sends a go-ahead signal to the calling party indicating that transmission may begin. During the data call, an attendant at either the transmitter or receiver can transfer from data to voice. He can return to the data mode by operating a data key. The data transmitter may be activated by a combination of contact closures delivered from a variety of business machines, such as simple paper-tape reader or a punched card reader.

If clarity, accuracy, and speed are criteria for effective communication, the output of a machine has an advantage over the human voice. Recent developments in data systems may make the language of machines commonplace in American business and industry.

Let's take a hypothetical example of how the system might function. Consider a business whose major income is from catalogue sales. The present ordering procedure might be something like this: After making his choice of items from the catalogue, a customer calls the sales office. The salesman answering the call writes down the customer's account number and the items he wishes to purchase. After he hangs up, and when time permits, the order is transcribed for transmission to the central warehouse. In all, an order may be handled three or four times by various



Author R. Sokoler adjusts frequencies on the answer-back oscillator in the 401 data receiver.

people. At the warehouse, if the item is temporarily out of stock, the customer may get a substitute product of "comparable" value or nothing but a note to the effect that the item the customer wants is out of stock.

Now let's examine the procedure using a data transmission system: The sales force has punched cards on file that cover each item in the catalogue. When a call comes in, a customer asks for the particular items he wants and gives his account number. A salesman takes the associated cards from the file and a data call is placed to the warehouse on another line. At the warehouse, the call is automatically answered and a go-ahead signal sent back to the sales office. The salesman inserts the punched cards for each item into a card reader, one at a time, and the information they contain is transmitted. The quantity of each item may be manually transmitted after each card by pushbuttons on the card reader. After each item is transmitted, information is immediately returned to the sales office as to whether or not that item is available. If everything is satisfactory, the customer's account number is manually transmitted, and the order is processed and billed by automatic equipment at the warehouse, with verification on each item—before the customer hangs up his phone.

The actual transmission of the information occurs as the holes in the punched cards are read by the card reader. These holes are converted to contact closures in the reader and cause voice frequencies to be generated in the data transmitter. As the holes are read in sequence, on-off bursts of coded signal frequencies are transmitted over the telephone voice channel as any voice message might be. Each burst represents one character. Because of this on-off method of transmission, neither the speed at which the characters are sent nor their timing is critical, since the start of a character is recognized by the start of the signal burst, and the end of that character by the end of that burst. This asynchronous operation permits transmission at any speed up to 20 characters per second.

Data signals do not possess the redundancy inherent in the spoken word. Therefore, in designing a data-transmission system which uses the regular telephone network (rather than private lines tailored to the system), the network characteristics and limitations must be kept in mind constantly to insure optimum system performance. Since this data system uses multifrequency signaling as its method of transmission, such considerations as limited bandwidth, frequency shift, echo, noise, net loss, and coding played important roles in the system's final design.

The voice channels in today's telephone system pass voice frequencies from a few hundred cycles per second to about 3000 cps. Of course, there are variations in these cutoff frequencies. To afford sufficient reliability to the system, the designers selected frequencies from 600 to 2350 cps which conform to this voice-frequency band limitation but still allow some guard space at the edges of the band.

Transmission frequency shift is another important factor in any multifrequency signaling system. If the transmitting and receiving carriers of a telephone transmission system differ in frequency by some number of cycles, then each frequency component of the received signal will suffer a frequency shift of that many cycles. Although there are shifts in frequency up to 20 cps on a few carrier systems still in use, these shifts are unnoticed by the human ear. They are, however, substantial by multifrequency data standards. To allow for a maximum 20-cps shift, the system designers allotted a band of frequencies over which each data frequency would be clearly recognized. This "recognition band" for each data frequency is 65 to 80 cps wide.

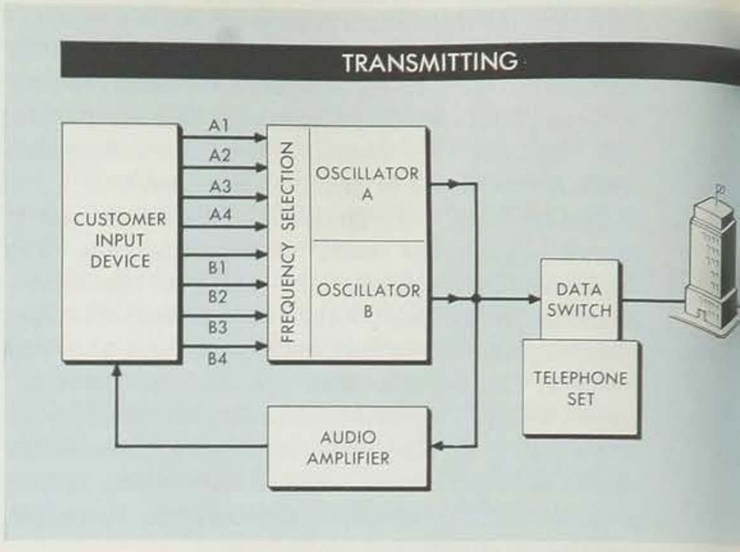
The low-speed parallel data system provides a reverse transmission signal to permit the receiving party to acknowledge a message. The data receiver returns "answer-back" tones to the transmitting station to indicate either satisfactory or unsatisfactory reception. To avoid interfering with these answer-back signals, the transmitter does not send continuous carrier when it is not transmitting data. If it did, echo suppressors on long circuits might be held in one transmitting direction, prohibiting reverse transmission. This consideration suggests the use of amplitude modulation or "on-off" keying. However, echoes on lines of intermediate length make AM undesirable, and for this reason, the system designers chose a modified FM transmission method.

Carrier at a rest frequency in each group is turned on at the start of transmission. The data message controls the shift to data frequencies. After each character is transmitted, the rest frequencies are restored. At the end of transmission, the carrier goes off after an 80-millisecond delay. This 80-millisecond rest tone signal following each character eliminates undesirable effects of line echoes. If the transmission rate is greater than about six characters per second, a continuous signal is transmitted.

The maximum net loss is less than 30 db on most lines. The intensity of the signal is limited principally by potential crosstalk; a maximum level of about −6 dbm is considered satisfactory. Line noise and signal echo problems, however, restrict the maximum receiver sensitivity to some reasonable value consistent with system requirements to keep a minimum error rate. For example, a 401 transmitter that delivers −11 dbm per frequency to the line requires a receiver with a minimum sensitivity set to a few db below −41 dbm to adequately detect the weakest incoming signals in the presence of noise.

The frequencies used in this system—ranging from 600 to 2350 cps—are divided into three channels. Each channel contains four data frequencies. A single character is represented by

Miss Sue Ehlers demonstrates data set in Laboratories computer center. Note receiver on rear table.



Block diagram of the numeric 401 data transmitter and receiver. The transmitter, controlled by the customer's business machine, sends parallel multifrequency signals over a telephone line to a receiver. At that point, the data signals are decoded and presented to an associated business machine in the form of simple contact closures.

one frequency from each channel. This arrangement provides a maximum of 64 frequency combinations — 26 codes for alphabetic characters, 10 for numerics and 28 for use as special symbols or functions. This form of coding provides inherent error-detection because the receiving business-machine equipment immediately detects any signal combination that contains either more or less than one frequency from each channel.

Although the low-speed parallel system can transmit alpha-numeric data, the present trend indicates a large demand for a purely numerical system which uses only two of the three channels. Such an arrangement provides 16 two-frequency combinations—10 codes for numerical digits and six for other functions.

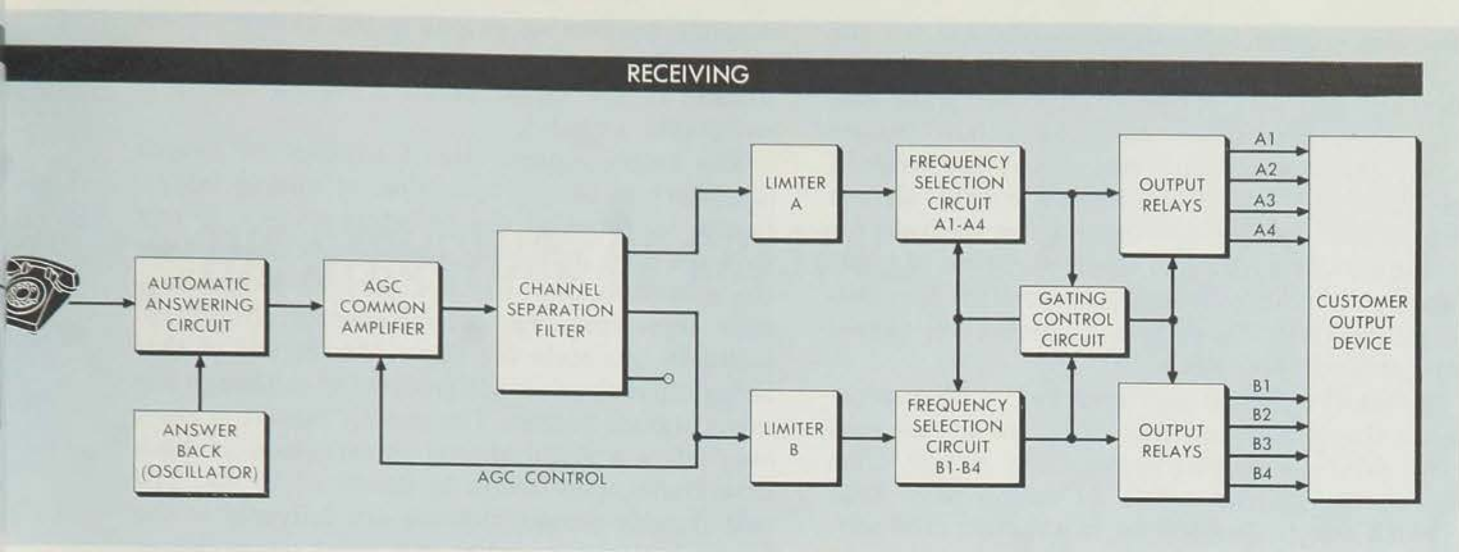
The Data Transmitter

The transmitting terminal that generates the multifrequency signals for the purely numerical system is shown in block form above. It consists of two transistor oscillators operated in parallel. Each oscillator can produce a rest frequency or one of four higher data frequencies, depending on the input data leads chosen. In addition to the oscillators, the transmitter contains a two-stage amplifier which receives the answer-back signals from the data receiver. This amplifier drives an external speaker that produces an audible answer-back tone as well as side-tone that allows a customer to hear the data signals being transmitted. The transmitter is powered directly from the telephone line using a polarity guard bridge network at its input to insure the proper polarity of dc potential. As an optional feature, the transmitter may also be equipped with a slightly more elaborate answer-back amplifier that will produce either of two relay contact closures in response to one of two acknowledgment signals.

Each oscillator uses a three-winding ferrite transformer to generate feedback and control frequency of oscillation. Tight coupling and large feedback are provided to insure fast oscillator start up. The lowest frequency in each group is the rest tone generated by a fixed polystyrene capacitor across a portion of the tuning winding of the transformer. The remaining frequencies are obtained by shunting the main tuning winding at appropriate taps by a second inductor. The transformers and inductors are wound on similar ferrite structures and the inductance of each can be adjusted with a center slug.

The keying of the transmitter is controlled by business-machine equipment, which makes parallel contact closures to select one data frequency in each channel. Immediately following this selection, a third contact closure (the keying contact) applies power to the oscillators, and only then are the data signals transmitted. The data receiver tolerates only a fixed amount of time separation, or skew, between the two data frequencies. For this reason, the order in which the data-keying functions are performed is necessary to eliminate any excessive skew that may be inherent in the data contacts of the controlling business machine. That is, if the data frequencies were transmitted at the time each frequency selecting contact was closed, excessive delays of one frequency relative to the other might destroy transmission of data. If however, this skew, or time separation, between the start of the frequencies is less than about 6 milliseconds, the order in which these operations are performed is unimportant.

As mentioned earlier, in addition to the four



data frequencies, there is one rest frequency in each channel which suppresses any echo signal in the data receiver. To provide a rest tone of the desired duration following each data frequency, a series resistance-capacitance arm is connected across the keying contact terminals that supply power for the oscillators. The network is adjusted so the charging line current sustains these rest tone oscillations for the required time. As the capacitor charges, the current available to the oscillator diminishes, and after about 80 milliseconds this current is insufficient to allow continued oscillations. This is why rest tones follow data tones for the prescribed duration.

If the character repetition rate is greater than about six to eight characters per second, the transmission is continuous FM; that is, the normal off periods between data tones will be completely occupied by the rest tones with no interruption of signal on the line. The transmission of a character before the rest tones have subsided simply generates frequency-shift signals. For rates less than about six characters per second, the "hangover tones" (that is, the 80 milliseconds that include both rest frequencies) do not completely fill the interval and periods of no signal will be present. Regardless of the character rate, however, there will always be a return to quiescent condition following the opening of the keying contact after the last character of the sequence is transmitted. This permits the receiving terminal to acknowledge or deny satisfactory reception of the data message. The normal quiescent conditions recognized at the data receiver are either all rest tones or the absence of all data frequencies.

The two-stage receiving amplifier in the transmitting terminal produces the necessary audio power to drive a small speaker for the audible answer-back tone. Most of the current from the telephone line passes through a choke coil and a string of six silicon alloy diodes. The nearly constant voltage drop across these diodes is the power source for the amplifier, which delivers between 1 and 2 volts rms to its speaker when receiving answer-back signals over transmission paths having loss as great as 30 db.

The Data Receiver

The current numeric data receiver, shown in block form above receives data signals from both channels over telephone circuits with as much as 30-db net loss. The receiver output to the customer's business machine consists of a pair of contact closures (one contact out of four in each channel), which correspond to the closures at the transmitting terminal.

When a call is received, answering circuits in the data receiver automatically answer the call and transfer the line to the data circuits. (The answering circuit may be disabled for customers who do not desire automatic answering.) If power is not applied to the receiver, or if the business machine is not in the data mode, the telephone rings in the normal manner (regardless of the receiver's answering option) and some manual action is necessary.

The received input data signals are in the form of tone bursts. Each burst consist of two data frequencies: one from the first channel and one from the second. Signal power may vary over 30 db depending on the particular transmission circuits, and amplification is sometimes necessary to compensate for such loss. Input signals pass through a common amplifier providing a maximum gain in excess of 40 db. This high gain is required for weakest signals but is quite excessive for the strongest signals received. For this reason, the common amplifier possesses automatic gain control characteristics which substantially reduce the receiver sensitivity for all but the weakest signals. The amplifier delivers output signals which are constant to within a few decibels for input signals with up to 30-db variation in input power. The transmission of the amplifier is sufficiently linear to insure that no errors are caused by harmonic distortion.

After the signals are amplified, a filter separates the data frequencies by groups so that each may drive its respective detection circuit. This separation filter consists of a low-pass filter (which selects frequencies in the first channel), a band-pass filter (which selects frequencies in the second channel), and a high-pass filter (which selects frequencies in the third channel). The inputs of these filters are driven in parallel by the amplified input signals. The single frequency output of each filter drives a single-stage limiter which supplies enough gain to remove the small variations in signal level permitted by the amplifier circuit. The resulting square-wave output maintains the same peak-to-peak value over the entire range of receiver input levels.

Actually there are five frequencies in each channel: Four are for data, and one is the rest tone which lasts approximately 80 ms after each data tone. This fifth frequency is not recognized by the numeric data receiver, and so it does not produce any output; it does, however, play a vital role in suppressing echoes which might otherwise seriously disrupt transmission. Design engineers found these echoes existing on some lines without echo suppressors, with delays as great at 35 ms and levels sometimes only 10 db below the main signal. These echoes arrive at the limiters in the data receiver with energy identical in frequency to the previous data character but delayed up to 35 ms. If both echo frequencies are of sufficient magnitude they may cause a repeated output of that character. If only one echo frequency is strong enough to activate the limiter, only one channel will produce an output closure, and an error may be generated. However, if a rest tone follows each data tone for 80 ms, it will saturate the limiter producing output axis crossings almost purely of the rest tone frequency, suppressing any effects caused by these echoes.

Each channel limiter supplies its signal to four tuned circuits. Each of these circuits responds to one of the four data frequencies in that channel. When the response of one of the tuned circuits exceeds a fixed threshold voltage, the associated detector delivers an output to the gating-control circuit. The gating-control circuit then starts timing. If the signal persists for 10 ms, it is recognized as valid.

The gating-control circuit enables the output amplifiers to permit operation of output relays. It also operates on the detectors to lock in any that are then delivering signals and desensitizes the others so they will not respond to trailing-edge transients. The gating-control circuit remains in this state for 22 ms. At the end of this time output closures are removed even though the input signals persist. The control circuit is reset only when a simultaneous interruption of both data frequencies occurs in excess of 10 ms. The output relay contact closures are delivered to the business machine, and at this point the customer may decide whether he has a valid combination.

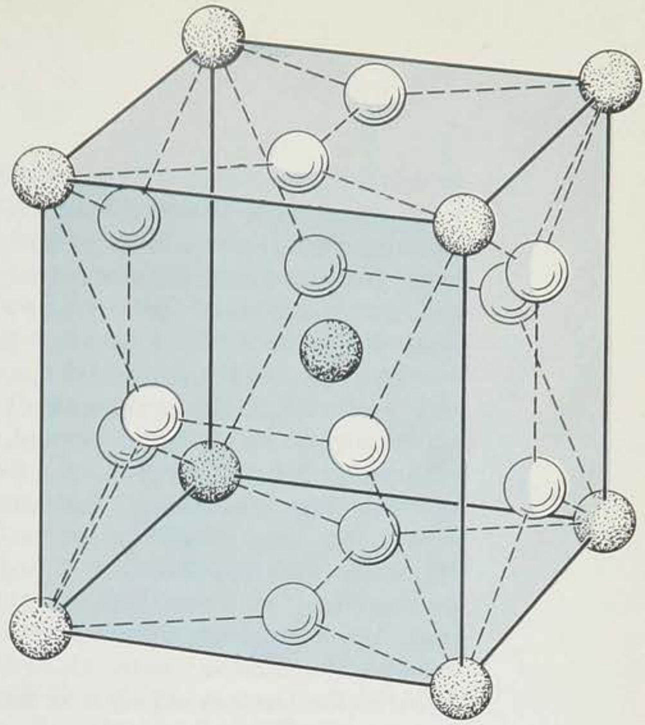
Data-System Variations

This system can transmit any one of sixteen different characters by sending two frequencies at one time, with each frequency chosen from a group of four. For this reason, it is often called a two-out-of-eight system. It can handle the ten numeric digits and a few control codes. Acknowledgment, or answer-back, is provided audibly.

When alphabetic and numeric characters are sent, a third oscillator is added to the transmitter and a third group of detectors is provided in the receiver. In this case, the transmitter may be equipped to provide audible answer-back or to respond to either of two acknowledgment frequencies and operate one of two relays. This system is often called three-out-of-twelve.

The three-out-of-twelve systems imposes rather stringent skew tolerance on the timing of contact closures in the transmitting business machine. An alternative system, called three-out-of-fourteen, eliminates this requirement and leaves timing entirely to the machines. This data receiver has no gating. It is, however, arranged to detect rest tones as well as message tones in each group and give indication by contact closures. Thus, there are five detectable frequencies in each of the lower groups. The top group needs only four. This positive detection of rest frequencies provides information to permit use of a stronger error-detection scheme than is possible with the three-out-of-twelve system.

The low-speed parallel data set has been field tested, and is currently available for industrial and private use. Because of its basic simplicity, this system, as part of the general DATA-PHONE service, should become an integral part of American communication facilities.



THE STRUCTURE OF CRYSTALS

S. Geller

Scientists began to speculate on the structure of matter many years before the modern, powerful tools for its determination were discovered. Then, about fifty years ago, actual investigation into crystal structure—the arrangement of the atoms in the fundamental building block of the crystal, the unit cell—was begun, with little consideration given to its technological importance. The scientists hoped only to gain a deeper insight into important natural phenomena.

Today the situation is considerably altered. Many advances in both science and technology have been made hand in hand with advances in the knowledge of structures, since it is usually almost impossible to understand the fundamental physical and chemical behavior of materials without at least a knowledge of the approximate arrangement of the atoms involved. Although this increasing knowledge has had a tremendous impact on the various sciences, its full potential has not yet been realized; the science of structure determination is presently ahead of the scientist's ability to express in precise mathematical terms the correlation between specific structures and corresponding physical and chemical properties.

In spite of this, it is still unwise to expend a large effort in studying a crystalline material on which no structural data whatever have been obtained. Even rudimentary knowledge of the structure allows the scientist to make predictions about the possible existence of structurally related crystals. It gives him an intuition for the properties such a crystal might have. In some cases, knowledge of structure may actually allow calculation of electrical properties, as it did for silicon and germanium, which have the same crystal structure as diamond. Also, the important magnetic properties of the ferromagnetic garnets were predicted using insight gained from studies of structures. From such studies, we can also obtain ideas on the structures into which various elements will go, and on any changes in properties that may be obtained.

Although this article will deal with the structures of solids, problems of structure in the liquid and gas phases are also of great scientific and technological importance. Some of the tools used for the determination of crystal structure are applicable to fluids as well.

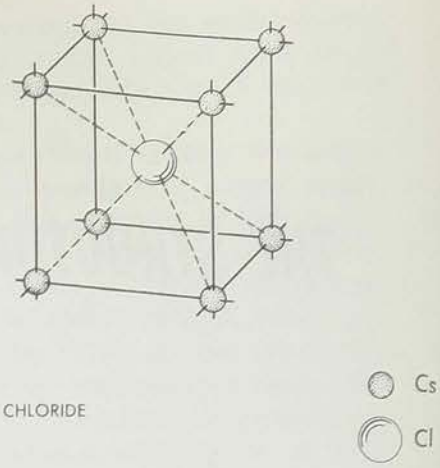
The most important tool for the determination of the arrangement of atoms in the crystal is the X-ray diffraction technique. A crystal behaves like a three-dimensional diffraction grating when irradiated by electromagnetic radiation with wavelengths comparable to the distances between the atoms in the crystal. This important discovery was made in 1912 by von Laue in Germany, and established the validity of speculations by earlier scientists that the atoms in a crystal must have a periodic arrangement.

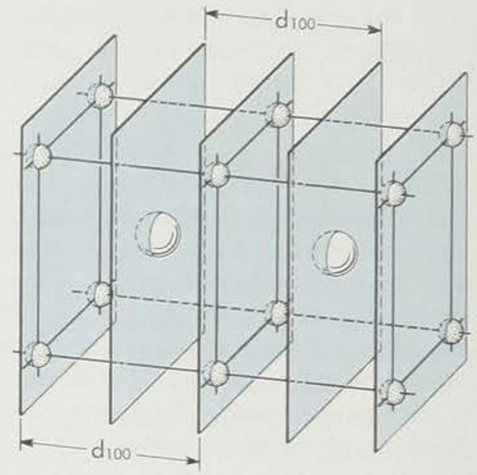
Historically, ideas concerning symmetry were the first deductions in crystallography. This is perhaps natural, because the external form of crystals could be observed without knowledge of their submicroscopic structure. Thus, by the middle of the nineteenth century, Miller had formulated a system for the classification of crystals into 32 classes. These classes represent all the possible true external symmetries of crystals and are made up of combinations of one or more of several types of symmetry, designated by the following terms: identity; center of inversion; two-, three-, four- and sixfold rotation axes; four- and sixfold rotary axes of inversion; and mirror plane. In 1848, the French physicist, Bravais, deduced the fourteen "space lattices" corresponding to the 32 crystal classes.

The crystal classes represent all the different ways in which the external *faces* of a crystal may be arranged about a point, but they cannot by themselves represent all the ways in which *points* may be arranged in space. To the X-ray crystallographer, this latter is indeed of great importance. Mathematical treatment of this spatial problem even preceded von Laue's discovery—by the Russian scientist Fedorov in 1885-1890, by the German scientist Schoenflies in 1891 and by the English scientist Barlow in 1894. These men showed that there are a total of 230 different ways of arranging points symmetrically in space; these arrangements are called "space groups." To derive all of these space groups, two new types of symmetry operation—screw axes and glide planes—must be introduced. The former involves the rotation and translation of the point; the latter, the reflection and translation of the point. The space groups and their point arrangements are given in detail in Volume 1 of the *International Tables for X-ray Crystallography*. In every crystal structure, the atomic centers are arranged in accordance with one of these space groups. The task in determining a crystal structure is to find the space group by which the crystal may most probably be represented, and to determine the positions of the atomic centers in the unit cell. (The ultimate solution of the problem also includes the determination of the thermal vibrations of the atoms and the density of electrons throughout the unit cell.)

X-Ray Data Essential

All X-ray diffraction techniques for solving crystal structures involve collecting data from specimens irradiated by intense, collimated X-ray beams of specific wavelengths. Usually, the study of single crystals leads to the most accurate determinations of atomic positions, but in many cases the data from powdered specimens are indispensable. Data are collected by photographic or counter methods, although the photographic method is still most widely used. The diffraction data always contain the secret of the crystal structure—the crystallographer must use his ingenuity to unravel the secret from these data. Whenever possible, he also uses data from other sources to help solve the structure, including optical, magnetic and electrical measurements.



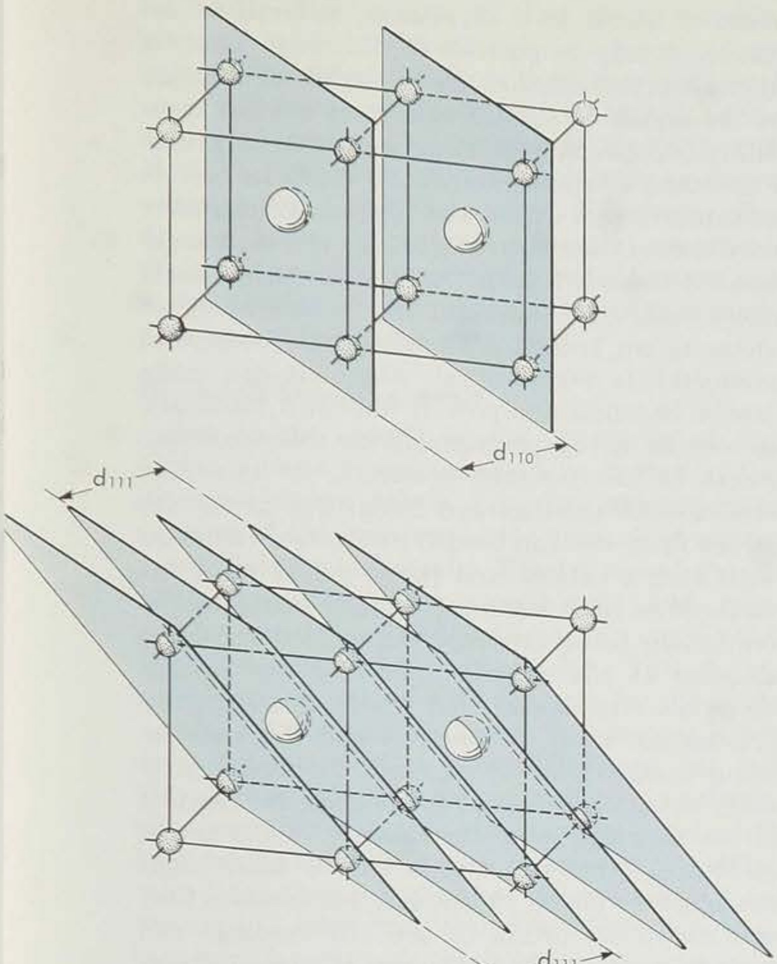


The arrangement of atoms in the unit cell of cesium chloride (upper left). The other figures represent the

In X-ray diffraction, a beam of X-rays of a particular wavelength irradiates a single crystal and "reflects" from an infinite set of parallel planes of equally spaced atoms lying in a particular direction in the crystal. The intensities of these reflections and their spacings are a direct result of the kinds of atoms present and their arrangement in the crystal.

Measurements of the diffraction effects from the crystal lead first to a determination of the Bravais lattice on which the crystal may be indexed. From the measurements of the unit cell edge length and the included angles obtained from these data, one may easily calculate the volume of the unit cell. Knowledge of the density of the crystal and of the chemical formula of the compound then leads to a determination of the number of formula units in the unit cell.

An examination of all the coherent diffraction effects for a given crystal leads next to determination of the probable space groups to which the crystal may belong. In some cases there are sev-



arrangement of the atoms of cesium and chlorine in the (100) plane, the (110) plane, and the (111) plane.

eral of these, while in others the most probable space group is uniquely determined by the diffraction effects. When there are several possible space groups, various techniques can be employed to choose the most probable. Statistical methods make use of the intensities of the reflections. Also, the physical techniques mentioned before play an important role. For example, suppose the diffraction effects indicate that a crystal could belong to one of three space groups, one having a center of symmetry and the other two without such a center (acentric). If we find that the crystal is piezoelectric, a property exhibited only by acentric crystals, then it can only belong to an acentric space group. If we further find that the crystal is ferroelectric, the possibility of an even-fold axis, or a plane of symmetry perpendicular to the polar axis of the crystal, is also eliminated, thus leaving only one possible space group. This was the way the most probable space group of the ferroelectric crystal gadolinium aluminum sulfate, hexahydrate (GASH), discovered at Bell Telephone Laboratories by A. N. Holden, B. T. Matthias, W. J. Merz and J. P. Remeika, was deduced.

The final evidence, however, must always come from the credibility of the structure postulated by the crystallographer. This includes its relation to structures already solved and the agreement of calculated and observed data.

Following the determination of crystal symmetry, unit cell, number of each kind of atom in the unit cell and the probable space groups, the real problem for the crystallographer begins—the determination of the positions of the atomic centers. In some cases, this is very straightforward; in others, extremely complicated. A detailed exposition of how structure problems are solved is beyond the scope of this article. Many techniques are used to give information, and needless to say, know-how is of paramount importance. Even though at times there are surprises when a structure is finally resolved, an intuitive understanding of how atoms in general prefer to "fit together" is, in the author's opinion, the first requisite of a good X-ray crystallographer. With the knowledge of the probable space groups and of crystal chemistry, one can sometimes sort out the probable sets of positions which the atoms occupy, and by trial and error ultimately obtain approximate values of unknown parameters.

After an approximate structure is obtained it must be refined. In this procedure also, several mathematical techniques are available, and the large computing machines have now made possible calculations which not so long ago were tremendously burdensome, some in fact, entirely impractical. Recently, for example, a single "least squares" calculation involving the refinement of 116 structural parameters took about 1½ hours on an IBM 704 computer. A person making this calculation manually on a desk calculator would have had to work diligently and expertly for about five years of forty-hour weeks. Also, the human calculator must have made no errors during his calculation, a virtually impossible task.

Obviously, because of the limitation of both space and nonmathematical presentation, the above discussion of structure determination and refinement is brief and oversimplified. However, readers interested in more detail will find it in a few books now available in this field.

Cesium Chloride Simple Structure

To make some of what has been said a little more understandable, a very simple structure, that of cesium chloride (CsCl), is shown at left above. In each unit cell of CsCl, there is a cesium ion at each corner (000), and a chloride ion at each body center (½½½). It should be kept in mind

Author Seymour Geller adjusts an X-ray camera, prior to taking photograph of single crystal sample.

that each cesium ion is shared by eight unit cells, so there is really only one cesium ion in each unit cell. Each cell edge is 4.112 Angstroms long (1 Angstrom equals 1/100,000,000 centimeter). The planes designated (100) contain atoms as shown in the diagram at upper right. A beam of radiation from an X-ray tube with a copper target, at an angle of incidence of 10.8 degrees with these planes, results in a diffracted beam with an intensity determined by destructive interference of the scattering from the equal numbers of cesium and chloride ions. However, in the planes designated (110), radiation from a copper target at an angle of incidence of 15.4 degrees produces scattering from the two kinds of atoms which interferes constructively. In the planes designated (111), with an angle of incidence of 18.95 degrees, the scattering from the two is again opposed. Thus one can deduce the arrangement of the atoms from the intensities.

The structure of cesium chloride is the simplest one of all chemical compounds. Even many elements have far more complicated structures than this. An extreme example is that of one of the forms of boron, which has fifty atoms in a tetragonal unit cell. Another more complicated form of boron, not yet completely worked out, has over 100 atoms in a rhombohedral unit cell.

The simplest and most obvious application of the X-ray diffraction technique is to the identification of crystalline solids. Even if the arrangement of atoms in a crystalline material is unknown, it may be possible to determine what its formula is and whether the arrangement of atoms in the crystal is similar to that of another crystalline compound consisting of different atoms. For example, many compounds (such as cesium bromide, cesium iodide, and thallium antimonide) have the CsCl structure. Of course, if the arrangement of atoms is known, the identification is made more easily. If, however, the arrangement of atoms is not known, a knowledge of the crystal symmetry is very helpful. Also, one can make careful chemical analyses of unknown materials, as well as X-ray photographs or diffractometer traces of the powered materials. If one then catalogs the spacings and intensities of the observed lines, one can compare unknown materials with such a catalog and possibly find what the material is. Such a catalog actually exists, and is continually being expanded and revised under the auspices of the American Society for Testing Materials. The use of such a technique naturally presupposes some knowledge about the material being analyzed, but it may not be necessary to carry out a precise quantitative chemical analysis if the material is in the catalog. If the actual structure of the material is known, more confidence can be placed in the analysis, because then one knows the origin of the line spacings and their intensities. This technique of analysis is extremely useful in these Laboratories. It not only can determine directly the formula of a particular compound, but aids in the determination of the existence of compounds of like structure containing different elements.

The X-ray diffraction technique is also of great importance in aligning crystal oscillators and for scientific experiments. Measurement of directional properties such as microwave resonance absorption of spheres of garnet or ferrospinel crystals, for example, requires such alignment.

Much of the time on the X-ray machines and cameras at our Laboratories is devoted to the kinds of work mentioned above. But probably among the most important data are those used for the determination of the atomic arrangement in crystals. This activity has also been increasing at our Laboratories.

All scientists, in their constant attempts to unravel the complexities of natural phenomena, find patterns among these phenomena; this is true of the relation of the properties of a crystal to the arrangement of its atoms. Of course, there are other dependencies and the reader should not get the impression that atomic arrangement is the only cause of the behavior of materials.

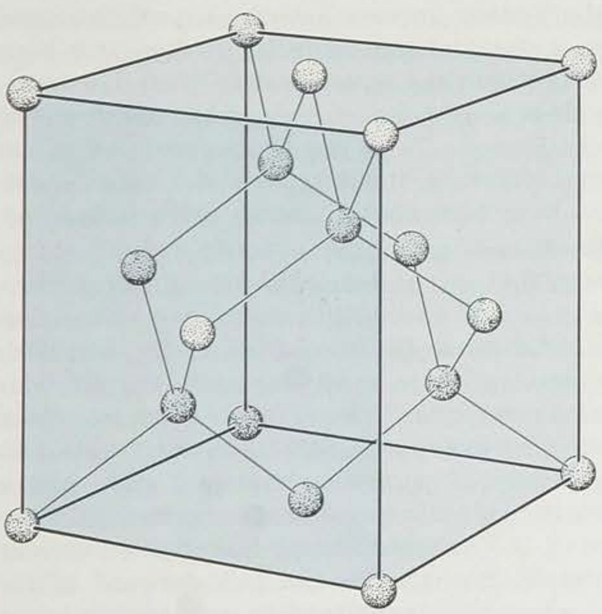
Obviously the nature of the atoms present plays a most important role — heavy atoms will behave differently from light ones, magnetic ones will behave differently from nonmagnetic ones, and so on. The compounds $MnFe_2O_4$ and $MgAl_2O_4$ both have the spinel structure as shown on page 86, but behave very differently. The former is an important magnetic compound, whereas the latter is nonmagnetic. However, an understanding of this magnetic behavior depends on a knowledge of the structure.

Diamond Structure Basic

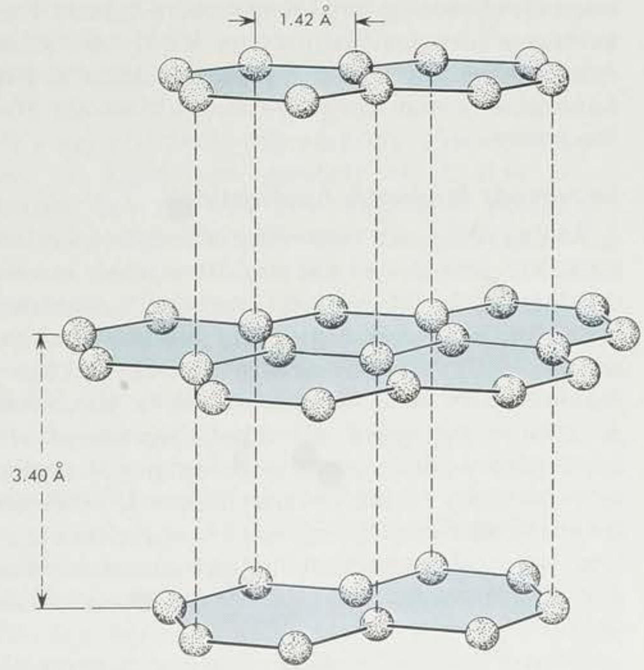
One of the specific crystal structures of importance to us at the Laboratories is that of the diamond, shown below. The diamond structure consists of a three-dimensional network of carbon atoms linked tetrahedrally. The distances between nearest neighbor atoms are short (1.54 Angstroms or about 6 billionths of an inch) and therefore the bonds are strong. This tight, three-dimensional network accounts for the hardness of the diamond. Its hardness, however, is not its only important property. Diamond has the structure of the ideal semiconductor. Any element or compound with this structure is a potential semiconductor, even though its specific properties will depend on the elements themselves and on the type of impurities included. Silicon and germanium, for example, both have this structure, and their importance can hardly be overestimated. Because an understanding of the properties of these materials is largely dependent on the knowledge of their structure, experience with the diamond structure has started many researchers looking for new materials with related structures. This in turn has led to the discovery of new binary and ternary compounds with such structures, some of which may have not only scientific importance but potential technological use. Some of these are the so-called III-V compounds made up of one element from Group III and one from Group V of the Periodic Table (*Record*, November 1961). Examples are gallium arsenide, gallium phosphide, and indium antimonide. The atoms in these compounds are also arranged tetrahedrally, although the bonding is not as simple as that in diamond.

The structure of graphite, another form of carbon, demonstrates the difference in properties between different structural forms of the same element. In this structure, shown below with diamond, the carbon atoms are strongly bonded in regular hexagonal array; the planes of carbon atoms so formed are only loosely bound in the direction perpendicular to these planes. The bond distance between carbon atoms in the plane is 1.42 Angstroms, while in the direction perpendicular to this plane, the nearest neighbor distance is 3.40 Angstroms, more than twice as far away. This large distance accounts for the lubricant property of graphite. The planes of tightly bonded carbon atoms are held together only loosely, and apparently slide over each other easily. Within the planes, however, the bonding is stronger than that existing in diamond.

Another field in which the study of structure

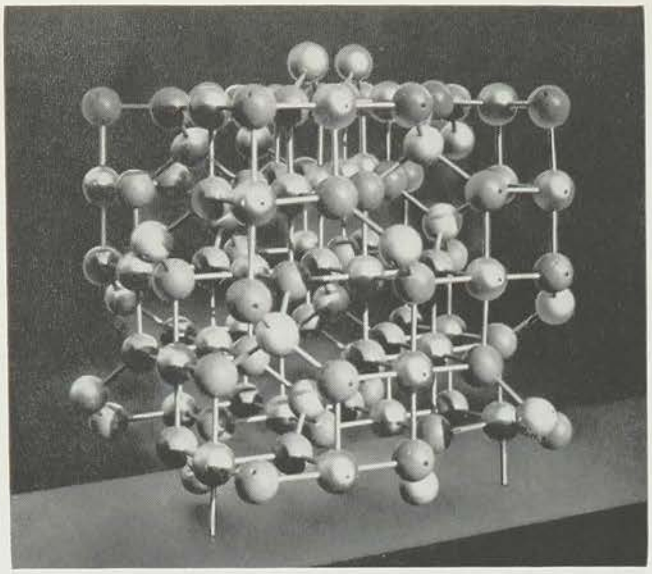


DIAMOND



GRAPHITE

Crystal structures of diamond (left) and graphite show why the materials exhibit different properties.



Model of the spinel structure. This structure is exhibited by crystals of many different materials.

has been of great value is in the rapidly developing one of superconductivity. Considerable searching for superconducting materials has indicated at least a secondary relation of superconductivity and structure. Recently, Bell Laboratories scientists announced that a compound of niobium and tin, Nb_3Sn (discovered by B. T. Matthias and co-workers), may be useful in coils of superconducting electromagnets (RECORD, *March* 1961). The compound has the beta-tungsten structure shown on the title page. Compounds with this structure are not all superconductors, of course, but the structure-type is very favorable to superconductivity. We do not know exactly why this is so, but further studies at Bell Laboratories and eleswhere may ultimately give the answer.

Important Magnetic Applications

Among the most rewarding attempts to relate structure and properties are those that involve crystals with interesting magnetic properties. When the magnetic moments of individual atoms or ions in a crystal are ordered, the crystal has a *magnetic* structure not discernible by the X-ray diffraction technique. However, because of the wave nature of neutrons, and because the magnetic moment of the neutron interacts with the magnetic moment of the electron, neutron diffraction is a technique by which one can determine the directions and sizes of the moments of the magnetic atoms.

Before discussing some important magnetic materials, a brief definition of the terms ferromagnetism, antiferromagnetism and ferrimagnetism may be in order. The magnetic moments of the magnetic ions or atoms in any crystal possessing one of these properties are ordered, or arranged symmetrically in three dimensions. In a *ferro*magnetic crystal, all magnetic moments ideally point in the same direction. In an *antiferro*magnetic crystal, the arrangement of moments is such that the total magnetic moment of the crystal is zero. The simplest cases are those in which moments of pairs of similar atoms are antiparallel. A *ferri*magnetic crystal is one in which there is uncompensated antiferromagnetic interaction of magnetic ions or atoms, leading to a substantial net moment for the crystal.

While there are many scientifically important materials in all these categories, the ferromagnetic and ferrimagnetic materials are of greatest technological importance. One of the most exciting recent discoveries in this field is that of the ferrimagnetic garnets, discovered independently at Bell Laboratories and at the University of Grenoble in France. The name garnet is usually associated with a family of silicate minerals. A typical ideal formula of one of these is $Ca_3Al_2Si_3O_{12}$, or calcium aluminum silicate. Although the structure is rather complex, especially when compared with those discussed earlier, it was solved in 1928 and recently refined here.

It has now been found possible to substitute trivalent yttrium ions for the calcium ions, and trivalent iron ions for both the aluminum and silicon ions, leading to the formula $Y_3Fe_2Fe_3O_{12}$. Crystals of this compound have the garnet structure, and the compound has therefore been named "yttrium iron garnet" or YIG.

Many other garnets have been predicted, and crystal chemical and magnetic studies have been carried out in the larger part in these Laboratories. It is now known that about half the elements in the Periodic Table can be incorporated in the garnet structure, and the effects of these substitutions have been studied rather extensively.

Needless to say, many more examples could be given. The need to know the structures of crystals grows rapidly with increasing investigation into solid state physics and chemistry, and with the striving of the scientists to obtain a fundamental understanding of the materials with which they are concerned. One has only to look at the variety of papers on the solid state in the scientific journals to see that reference to structure of the materials being investigated is very prevalent. Perhaps we can look forward to the day when our understanding will enable us to tailor-make materials for any purpose. In this effort, structure will play an important role.

UNIQUE ACOUSTIC PROPERTIES FOUND IN YTTRIUM IRON GARNET

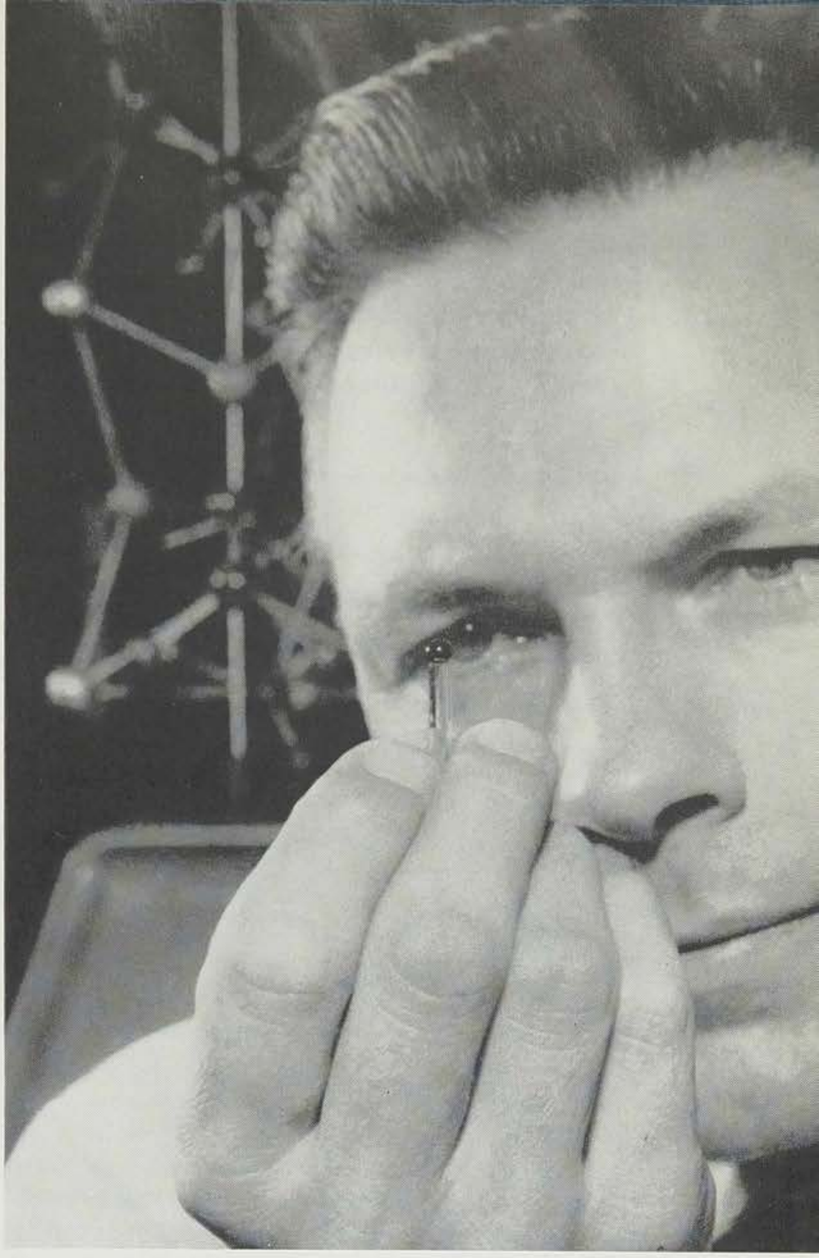
Scientists at Bell Telephone Laboratories have found that yttrium iron garnet (YIG) (see the preceding article in this issue), is exceptionally efficient as both a transmitter and a transducer of acoustic energy. The finding is expected to be of particular importance to such applications as acoustic amplifiers, acoustic delay lines for radar and computers, and acoustic oscillators as frequency standards.

The high efficiency (low loss) of YIG in transmitting or storing acoustic energy was first described earlier this year by Conway LeCraw and Edward G. Spencer of the Solid State Device Laboratory and Eugene I. Gordon of the Electron Device Laboratory. Its efficiency as a microwave-frequency transducer is described by Spencer, Richard T. Denton also of the Solid State Device Laboratory and Robert P. Chambers of the Mathematics and Mechanics Research Center in a forthcoming article in *The Physical Review*.

As an acoustic resonator, YIG has losses at room temperature of only about a tenth those of quartz over a frequency range of about one megacycle up into the microwave region. Quartz has the lowest loss of any previously investigated material. The quantity ordinarily used to describe acoustic efficiency, the Q of the material, has been found to be for YIG approximately 10^7 at room temperature for a frequency of about 10 megacycles. Higher values ultimately may be possible.

Along with its low acoustic loss, YIG has been found to be an extremely efficient microwave-acoustic transducer, requiring only a small fraction of the power required of a similar quartz transducer. The microwave energy can be fed into a YIG cylinder by a fine wire loop near the end of the cylinder; no bonds or contacts are necessary. A microwave pulse in the wire loop generates an acoustic pulse by a magnetostrictive process. Since YIG is also a ferrimagnetic resonator with the sharpest ferrimagnetic resonance peak known, it can be tuned to be in resonance with the microwave input, producing a very efficient transfer of magnetic energy from the wire loop to the YIG cylinder.

The low acoustic loss of YIG implies an extremely stable short-term vibration frequency. As is true of most materials, the frequency of a YIG resonator varies with temperature, thus limiting its long-term frequency stability. For some applications, short-term stability is all that is required, and YIG may be immediately useful. An example is synchronous detection (picking a weak return signal out of noise by comparing it with a reference signal of highly stable frequency).



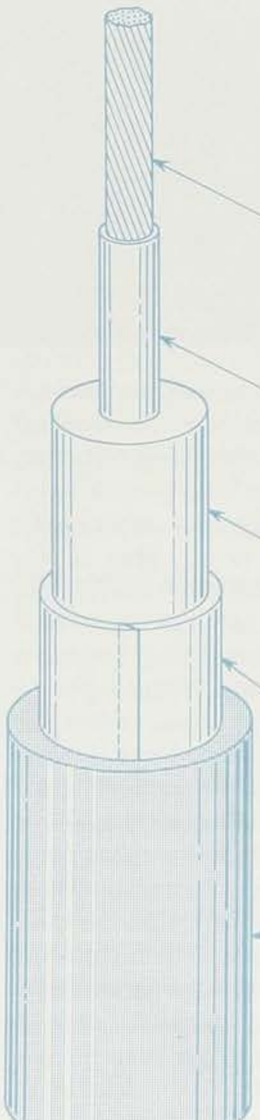
Conway LeCraw examines a spherical resonator of yttrium iron garnet (YIG) used in making measurements of the acoustic loss of the material.

One promising application for these properties of YIG is wideband ultrasonic delay lines in computers and radar. Such delay lines would be used to store information in the form of short acoustic pulses. One problem with microwave delay lines has been the rapid attenuation of signals due to acoustic loss in the storage medium. Considerable loss also occurs in the transducer and in the bond between transducer and storage medium. Since YIG can serve as both transducer and storage medium, and is more efficient than present materials for both purposes, it may drastically reduce all three of these sources of loss.

In 1963 a new transatlantic coaxial cable system will begin operating between the United States and Europe. The system will use an armorless cable designed and developed by Bell Telephone Laboratories engineers.

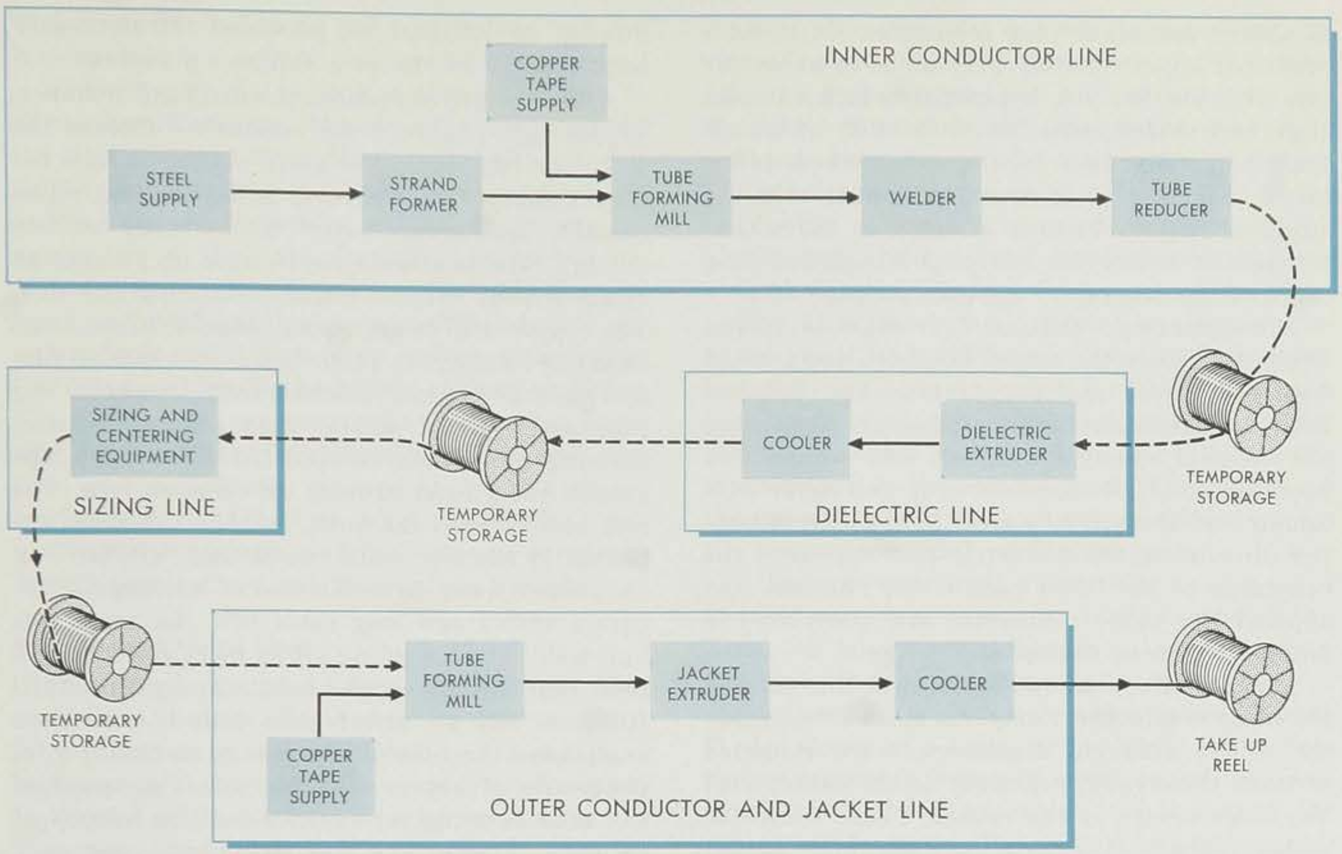
Laboratory for Ocean Cable

J. W. Phelps and R. M. Riley



On September 25, 1956, a telephone call between New York City and London started the first commercial transatlantic telephone service over coaxial ocean cable. The rapid growth of transatlantic telephone traffic soon created a need for a second cable system, and by 1960 it too was completed and operational. But just as newer and better highways generate additional automobile traffic, so these two cable systems have created a need for additional facilities to handle the rapidly increasing volume of transoceanic telephone traffic.

Anticipating this growth, research and development for a new cable system began at Bell Telephone Laboratories even before the first cable became operational. The new system, to be completed sometime in 1963, will have several advantages over the first two systems. One of these advantages is the use of an armorless cable structure. This armorless cable will be used also for the Florida-Jamaica cable scheduled for completion later this year. The development of armorless cable and more specifically the laboratory constructed to facilitate the cable development and to test its design have provided the subjects of this article.



A simple flow diagram illustrates the various operations of each of the four lines in the cable laboratory.

Armorless ocean cable, in contrast to earlier armored types, has its strength member enclosed within the inner conductor instead of surrounding the outer conductor. The earlier cables of armored design have a copper conductor in the center, separated from the copper outer conductor by polyethylene insulation. The outer conductor is wrapped with copper tape for protection from the teredo, a type of marine termite, and the copper tape is then wrapped with jute. Corrosion resistant steel wire, wrapped around the jute bedding, forms the strength member of the cable. Finally, tar impregnated jute is wrapped around the strength member to protect the steel from the corrosive effects of its marine environment.

Armorless cable is a distinct departure from this conventional design. As shown by the drawing on the opposite page, it incorporates only polyethylene, copper and steel. The details of this design include: (1) wires of high tensile strength steel at the center of the cable forming the strength member; (2) a tubular copper inner conductor around the steel; (3) a polyethylene dielectric jacket around the inner conductor; (4) a tubular copper outer conductor around the dielectric; and (5) a polyethylene jacket around the entire cable.

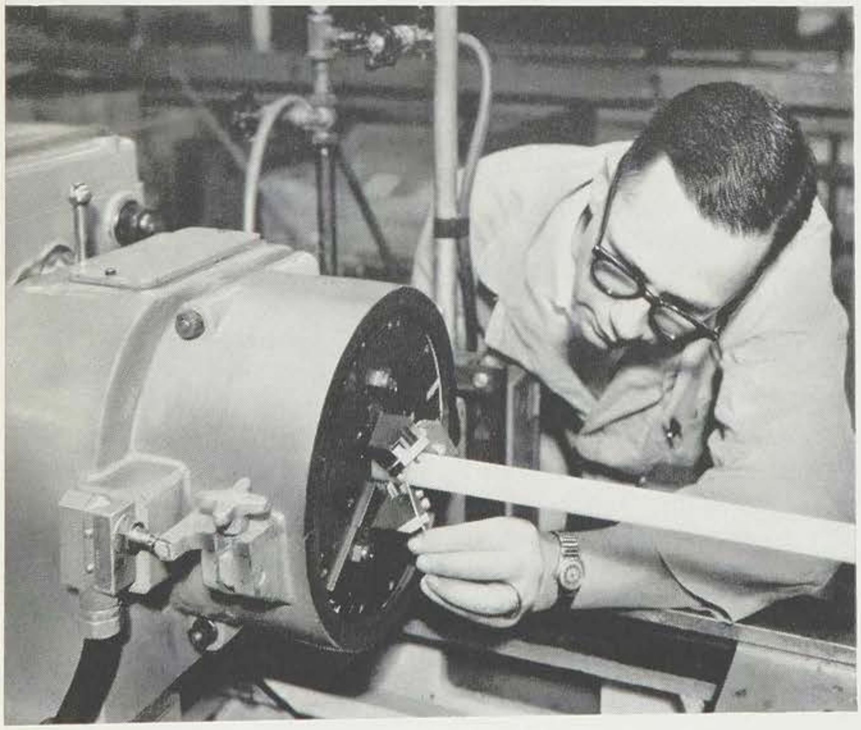
The major advantage provided by this design is improved electrical performance. At the same time, both the over-all diameter of the cable, and the estimated price per mile remain essentially unchanged from the armored cable used in the earlier transatlantic systems. The weight per mile, however, is much less. This reduced weight is especially significant when one realizes that as much as 18,000 feet of cable may hang suspended from the cable-laying ship. The breaking strength of the cable is nine tons, in spite of the substantial reduction in weight. This breaking strength compares favorably to that of the armored cable.

During the development period, Bell Laboratories equipped a laboratory for testing the feasibility of several different armorless cable designs. This laboratory, located at Cambridge, Mass., was operated by the Simplex Wire and Cable company under contract to Bell Telephone Laboratories. Three principal activities were carried on in the operation of this facility. First, the plant produced the cable samples needed for making the mechanical and electrical tests and measurements necessary to verify the design principles and to establish the necessary manufacturing tolerances. In it were produced approximately fifty miles of cable for this purpose. Second, it permitted Laboratories engineers to determine the feasibility of manufacturing the cable to the established tolerances, and finally, it provided a basis for the study of factory layouts adapted to the manufacture of armorless cable. A simplified flow chart of the laboratory appears on page 89.

The laboratory utilized four manufacturing lines to produce the cable. The first line started with steel wire and copper tape and finished with a completed inner conductor containing the internal strength member. The second line applied dielectric material over the inner conductor and the third "sized," or reduced to proper dimension, the dielectric and improved the centering of the inner conductor. The last line applied the outer conductor and polyethylene jacket completing the cable.

A series of operations in the first line formed the inner conductor. Forty-one steel wires, made up of five different diameters, were stranded to make the strength member of the cable, with the largest wire at the center. These forty-one wires reeled off supply bobbins and passed through a plate which established the wire pattern, and then entered a closing die of special design. The die, having a very snug fit and requiring no lubrication, provided the necessary back tension to assure a compact structure.

D. M. Mitchell, Bell Telephone Laboratories engineer, adjusts the cutting blades on the rotary sizing machine in the sizing and centering line.



After the die completed the strength member, copper tape for the inner conductor entered the line. The line could not store sufficient tape for a continuous run of several miles, instead, when needed, an accumulator periodically stored enough tape to allow time to weld on successive quantities of copper without stopping the line. The copper, still in tape form, passed through one cleaning machine to remove any residual oil film and another to remove oxides from its edges. The tape and twisted strand then entered a tube-forming mill, which shaped the flat copper tape around the strand to form an oversize tube. The mill also aligned the tube, so that the seam appeared at the top, while the strand "cradled" on the bottom away from the heat of welding. To insure a stable and long cable life, the seam was butt welded by a welding arc in inert gas. The mill then reduced the copper tube step-by-step until it was a "slip fit" around the strand. A die then compacted the tube on the strand so that a solid composite structure was formed. The speed of the tube forming mill controlled the volume of copper applied. The copper volume per unit length of strand remained constant once the drive motors were electrically coordinated; however, an operator at the line double checked the volume. The last step, a cleaning station located at the end of the line, removed the lubricants and coolants used on the copper during the welding and reducing operations.

The second operating line applied the polyethylene dielectric over the composite inner conductor. Another cleaning machine at the beginning of this line removed any contamination from the inner conductor before an extruder applied the polyethylene. To monitor the extruder output, a gage controlled a servo system to reduce the variations of the dielectric diameter. The gage timed the interruption of a light beam sweeping across the dielectric. This system restricted diameter variations to a few thousandths of an inch, in spite of the large dimension to be controlled and the large volume of dielectric extruded. In addition, a capacitance unbalance gage monitored the centering of the conductor in the polyethylene so an operator could make any necessary corrections manually (RECORD, *May*, 1961). The last step in the line was a water trough which cooled the insulation at a carefully controlled rate to obtain the proper mechanical and dielectric properties. At this point, the over-all diameter of the core was purposely larger than specifications allowed.

The diameter had to be reduced before the last line applied the copper outer conductor.

The third or sizing line reduced the core to the proper diameter. The oversize core entered the line where cutting blades rotated around it similar in operation to a pencil sharpener, removing excess dielectric and reducing any eccentricity of the core. Capacitance probes detected the eccentricity independently in the vertical and horizontal planes, and produced signals which controlled servo motors attached to the input guides of the rotary cutting machine. The sizing line served another important function by removing imperfections from the surface of the dielectric caused by cooling shock, contamination picked up while the surface was hot, water markings, and flat sides or scratches from brushing against the cooling trough.

Fourth and Final Line

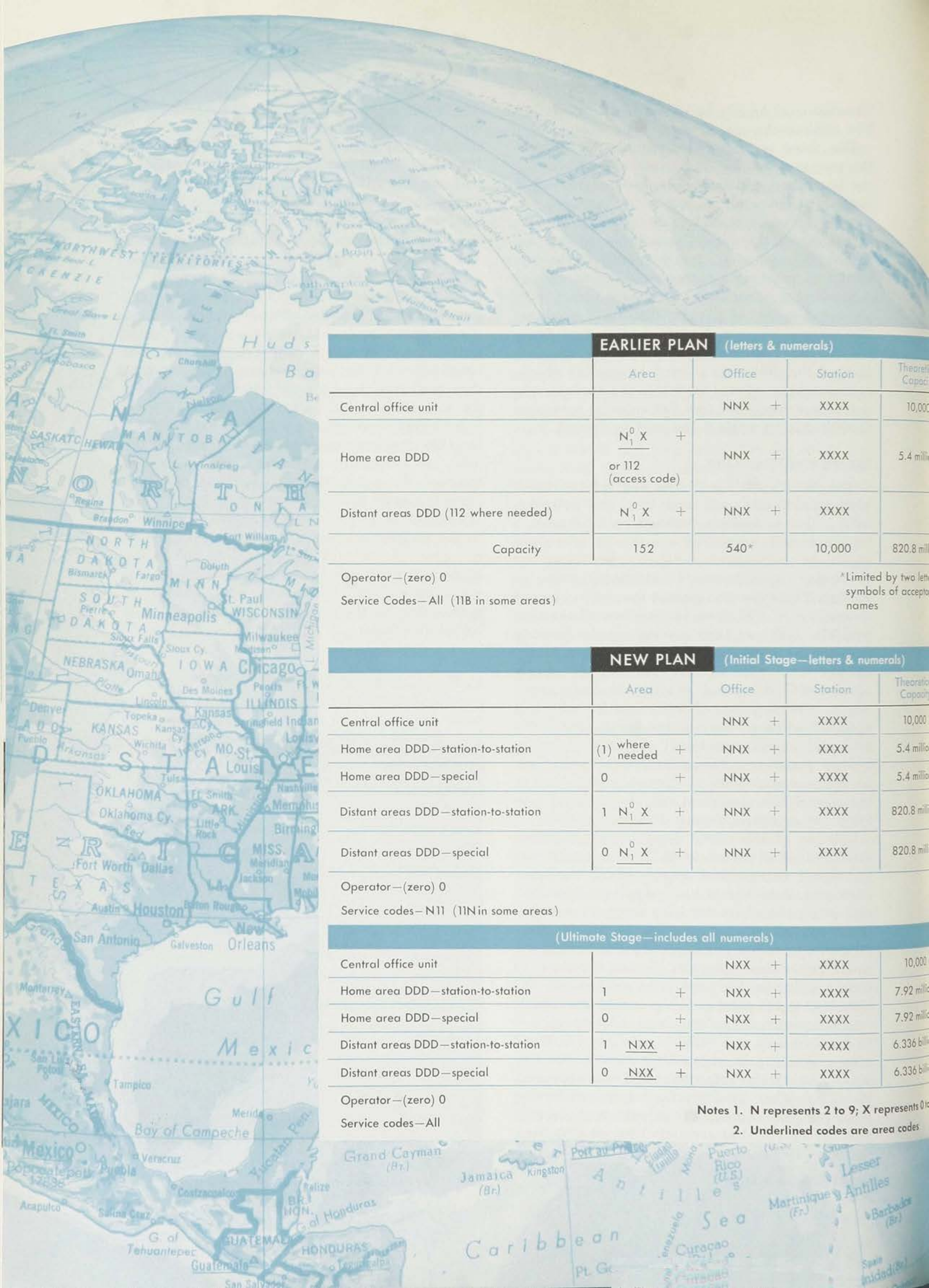
The fourth and final line applied the outer conductor to the core and then the polyethylene jacket to make a finished cable. Again, a tape accumulator stored a quantity of copper tape used as the outer conductor, providing the necessary time to weld additional tape as needed. This tape also passed through a cleaner to remove oil film from the surface of the copper. The core and tape entered a tube forming mill similar to the one used for the inner conductor. The mill formed the copper snugly around the core and overlapped the copper edges. The last set of rolls in the mill had special tooling to depress the lap seam so that it would exhibit electrical stability at ocean bottom pressures. The polyethylene jacket extruder was essentially the same as that used in the second line, and used the same type of controls for eccentricity and diameter control.

Typical of the many development problems investigated at the ocean cable laboratory, was the repair of imperfect seam welds in the inner conductor. A new weld could repair an imperfection while the conductor tube was still oversize, thereby preventing heat damage to the steel strand. Under normal operating conditions, approximately thirty seconds elapsed between the time a point on the seam was welded and the time that point entered the reducing process. It was necessary, therefore, to develop equipment to continuously and reliably scan the seam and give a warning in ample time to stop the line when one of the infrequent defects appeared. However, when an imperfection occured after reducing the copper, the repair was delayed until after the dielectric coating was applied. An operator then cut out the damaged portion removing approximately 3 inches of the dielectric and copper tape from each end of the core. He would then clean the steel wires, coat them with an abrasive powder and place a copper plated steel sleeve overlapping the ends of the conductor. A hydraulic press compressed the sleeve and the operator applied polyethylene over the splice.

The Laboratory had special equipment, located in an air conditioned room, for measuring the electrical characteristics of the cable. An insulated tank outside the room contained water to chill the cable to 3°C. which approximates the temperature at the ocean bottom. The equipment then measured the cable characteristics to insure the desired electrical performance.

Although more than a year has passed since the last significant amount of cable came off the lines, the laboratory continues to serve a useful function. It produces small lots of cable to evaluate refinements and improvements in the process. It also serves as a training facility for manufacturing engineers from companies, including Western Electric Company, which will be one of the cable manufacturers. In addition, inspection engineers train at this laboratory since they will be responsible for the quality of the cable produced by all suppliers.

F. Walsh, of Simplex Wire and Cable Company, operates and monitors the electric arc welder as it welds a butt seam in the inner copper conductor.



	EARLIER PLAN (letters & numerals)			
	Area	Office	Station	Theoreti Capaci
Central office unit		NNX +	XXXX	10,000
Home area DDD	$N_1^0 X$ + or 112 (access code)	NNX +	XXXX	5.4 milli
Distant areas DDD (112 where needed)	$N_1^0 X$ +	NNX +	XXXX	
Capacity	152	540*	10,000	820.8 mil

Operator—(zero) 0

Service Codes—All (11B in some areas)

*Limited by two lett symbols of accepta names

	NEW PLAN (Initial Stage—letters & numerals)			
	Area	Office	Station	Theoretic Capacit
Central office unit		NNX +	XXXX	10,000
Home area DDD—station-to-station	(1) where needed +	NNX +	XXXX	5.4 millio
Home area DDD—special	0 +	NNX +	XXXX	5.4 millio
Distant areas DDD—station-to-station	1 $N_1^0 X$ +	NNX +	XXXX	820.8 milli
Distant areas DDD—special	0 $N_1^0 X$ +	NNX +	XXXX	820.8 mill

Operator—(zero) 0

Service codes—N11 (11N in some areas)

	(Ultimate Stage—includes all numerals)			
Central office unit		NXX +	XXXX	10,000
Home area DDD—station-to-station	1 +	NXX +	XXXX	7.92 millio
Home area DDD—special	0 +	NXX +	XXXX	7.92 millio
Distant areas DDD—station-to-station	1 NXX +	NXX +	XXXX	6.336 billi
Distant areas DDD—special	0 NXX +	NXX +	XXXX	6.336 b

Operator—(zero) 0

Service codes—All

Notes 1. N represents 2 to 9; X represents 0 to

2. Underlined codes are area codes

Like the meshing of well-machined gears, the various facets of telephone service should operate with a minimum of friction. Foremost among the lubricants of a smoothly working telephone network is a system that assures compatibility among all switching and transmission elements.

F. J. Singer

Compatibility in Telephone Communications

Modern telephone service has become universally popular, if not indispensable, because it is informal, convenient, of good quality, reasonably priced and extensive in coverage. No other communications service provides all these features and it is unlikely that any ever will. The informality and convenience enable a customer to establish his own connections by dialing and to carry on a two-way conversation with the called party just as if they were together — yet the separation may be many miles.

During its evolution, telephone service has markedly improved in quality. It has also extended to great distances, with costs being held to nominal increases in spite of inflation.

The evolution of telephone service has involved using many new discoveries in science and the application of countless devices and system entities, many the result of ingenious inventions. But perhaps the greatest challenge to the planners and designers of a complex telephone network has been that of integrating the complicated physical entities — the earlier telephone systems — to enable them to work together. Today, thousands of these systems in North America are arranged to operate compatibly, largely on a fully mechanized basis with plans and developments for completion of the mechanization program well advanced. But the challenges continue and the designers are solving new problems to enable further integration of both domestic and international systems leading to a global mechanized communications network.

Instead of waging the battle to eliminate incompatibilities within and between existing networks as improvements are introduced, why not build new communications networks? This might be done in regions of the world where telephone service doesn't exist and, indeed, in local communities where it does. However, even in such places compatibility would sooner or later appear as a problem because of the trend to join all networks to form national, and eventually continental, systems. Obviously, one practicable approach, for political and economic reasons, is to gradually integrate existing national systems into a world-wide telephone network.

During the last three or four decades, isolated telephone networks in North America have been joined mostly by electromechanical and electronic "interpreters." These have permitted diverse transmission, switching and signaling equipment to be the building blocks for a completely mechanized continental telephone service. Such interpreters take the form of equalizers, hybrids, frequency changers, code converters, speed converters, number translators, and memory devices, to name only a few. No attempt will be made to catalog and describe these many ingenious devices, nor to indicate their respective roles in coping with problems of incompatibility. It is sufficient to say that without them modern integrated telephone service would be impossible.

Technical advances in overcoming incompatibilities economically have made it possible for a high percentage of telephone customers on the North American continent to dial directly both their local and toll paid station connections. For example, if Ted Jones and John Smith are located remotely from each other, but both are in areas where the telephone plants have been converted to this service, either party can call the other by direct distance dialing (DDD). Although there are about eighty million telephones and thousands of switching systems spread throughout North America, the required paths are selected and connected within a few seconds — usually in less time than it takes for the called party to answer.

When John dials Ted's number, the code conveys information to direct the hierarchy of switching systems involved in the over-all connection. These work together sequentially through one of a variety of alternate transmission routes until the connection is established between switching centers. The speed of interpretation and action of each switching system need not necessarily be the same as that of any other. All that is required is that the inter-office signaling between respective switching systems be able to handle compatibly the address signals and the network-supervisory and call-progress signals. Assuming operational objectives are met, the quality of Ted and John's speech for the two-way conversation is uniformly good regardless of the variety or type of circuits between the two stations.

Design Problems

Let us now highlight some of the problems challenging the planners and designers who are completing the mechanization of telephone service in North America and anticipating a world-wide mechanized network.

The first problem is that of "address." The numbering plan for the North American telephone network — adopted over 10 years ago and shown on page 92 — has been used sufficiently to demonstrate its basic soundness. This plan assigns each telephone station a 10 decimal-digit number. The first three digits of the number identify the toll area, the next three the central office code within that area, and the last four the station associated with that central office. This gives customers a uniform dialing procedure for both local and DDD calls throughout the continent — 7 digits for his home numbering plan area and 10 digits when the called station is outside his area.

The North American numbering plan gives each telephone a definite "telephone address" to distinguish it from all others. Such a uniform dialing procedure is important for convenience to the customer, and also for machine flexibility and economy in handling traffic.

Arrangement of keys and adjunct equipment at a Traffic Service Position. This "cordless-call" switchboard will be associated with common control switching systems, and will enable operators to assist customers when they dial special service calls.

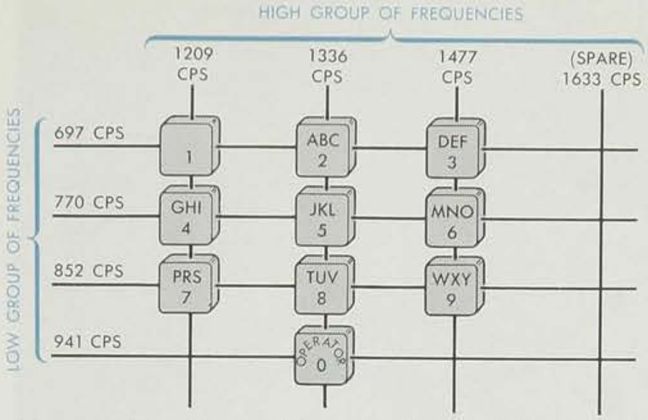
Applying the uniform dialing plan has necessitated modifying the older forms of mechanized switching systems. Adequate logic, memory, and control functions have been added to many of them to permit each to operate with all the others as well as with different transmission systems over direct or alternate routes.

The North American numbering plan was designed to be large enough for many decades. However, the telephone system has grown beyond expectations so that the present plan will probably reach its capacity in ten to twenty years. It is also now clear that additional numerical "space" will be needed for personal radio signaling, mobile and airborne telephones, direct in-dialing to Private Branch Exchange (PBX) extensions, and dialing of calls involving data and other communication services. In addition, direct distance dialing around the world will require even more numbers.

Recently, a new North American plan has been devised to anticipate the expanded requirements well into the next century, also shown on page 96. This plan will permit orderly transition from the earlier plan with minimum expense and confusion. Like the earlier plan, it maintains the decimal system of numbering for compatibilty reasons and provides a distinctive telephone address for each station. It has a theoretical capacity of 800 area codes, 792 central office codes per area and, 10,000 main stations per central office. This results in a total of 6,336,000,000 main-station addresses — a number substantially in excess of the present world population.

Additional features are all numeral dialing and the use of "access" codes. These codes include "1" for paid station toll calls, and "1" as a prefix of all calls (whether toll or local) in which the area code is to be dialed. The access code "0" (zero) remains for customer-dialed "special" calls, such as person-to-person, on which operator assistance is required to complete the call.

A second general problem in building a fully mechanized network of world telephones involves switching. Compatible switching arrangements are now available in most of the North American network that permit a larger degree of DDD service at low cost. New switching systems and compatible building block improvements to existing systems have made this form of service possible even for some types of PBX's. Compatible and economical switching arrangements will also soon become available to sparsely settled and, in some cases, isolated communities still being served by either manual or community dial offices. And, arrangements are under development to extend



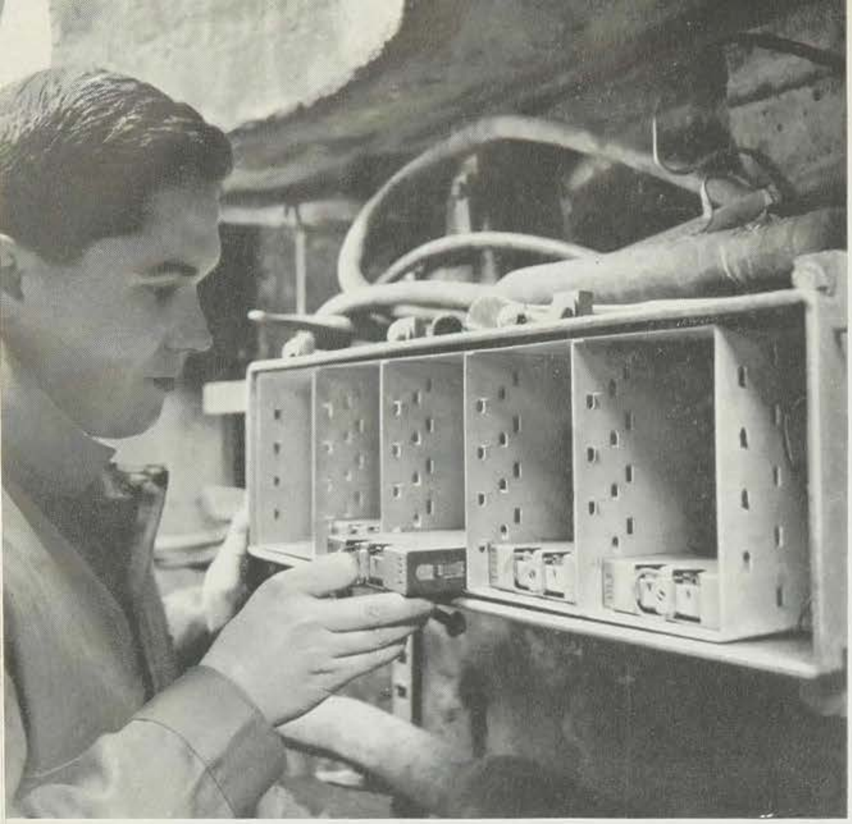
The combinations of frequencies used in present arrangement of TOUCH-TONE Calling "dial."

DDD service to coin telephone stations.

As universal distance dialing extends to include practically all telephone stations in North America, customer demand for person-to-person service will probably diminish. There will, however, continue to be a need for this service, and for some type of credit-card service. Still other customers will occasionally wish to have call charges reversed.

To enable a customer to obtain operator assistance in connection with these and other special service calls he will dial the code "0" (zero) rather than "1" before dialing the called station number. The switching machine will thus call an operator into the connection as soon as the dialing is completed. After determining the class of service the customer requests, the operator will control the completion of the connection by operating the proper control keys to enable the switching system to complete its functions. The "cordless call" switchboard arrangement to be used for this purpose is designated a "Traffic Service Position." It consists of a number of two-position consoles. The arrangement of keys and related arrangements used to handle traffic are shown on the opposite page.

Today's switching systems need other improvements to enhance their capabilities for handling a variety of other types of customer-dialed telephone calls and calls involving other communication services. Planning and design work is now under way on compatible ways to add these additional features. Included are four-wire switching in local plant and ways to route a "class-of-service" indication over the distant plant as a connection is being established (RECORD, *January*, 1962). This feature provides various needed switching system control functions, such as enabling each switching machine to select the proper type of transmission circuit to the next switching center



M. S. Coldenhoff installs transistorized repeaters on pulse code modulators in a manhole in Newark, N. J. Route of trial of short-haul carrier system called T-1, runs to Passaic, N. J. The new system uses time-division modulation techniques.

consistent with the particular class of communication being served.

If these fully mechanized services are to be integrated with others outside North America, new compatibility problems will need to be solved and applied. At least some of the switching systems in foreign networks will need to have class-of-service indications, with ways to pass this information forward at the proper time. They must also be able to store dialed digits, translate and convert dialed codes, add or delete digits, and provide automatic alternate routing of calls in transit. If these ingredients are added, the foreign networks will contain the essential features for universal DDD service. Fortunately, experience gained in converting the North American network to its present status indicates that these technical problems can be solved economically.

Long Distance Circuits

Long-distance transmission circuits in North America are derived by subdividing a cable, radio relay or open-wire carrier system by frequency division. They use "four-wire" operation — two independent channels, one for each direction of information transfer. These systems, with their inherent flexibility in furnishing various bandwidths of communication channels, pose few problems of incompatibility.

Two-wire voice frequency cable and open-wire circuits will also continue to be used for some time, for customer-dialed connections over short distances. They are susceptible to "echo" effects which degrade voice transmission and make them intolerable for some forms of digitalized transmission. To cope with this problem, four-wire transmission circuits may be provided in exchange plant by using either voice-cable facilities, or short-haul carrier systems using frequency division. Time-division systems are also being introduced in exchange cables. Repeaters of such a system located in a man-hole are shown at left.

Available overseas transmission systems will have to be augmented by reliable and economical transmission systems with large capacity. The rapid advances made recently in the technology of satellites and air-borne repeaters offer promise of the much needed large capacity. Meanwhile, the very reliable repeatered submarine cables provide excellent media. High-frequency radio systems are also available, but are too unreliable for customer-dialed telephone traffic.

There are three general types of signals required for customer dialing over long distances, including signals for called-station address; supervisory and control; and call-progress.

The first of these — the address signal — originates at the calling customer's station and is transmitted to the associated central office where the call originates. As the connection progresses through the switching systems, each one in turn transmits all or part of this address. The speed, code format, and information content need not be like the original signal as long as the signaling language remains compatible between switching centers.

A new form of station-address signal known as TOUCH-TONE Calling has high speed and other service advantages compared to the dial-generated signal. TOUCH-TONE signals, in contrast to direct-current signals generated by a dial, are alternating current pulses that can pass over any voice-frequency transmission circuit. As indicated on page 95, the signaling combinations of this system provide a maximum of 16 codes, ten of which replace the ten digital signals generated by the present dial. Six additional codes are available for other signaling purposes.

A further use of TOUCH-TONE calling is in the "Card Dialer" set shown on the next page. A cus-

TOUCH-TONE Calling may be extended to Card Dialer set where customer uses pre-coded cards in mechanism that will automatically dial frequently called numbers. This and similar sets make it possible to send data over established connections.

tomer selects a coded card from his file and inserts it into the dialer which sends the pre-coded address number to the central office. Other sets of this type using TOUCH-TONE signals are being designed to enable data and other communications to be transmitted over established connections. Some of these sets will be equipped to send as many as thirty-two codes in various combinations. For these additional codes the data set will generate additional frequencies.

A variety of supervisory and control signals, making up the second type, are involved in a customer distance-dialing network. Some of these are used internally within a particular switching or transmission system. Such signals do not pose problems of network compatibility. However, other supervisory and control signals required to integrate the switching systems into the complete network do pose problems. For example, signals are passed between switching systems over trunks (or common data links) to coordinate the joint action of the switching systems while the connection is being established or released. These must be compatible.

Call-progress signals — the third general type — are necessary to tell the calling customer (or data machine) and the switching system involved the status of a connection while it is being established. Typical call-progress signals would be "ready to dial," "ring-back," "busy," "no circuit," "dialing error," "no such number." Ideally all these signals should be uniform throughout the dialing network, although compromises can be made. The signals must, however, be recognized by switching centers, by customers, and by unattended station instruments. If they are not recognizable, they may need to be regenerated or even translated.

Other Services

The advantages to customers of a reliable continental network available for telephone DDD have led to a demand for a similar service to handle various forms of data communications. With few exceptions, the transmission, signaling and common-control switching systems have the basic capabilities to permit the network to handle this form of service. In fact, incompatibility problems have already been solved to enable certain forms of DATAPHONE service to be offered over the present telephone network.

Soon to be integrated into the telephone network to handle its part of customer-dialed voice and data traffic are the electronic central office (ECO) and electronic PBX (EPBX) systems. These new systems will operate compatibly with the rest of the telephone plant, including existing electromechanical switching systems. They will have the added advantage of completing any switching operation at high speeds — a desirable attribute particularly in handling short data communications. Through program control, rather than wiring changes, the computer-type central control of these systems will also enable a large variety of new customer services to be offered.

As we view the future there is a need for a universal telephone service that is flexible and fully-mechanized. We also see the demand for a correspondingly flexible data communication service impelled by the growth of automation and the needs of business and government enterprises for data communications. Experience with the growth and universal acceptance of telephone service leads us to conclude that remaining technical compatibility problems can be solved to meet new service requirements. This will further improve the present extensive universal telephone network in North America and enhance its value as it is joined to mechanized telephone networks of other continents.

TELSTAR-Satellite Tests

Telstar, the Bell System's experimental communications satellite, is now being painstakingly assembled in a super-clean room at Bell Laboratories, Hillside, N. J., location, to assure the greatest working reliability in space. Laboratories engineers are, in fact, busy assembling not just one but four flyable 34-inch spheres, any one of which might go into orbit. After the spheres have been given rigorous tests, two of them will be taken to Cape Canaveral, while the other two will be retained as backups.

Late this spring, one is scheduled to be placed atop a Delta rocket and launched by the National Aeronautics and Space Administration, with the costs to be paid by the Bell System. The experiment will test reliability of equipment on board the satellite, evaluate equipment and operating techniques at ground stations, and provide a thorough measurement of Van Allen belt radiation. It will also be a step toward the eventual goal of achieving continuous broadband communications across oceans by way of microwave radio.

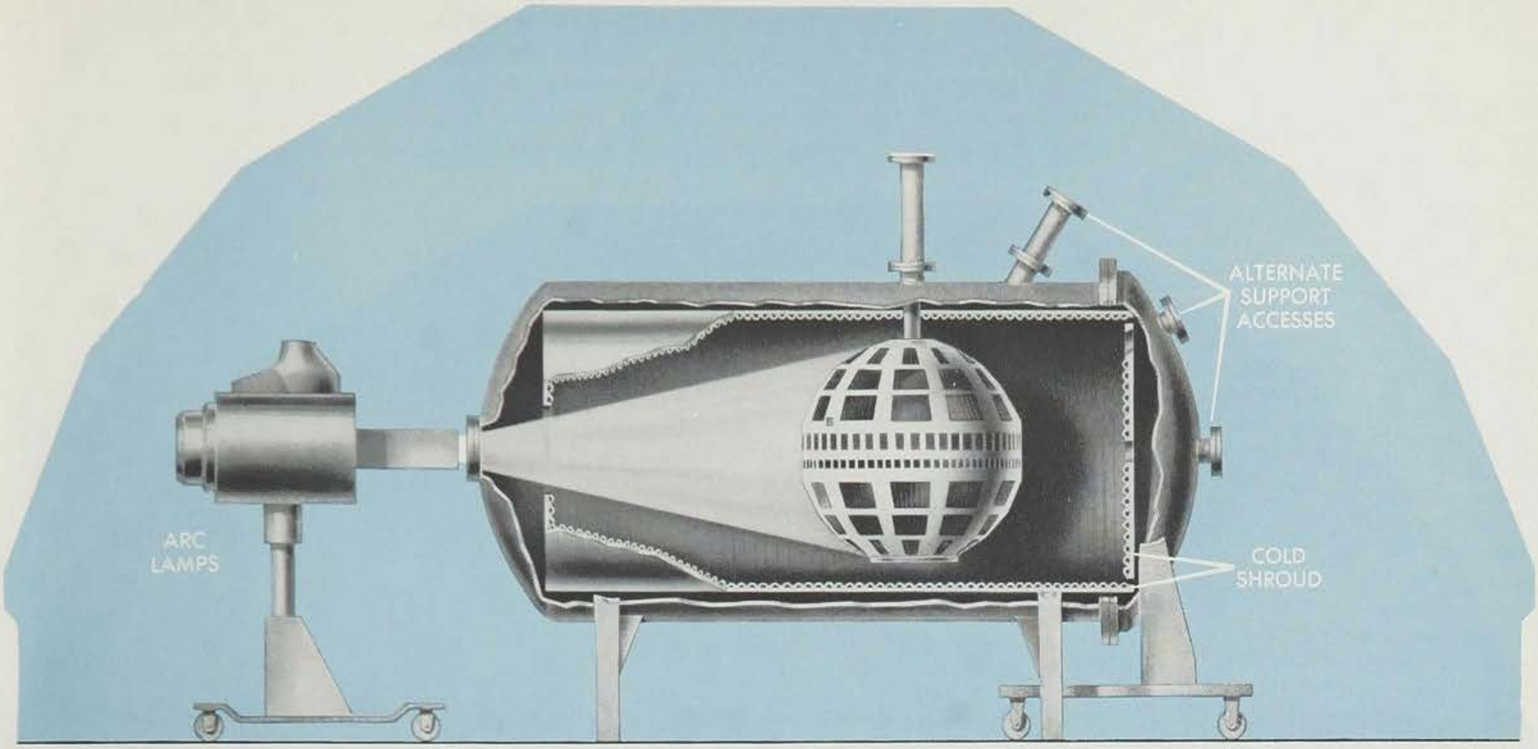
In the Telstar experiments, a signal will be beamed to the satellite from the Bell System's ground station at Andover, Me. The satellite will pick up this signal, amplify it, shift the frequency, and retransmit it back to a ground station in a "line of sight" from the satellite. In these tests, the Andover station will both transmit and receive the signal simultaneously. In addition, a Bell Laboratories ground station at Holmdel, N. J., will be equipped to pick up the signal as retransmitted from the satellite.

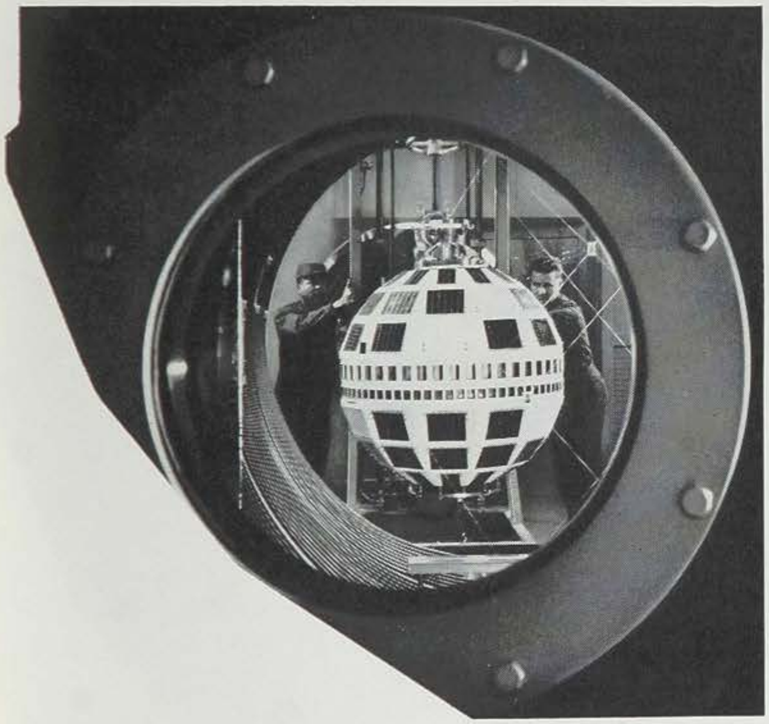
To achieve the greatest reliability, each tiny component, about 15,000 in each satellite, is selected from many others, and tested several times. Each subassembly is carefully tested and then molded into a block of foamed polyurethane. Finally, the entire electronic section of the satellite is sealed with the same plastic foam to provide a supporting structure which is highly immune to the effects of shock and vibration at launch.

As construction of the various Telstar satellites progresses, the pace of testing and evaluation also increases. Tests must be made to check the performance of groupings of components and subassemblies, as well as the effect of vibration, solar radiation, shock and rotation on the completed satellite itself. All these tests involve units of considerable size; thus, the test facilities themselves must be of considerable complexity.

Shown on the next several pages are photographs of typical activities involving the satellite framework and repeater. They are representative of the large-scale testing and evaluation now being conducted at many locations of Bell Laboratories, in preparation for the launching of the Bell System's experimental active satellite.

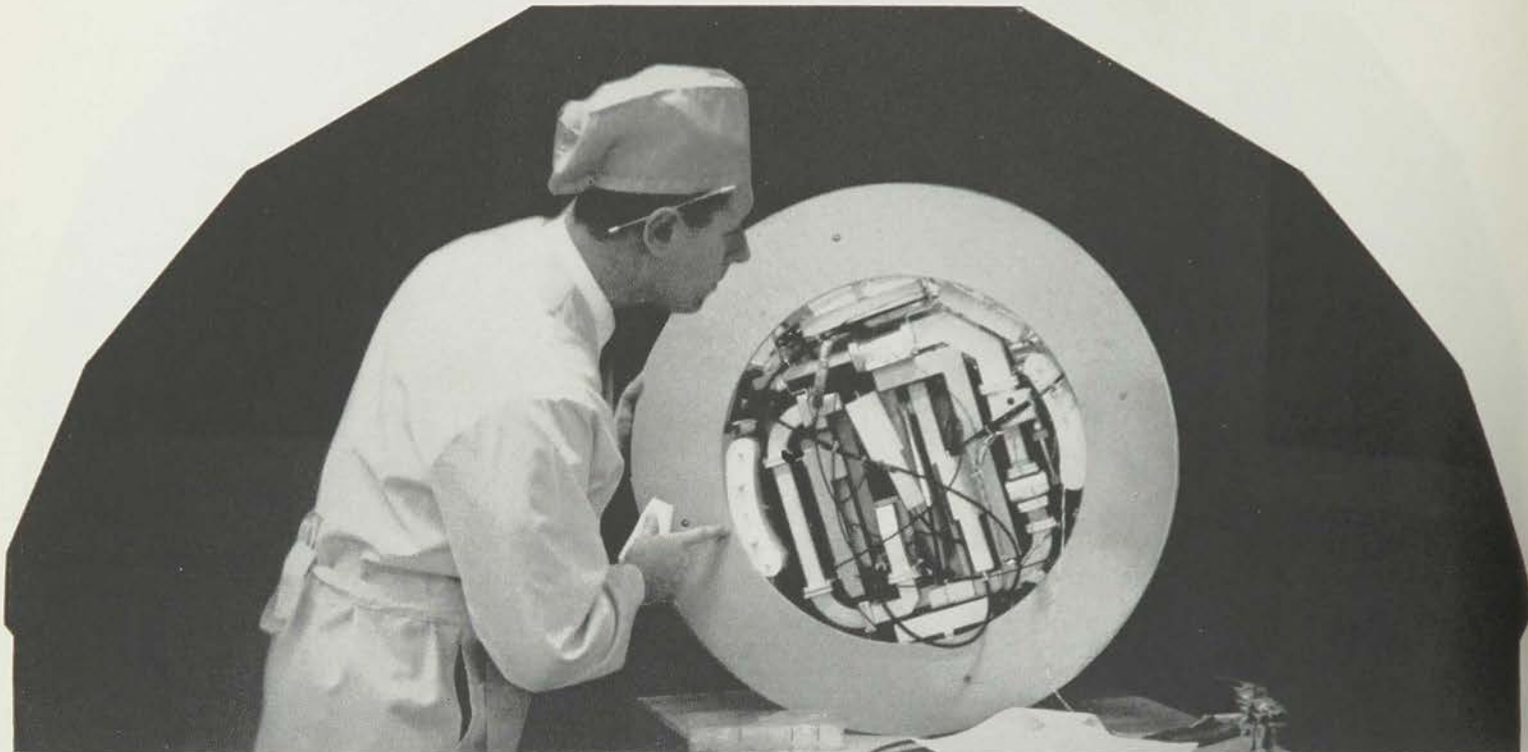
(Photos in the January issue of the RECORD showed typical scenes of component testing and evaluation in the Telstar research and development program.)

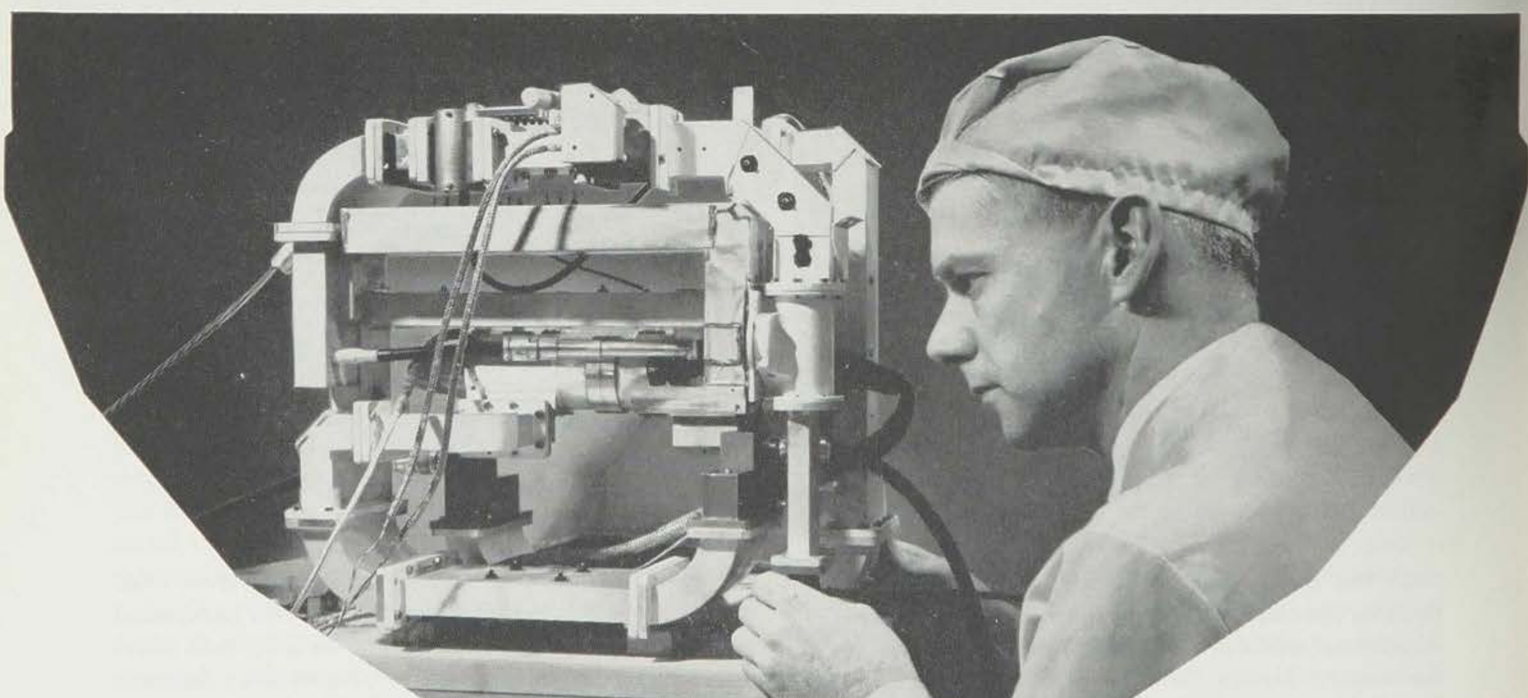




(Top) The space-simulation facility at Whippany, N. J., furnishes information on the thermal balance of a satellite exposed to simulated solar radiation. The drawing shows the essential features: A vacuum system capable of producing pressures of 3×10^{-7} mm mercury, a liquid nitrogen shroud to give a space-like temperature of -300 degrees F, and three carbon arc lamps, each producing 340 watts radiation, to simulate the sun's energy which will fall on the satellite at 130 watts per square foot. *(Lower Right)* John Munro, Whippany, inspects connecting wires to the satellite which will feed out information on the temperature when the satellite is exposed to solar radiation. In the background is the "blackbird," a black-painted satellite shell which serves as a black-body reference for controlling radiation intensity. *(Lower Left)* Seen through the viewing port, the satellite is pushed into space within the chamber. The fine silk threads in the foreground support special solar cells used for monitoring solar radiation during the tests. The corrugations on the inside wall are the tubes in the cold shroud through which liquid nitrogen circulates for cooling.

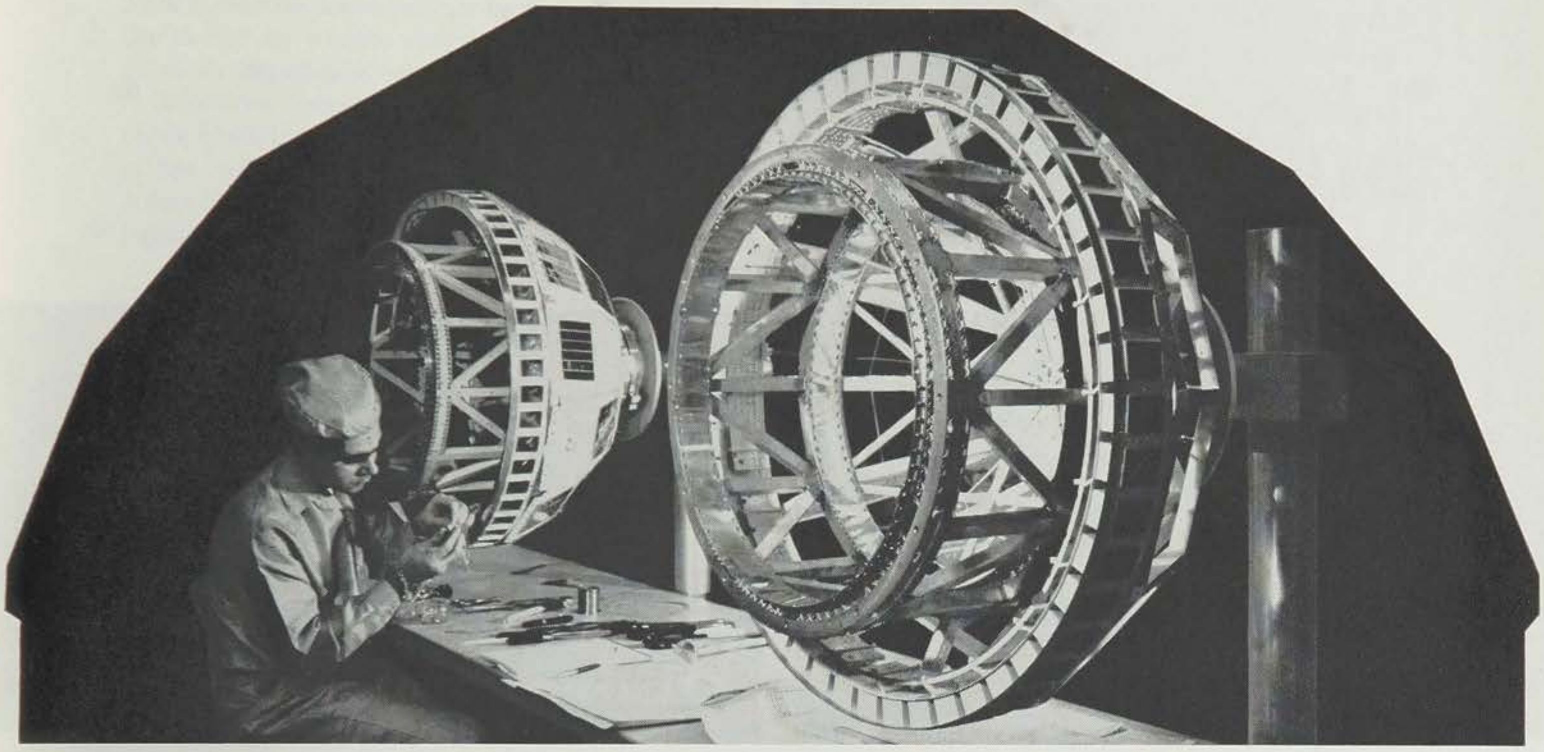
Bill Schober, Hillside, assembles a one-to-one wooden mockup of the "electronic package." With this mockup, methods were evolved for wiring and assembling subassemblies into large groups before they are fitted into the final canister before sealing and mounting in the satellite.





Here, Ian Maunsell adjusts waveguide connectors during the assembly of the "electronic package," the unit which contains the satellite repeater, including the traveling-wave tube, associated waveguide, intermediate frequency amplifier, and the command and telemetering equipment. After wiring is completed, domes will be automatically arc welded onto each end, and the entire canister will be slipped into place in the electrical development model.

At the Hillside location of Bell Laboratories, Sal Farino attaches a connector to a cable in the electrical development model of the Telstar active satellite as it nears completion. In the foreground is the mechanical development model, the last model to be built before the final prototype.



At Whippany, an assembled satellite model is mounted on the test fixture at the end of a 36-foot centrifuge. One of the more severe tests of the "bird," forces equivalent to 25 G's are developed on the satellite's internal assemblies.

John Kossyk conducts a dynamic balance check at Murray Hill on the framework of the first model of the satellite in its final design configuration. The actual active satellite will be balanced after assembly, so that it can be spin-stabilized.

K. M. Eisele makes final adjustments to new low-noise parametric amplifier before it is sealed in a metal cavity and immersed in liquid nitrogen. Cooling arrangement provides even cooling and adds to stability of operation. The non-degenerate amplifier has a noise figure of about 0.9 db.

New Low-Noise Parametric Amplifie Operates at 6 kmc

Last month, Michiyuki Uenohara, Electron Device Laboratory, announced the development of a microwave amplifier with the lowest noise performance ever achieved for its kind in a paper presented to the International Solid-State Circuits Conference in Philadelphia. Using a newly designed tuning cavity and an improved semiconductor diode as the amplifying medium, Laboratories scientists have built a non-degenerate parametric amplifier with an over-all system noise temperature of 60 degrees K at 6 kmc, corresponding to a noise figure of about 0.9 db. Thus it contributes only about 20 per cent to the degradation of the signal-to-noise ratio.

The new amplifier is being modified to serve as a reserve amplifier in the receiving antenna at Andover, Me., which will be used in the Bell System's experiment for satellite communications.

Parametric amplifiers fill a need in the communications field for devices which are simpler to construct than microwave masers and which do not require the very low noise figures that masers provide. In the parametric devices, amplification occurs when their capacitance is varied electronically at a high frequency. This frequency, called the "pump" frequency, is generally at least twice that of the incoming signal which is to be amplified. The operation involves a variable-capacitance semiconductor in a waveguide cavity which includes circuitry to handle the incoming signal, the pumping power and the amplified outgoing signal (RECORD, *October*, 1959).

Parametric amplifiers amplify both a signal and and an "image" of the signal, which appears at a frequency equal to the difference between the pump frequency and signal frequency. The image signal, an inevitable byproduct of parametric amplification, cannot be suppressed without also suppressing signal amplification. Therefore, the amplifier circuit must sustain three frequencies—signal, image, and pump—and meet all necessary circuit conditions at these frequencies.

In "non-degenerate" devices such as the one discussed by Mr. Uenohara, the image frequency must be several times higher than the signal frequency to obtain good noise performance. The amplifier circuit must thus be designed for three widely spread frequencies — relatively easy in devices operating at room temperature. However, to achieve the desired low-noise figure, the new amplifier needed the environment of liquid nitrogen, 77 degrees K. Low temperature operation complicated the design of a circuit, primarily because the impedance of the semiconductor diode changes as its temperature is lowered.

To compensate for impedance changes in the diode, the parametric amplifier uses a fluoroplastic wafer in the cavity as a tuning element. This dielectric material can be moved in or out of the cavity by remote control, offsetting the variation in impedance caused by the diode.

Improved characteristics in the semiconductor diode contribute to the improvement in the amplifier performance. N. C. Vanderwal of the Allentown, Pa., laboratories has developed a hermetically-sealed gallium arsenide diode with improved reliability and stability. New techniques have made possible a reduction in the temperature coefficient of the diode's junction impedance.

Another contributor to the improved performance of this parametric amplifier is a new cooling arrangement designed by K. M. Eisele, also of the Electron Device Laboratory. In a radically different dewar arrangement, the amplifier is contained in a metal cavity sealed by indium wire and immersed in liquid nitrogen. The liquid nitrogen cannot leak into the device and cooling is more even. Thermal leakage is so low that the amplifier can operate for as long as ten days without having additional liquid nitrogen added.

A.T.&T. Annual Report Cites Bell System Growth

News of the Bell System

A record construction program and a wide range of service improvements and technical advances helped make 1961 a year of substantial growth for the Bell System, A.T.&T. said in its annual report released last month. The Bell System spent $2.7 billion on construction in 1961. In the report, which went to some 2,050,000 share owners, F. R. Kappel, Chairman of the Board, "We have made improvements in service. Technical advances have continued to increase the efficiency, versatility and reliability of Bell System plant, both for everyday use and in readiness for emergency."

The report pointed to the Bell System's work in satellite communications as illustrative of part of its progress during the year. Under agreement between A.T.&T. and the NASA, launching of the first of the Bell System's "Telstar" experimental satellites is scheduled for this spring. In addition, A.T.&T. has continued building ocean cable systems. A link between the United States and Bermuda has just been completed. Late in 1962, a cable linking Florida and Jamaica will be laid. A third transatlantic cable, and cables to South America and Japan, will follow in 1963 and 1964.

Mr. Kappel called the Bell System "a growing business" and said it is "based on continuous technical innovation and improvement. "Further, our business requires big investment for the long run, and not infrequently (as in the case of satellites) some years may pass before the investment will produce a profit." Mr. Kappel said, "This emphasizes the importance of regulatory commissions allowing over-all earnings that create financial strength and encourage look-ahead action."

There was a gain of nearly 2,450,000 Bell telephones in 1961, bringing the year-end total to 63,177,957. Long distance conversations rose five per cent; overseas conversations increased 18 per cent. Direct Distance Dialing was extended to nearly two-thirds of Bell System customers.

National defense continued to be a major concern in 1961. The report said a vital part of the Bell System's job is "to exercise imagination in anticipating changing defense needs and in developing facilities and methods to meet them."

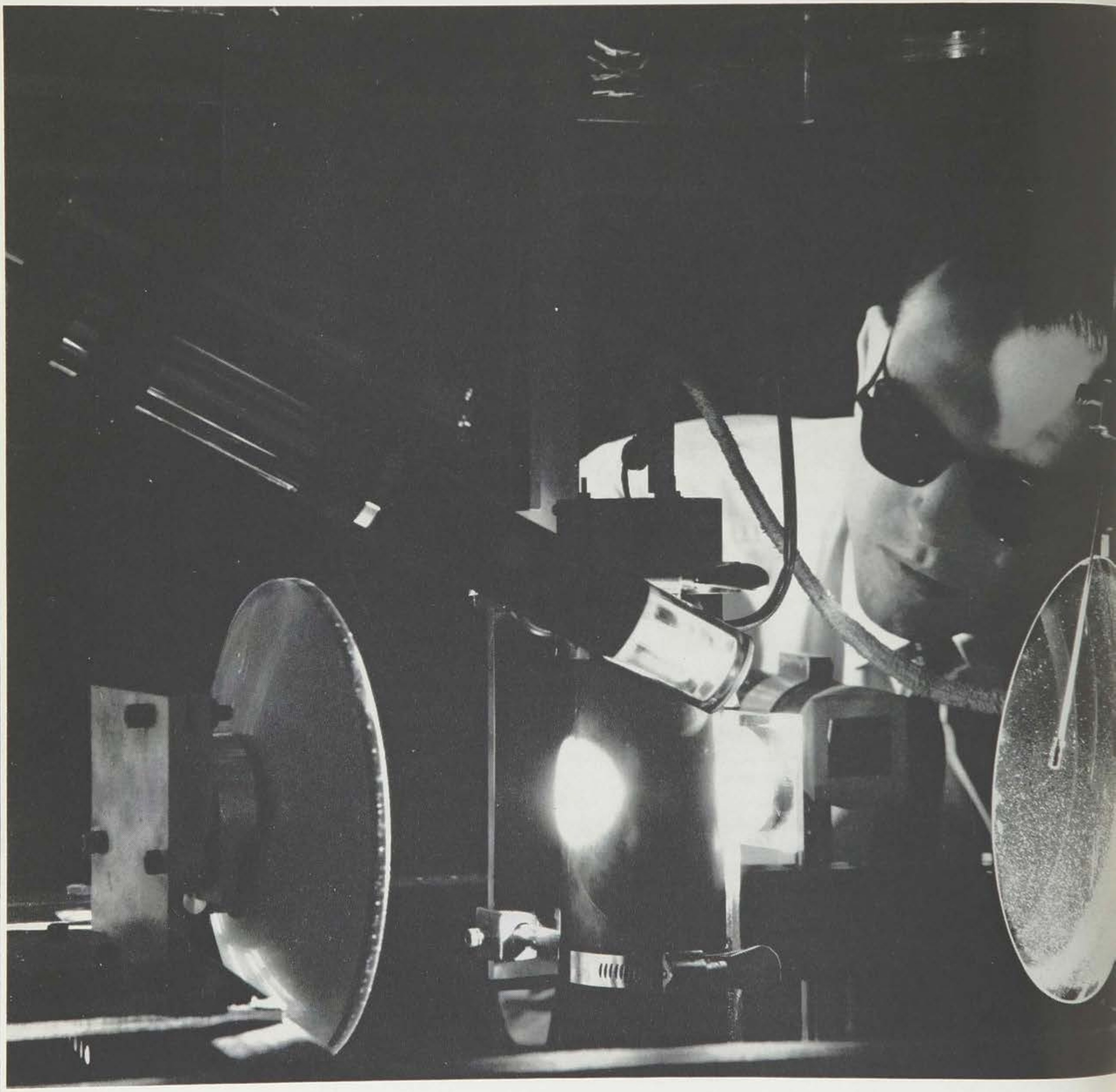
The Long Lines Department continued a blast resistant, transcontinental buried cable system. The completed system will run more than 3,700 miles. The entire system, including 959 amplifier stations and nine buildings connect with other communications routes, will be underground.

Western Electric and the Bell Laboratories worked together on development of the Army's Nike Zeus anti-missile missile system which was successfully tested in 1961 in preparation for full-scale tests this year.

The Bell Laboratories announced development of the first "solid state" optical maser that can produce continuous beams of pure light. Research on super-conducting materials opened the way to creating more powerful magnetic fields than were practically possible before. These developments are expected to have a great impact on the development of nuclear energy, and on the future of communications.

Continuous Operati

D. F. Nelson with new maser. Light is reflected between concave spherical mirrors and into face of maser crystal.



chieved in Ruby Optical Maser

A ruby optical maser emitting a coherent red beam has operated continuously at Bell Telephone Laboratories. It is the first solid-state optical maser to emit continuous coherent visible light. This advance has been made possible by development of a radically new way to excite the maser crystal which gives a "pumping" intensity five times greater than has been possible from previous continuous optical maser pumps.

News of Solid-State Research

The new technique was described at a meeting of the American Physical Society in January by Willard S. Boyle and Donald F. Nelson of the Solid-State Electronics Research Laboratory. Besides proving that a ruby optical maser can operate continuously, the configuration provides a convenient geometry for conducting a number of physical experiments. The pumping technique will apply to masers using materials other than ruby. This new development is another step towards communications over optical carrier waves.

It has been only a little over a year since the first solid-state optical maser was made to operate on a pulsed basis. That device contained a ruby rod, with highly reflective ends, surrounded by a spiral flash lamp. The discharging lamp caused a beam of coherent, monochromatic light to emerge from the ends of the rod in an extremely narrow cone. Similar configurations using other maser materials have since resulted in a number of pulse-operated, solid-state masers. Recently, Bell Laboratories announced continuous operation of a maser at infrared frequencies in a crystal of calcium tungstate containing a small amount of neodymium (RECORD, *February,* 1962).

One of the most significant improvements in solid-state masers is the lowering of the power requirements for the pumping source. Ruby originally needed over a thousand kilowatts for pulsed operation; it now needs less than one kilowatt to operate continuously. In the present ruby maser, action starts when the imput power exceeds 850 watts, giving an output power in the maser beam of a few milliwatts.

For the pumping source the Bell Laboratories scientists used a modified high-pressure mercury arc lamp. Mercury light is rich in the green and violet light necessary for exciting the ruby crystal. The maser is constructed so that the image of the mercury arc is reflected by a concave spherical mirror that is canted to avoid returning the image to its source. To compensate for aberrations, a second concave spherical mirror canted in a plane at ninety degrees to the first, picks up the image and transfers it to the face of the maser crystal. The crystal is located inside a dewar kept at liquid nitrogen temperatures.

The maser material consists of two separate materials grown as a special boule of one crystal. The maser crystal is shaped like a trumpet. Its "front" is pure aluminum oxide (sapphire) in the shape of a cone forming the "bell" of the trumpet. The face of the bell, approximately 60 mils in diameter, receives the pumping arc. The cone portion of the trumpet tapers down to meet a shank of chromium-doped aluminum oxide, or ruby, which has a diameter of approximately 24 mils. It is in this shank that maser action takes place, producing the intense red maser beam.

The image of the arc of the pumping lamp reaches the face of the trumpet at the same size and intensity as the arc itself. The cone of the trumpet acts as a "radiation condenser," making the arc light six times more intense as it enters the shank. The light then travels down the shank by a series of internal reflections. A silver coating at the end of the rod causes the pumping light to return and emerge at the original face. Since the pumping light travels a "double path" its intensity, already increased six times, is doubled, thus making it much greater than that in a conventional maser rod which receives light from the side. The result is a lower required power to the pumping lamp that produces the continuous maser action.

Because the maser rod is not surrounded by the pumping source, it is physically available for a number of experiments. For example, slipping a coaxial magnet over the rod would permit studying the magnetic splitting of emission lines. It may be possible to show changes in the basic frequency of a solid-state maser by applying mechanical stresses. Also, the cause of the "spiking" phenomena associated with solid-state maser action may be uncovered in this apparatus.

Tracking and Communications Network Vital To Glenn's Orbital Flight

America's biggest day in space—last month's three-orbit flight by John Glenn—was made possible by the National Aeronautics and Space Administration industrial team that included Western Electric and Bell Telephone Laboratories. After the successful launching, flight, and recovery of Colonel Glenn, NASA officials reported that "tracking and telemetry were beautiful" and that "plot boards showed the smoothest tracking" of any Project Mercury mission.

The vast 18-station tracking and communications network was built for NASA by five companies which were led by the Western Electric Company. Bell Laboratories served as consultant on all technical phases of the project and was responsible for systems analysis and test planning. In addition, the Laboratories supervised the design of the Mercury Command and Control Center at Cape Canaveral and developed a simulator for training the Mercury flight controllers (RECORD, *October*, 1961).

The tracking and instrumentation system followed Glenn with radar and collected and transmitted telemetry data covering nearly 100 items, including environment in the capsule and the astronaut's physiological condition. This information was funneled into the Goddard Space Flight Center at Greenbelt, Maryland, the computer and communications hub of the entire network. Here high-speed computers and switching equipment organized and relayed this information to the Mercury Control Center.

Cape Canaveral is the focal point for all the information gathered by the stations in the tracking network. Sixteen of the eighteen stations serve as collection points for data on the condition of the astronaut and the capsule. Six of the ground stations are also equipped to control certain flight operations or events within the capsule.

The tracking and information system offers essentially continuous, two-way radio contact with the orbiting capsule; for talking with the astronaut, for receiving telemetry of instrument readings in his spacecraft and for controlling remotely certain flight equipment in the capsule. These radio links use one channel in the HF range between 15 and 30 megacycles and three in the UHF range of 200 to 300 megacycles.

The system also has a world-girdling network of communication circuits for voice, teletype and data transmission between stations. Leased facilities of communications carriers in many lands are used as well as a wide variety of communication techniques. These facilities include land lines, submarine cables, microwave and HF point-to-point radio systems and both wire and radio carrier arrangements.

Extent of Communications Network

Altogether the communication facilities comprise some 35,000 miles of voice channels interconnecting 13 sites; 96,400 circuit miles of teletype channels connecting all sites (this circuit also transmits radar data from 13 sites); and 5,500 circuit miles of high-speed data transmission channels between Canaveral and Goddard Space Flight Center. A significant achievement of the Laboratories engineering effort was the development of a system that handled vast amounts of data, generated at points sometimes separated by the entire world, in essentially "real time"; that is, nearly instantaneously.

The Mercury capsule is tracked by radar for the entire period of *powered* flight and as it passes within range of radars at eleven of the sites. Radar data flows by automatic teletype connection directly into electronic computers at Goddard. The computers maintain a continuous "estimate of present position" of the spacecraft and predict when and where it will arrive for succeeding sites. These "acquisition messages" are originated by the computer and are teletyped automatically to remote sites.

Approximately 37 quantities vital to the success of the mission are derived from the computers and transmitted over high-speed data channels

Friendship 7, the Mercury capsule which carried astronaut John Glenn during this country's first manned orbital flight is lifted to deck of USS Noa during recovery operation. (U. S. Navy photo from UPI)

for display in the control center at Canaveral. The many complex programs that the computer uses to analyze and predict the position and condition of the capsule are selected and controlled automatically by a "monitor," or master program, which maintains order within the computer, recognizes the apparent situation and arranges the computer activities to fit appropriately into the time sequence of the flight.

Control Center Arrangements

The Command and Control Center at Cape Canaveral has 14 control consoles, 37 computer-operated displays, uses four duplex 4-wire voice channels to the network, has six full duplex teletype channels to the network, and displays or records approximately 100 telemetered quantities from the capsule.

A supplementary control center at the Bermuda tracking site can control the capsule's insertion into orbit if the Canaveral control is weak. The Bermuda control center has seven operating consoles, access to four, full-duplex teletype channels, and two channels to the world voice network. It is served by two radars, a computer, telemetry, and command control equipment.

To give the NASA flight controllers the specialized training needed to conduct Mercury missions, Bell Laboratories designed an elaborate training simulator that activates the Goddard computer just as though a real mission were taking place.

From the simulation room, located in another part of the control center building, all displays in the control room can be realistically operated. For example, the displays that would normally be activated by telemetry data can be operated either with tape recordings or by controls on an instructor's panel. The decisions that the flight controllers make during these simulation tests can be realistically followed by appropriate indications from the computer, so that the machines as well as the men can be exercised.

In an actual training exercise, a tape recording of an Atlas launch is played over the connections to Goddard, starting the computers into their launch computations. The computers, in turn, send back their indications to the control center. The flight controllers response to these indications are followed by realistic displays on the various meters and dials on the control consoles and other control displays. This is called "closed-loop" simulation.

To insure reliability in the high-speed data circuits between Canaveral and Goddard, two transmission paths on separate wires are used in each direction. Only one of these paths need operate for reliable transmission. If both the original paths fail, a similar pair of paths are provided by an entirely different route.

In the ground communications network, duplicate communication channels are provided to all critical stations. Alternate routes are provided as standbys in the critical paths. Acquisition messages are transmitted to each site three times, approximately twenty minutes apart, to minimize the possible effects of radio path "drop-outs." These were not the only precautionary measures. In addition, every feasible principle of operational integrity, human factors, and safety was engineered into this pioneer tracking and communication network for America's first experiments in manned space exploration.

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Nelson, L. S., see Kuebler, N. A.

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PATENTS

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

Andrew, H. B., Hipkins, C. C. and Towsley, L. M.—*Magnetic Record Device and Method of Preparing It*—3,016,310.

Backman, G. A. and Ortel, W. C. G. —*Gated Accumulator*—3,018,048.

Borchard, E. H.—*Conector Assembly*—3,016,512.

Courtney-Pratt, J. S.—*Accelerometers*—3,015,959.

Cirone, F. P.—*Sawtooth Oscillator*—3,015,784.

Dehn, J. W. and Vroom, E.—*Magnetic Recording and Analyzing of Traffic Observations*—3,016,-189.

DeLoach, B. C., Jr. and Ring, D. H.—*Microwave Device*—3,016,-499.

Dewald, J. F. and Lander, J. J.—*Signal Translating Device*—3,017,548.

Dreyfuss, H., Hose, R. H. and Illium, H. C., Jr.—*Integrated Voice and Data Telecommunications Desk Stand*—D-192,117.

Dreyfuss, H., Hose, R. H. and Illium, H. G., Jr.—*Integrated Voice and Data Telecommunications Desk Stand*—D-192,118.

Entz, F. S.—*Multiparty Selective Signaling System*—3,016,426.

Friis, H. T. and Unger, H. G.—*Helix Wave Guide*—3,018,452.

Fuller, C. S.—*Method of Forming Semiconductive Bodies*—3,015,-590.

Gilbert, E. N. and Moore, E. F.—*Apparatus for Utilizing Variable Length Alphabetized Codes*—3,016,527.

Goldstein, H. L.—*Alternating Current Voltage Regulator*—3,018,-431.

Harmon, L. D.—*Electrographic Transmitter*—3,016,421.

Hawks, V. J.—*Control Circuits*—3,016,857.

Hewitt, W. H., Jr.—*Slotted Waveguide Antenna*—3,016,535.

Hipkins, C. C., see Andrew, H. B.

Hose, R. H., see Dreyfuss, H.

Hose, R. H., see Dreyfuss, H.

Ilgenfritz, L. M., Moore, H. R., and Robertson, D. D.—*Apparatus for Field Testing Signal Guided Bodies*—3,016,514.

Illium, H. C., Jr., see Dreyfuss, H.

Illium, H. C., Jr., see Dreyfuss, H.

Kamentsky, L. A.—*Character Recognition System*—3,018,471.

Kammerer, F. W., Riesz, R. P. and Wallace, R. L., Jr.—*Signal Translating Device*—3,015,738.

Klingenberg, A. S.—*Swaging Tool*—3,016,083.

Kostelnick, J. J.—*Microwave Selective Mode Isolator*—3,017,577.

Kostelnick, J. J.—*Non-reciprocal Electromagnetic Device*—3,016,-497.

Krause, J. T.—*Vapor Deposition Apparatus*—3,017,851.

Lander, J. J., see Dewald, J .F.

Lundry, W. R.—*Equalizer*—3,-017,578.

Lundry, W. R.—*Wave Transmission Network*—3,017,584.

Mallery, P.—*Arithmetic Carry Generator*—3,016,196.

Mann, H.—*Conversion Between Analog and Digital Information on a Piecewise-Linear Basis*—3,015,815.

Mason, W. P.—*Combined Memory Storage and Switching Arrangements*—3,015,708.

McGuigan, J. H.—*Magnetic Core Memory Matrix*—3,016,521.

Middaugh, J. K.—*Automatic Traffic Sampler and Recorder*—3,018,334.

Moore, E. F., see Gilbert, E. N.

Moore, H. R., see Ilgenfritz, L. M.

Moraff, H.—*Transistor Monostable Circuit*—3,016,468.

Muller, D. E.—*Asynchronous Encoder*—3.017,626.

PATENTS (CONTINUED)

Myers, P. B.—*Magnetic Memory Matrix*—3,015,809.

Ortel, W. C. G., see Backman, G. A.

Perreault, G. E.—*Relay*—3,015,-707.

Pierce, J. R.—*Helix Wave Guide*—3,016,503.

Pollard, C. E., Jr.—*Means for Preventing Contact Sticking in Mercury Contact Switches*—3,018,354.

Riesz, R. P., see Kammerer, F. W.

Ring, D. H., see DeLoach, B. C., Jr.

Robertson, D. D., see Ilgenfritz, L. M.

Rongved, L.—*High Pressure Seals for Lead-In Conductors*—3,017,-452.

Saltzberg, B. R.—*Redundant Logic Circuitry*—3,016,517.

Schelleng, J. C.—*Phase Stabilization of Circuits which Employ a Heterodyne Method*—3,019,-296.

Schneider, H. A.—*Digital Data Generator Circuits for Computer Testing*—3,015,444.

Schwenzfeger, E. E.—*Ferroelectric Translator*—3,016,425.

Schwenzfeger, E. E.—*Selection Circuit*—3,019,293.

Thurber, E. A.—*Method of Fabricating Cathode for Electron Discharge Devices*—3,015,560.

Tien, P. K.—*Magnetostatic Microwave Devices*—3,016,495.

Towsley, L. M., see Andrew, H. B.

Ulrich, W.—*Digital Error Correcting Systems*—3,017,091.

Unger, H. G.—*Suprious Mode Suppressing Wave Guide*—3,016,-502.

Unger, H. G., see Friis, H. T.

VanDine, G. A.—*Shift Register*—3,016,470.

Villars, C. P.—*Nonlinear Conversion Between Analog and Digital Signals by a Piecewise-Linear Process*—3,016,528.

Vroom, E., see Dehn, J. W.

Wallace, R. L., Jr., see Kammerer, F. W.

TALKS

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

Benes, V. E., *Maximum Likelihood Estimates of Fluctuations of Traffic Intensity,* Columbia Univ., N.Y.C.

Bennett, W. R., Jr., *Recent Experiments with Helium-Neon Optical Masers,* Yale Univ., New Haven, Conn.; Acad. Sc., N.Y.C.

Black, H. S., *World Wide Communications Via Satellite Relays in Space,* AIEE, ISA, IRE and ASME Meetings, Cleveland, Ohio

Bogert, B. P., *Techniques for Digital Processing of Seismic Data,* Colloq. Detection of Underground Nuclear Explosions, Pasadena, Calif.

Boyd, G. D., see Johnson, L. F.

Branower, Miss M. R., *Analog Simulation of a System: Pulse Timing in a PCM System,* Eastern Simulation Council, Murray Hill, N. J.

Buchsbaum, S. J., *Electron and Ion Resonance in a Plasma in a Magnetic Field,* Univ. of Pittsburgh, Pittsburgh, Pa.; Case Insti. of Tech., Cleveland, Ohio

Burbank, R. D., *A Redetermination of the Orthorhombic IF_7 Structure,* Brooklyn Poly. Insti., Brooklyn, N. Y.

Chernak, J., *An Analog Computer Technique that Determines the Wide-band Equivalent Circuit of the 2105 Transistor,* Eastern Simulation Council, Murray Hill, N. J.

Christensen, H., see Kuper, A. B.

DeCoste, J. B., *Colored Vinyl Plastics for Outdoor Applications,* Soc. Plastic Engrs., N.Y.C.

Edelson, D., see Morrison, J. A.

Ferrell, E. B., *Fundamental Concepts of Statistical Analysis,* Am. Soc. Quality Control, Charleston, W. Va.

Galt, J. K., *The Relationship Between Science and Engineers,* Engrs. Joint Council Symp., N.Y.C.

Garn, P. D. and Kessler, J. E., *Repetitive Gas Chromatography of Thermal Analysis Effluence,* Am. Chem. Soc., N.Y.C.

Gohn, G. R., *New Methods for Determining Stress Relaxation,* A.S.T.M., Atlantic City, N. J.

Gordon, E. I., see LeCraw, R. C.

Grisdale, R. O., *Horizons in Communications Technology,* Columbia Univ., N.Y.C.

Hamming, R. W., *Intellectual Implications of the Computer Revolution,* IBM, N.Y.C.

Hansen, R. H., and Martin, W. M., *The Induction Period in the Thermal Oxidation of Polyolefins,* Am. Chem. Soc., N.Y.C.

Hefele, J. R., Lundberg, J. L., and Salovey, R., *A Simple Ratio Photometer,* Am. Chem. Soc., N.Y.C.

Heidenreich, R. D., *Electron Interference Phenomena,* Pittsburgh Diffrac. Conf., Pittsburgh, Pa.

Heidenreich, R. D., *Investigations on Magnetic Alloys,* Phila. Elec. Microscope Soc., Philadelphia, Pa.

Herber, R. H., and Wertheim, G. K., *Nuclear Resonant Gamma Ray Absorption in K_2FeO_4,* Am. Chem. Soc., Washington, D. C.

Highleyman, W. H., *Linear Decision Functions, with Application to Pattern Recognition,* Symp. Optical Character Recog., Washington, D. C.

Hoover, C. W. Jr., *Applications of Delay Lines in Correlation*

Processing, Acoust. Soc. and IRE, Cincinnati, Ohio.

Hutson, A. R., *Ultrasonic Amplification and Scattering Phenomena in Piezoelectric Semiconductors*, Univ. Calif., Los Angeles, Calif.; Prof. Group IRE, Stanford Univ., Palo Alto, Calif.; Stanford Univ., Stanford, Calif.; Univ. of Calif., Berkeley, Calif.

Johnson, L. F., Boyd, G. D., Nassau, K., and Soden, R. R., *Continuous Operation of a Solid State Optical Maser*, Am. Phys. Soc., Los Angeles, Calif.

Keister, W., *The Introduction of Electronic Switching*, Bell System Training Program, Cooperstown, N. Y.

Kessler, J. E., see Garn, P. D.

Knox, K., *Crystal Structure and Stereochemistry of Transition-Metal Compounds*, Am. Chem. Soc., Philadelphia, Pa.

Kontos, E. G., and Slichter, W. P., *Transition Phenomena in Homopolymers and Copolymers of Ethylene and Propylene*, Am. Chem. Soc., N.Y.C.

Kunzler, J. E., *Superconductivity and High Field Magnets*, Am. Phys. Soc., Los Angeles, Calif.

Kunzler, J. E., *High Field Superconductors and Superconducting Magnets*, Univ. of Ill., Urbana, Ill.; IRE, Red Bank, N. J.; Rensselaer Polytech. Insti. Math. Stat., N.Y.C.

Kuper, A. B., and Christensen, H., *Some Properties of Epitaxial Germanium*, Electrochem. Soc., Detroit, Mich.

LaMarche, R. E., *An Analog Simulation of a Circuit—A Junction Diode in a Waveguide*, Eastern Simulation Council, Murray Hill, N. J.

Laudise, R. A., *The Growth of Yttrium-Iron Garnet on a Seed from a Molten Salt Solution*, Magnetics Conf., Phoenix, Ariz.

Laue, R. V., *A Multivariate Approach to Screening Test Data*, Insti. Math. Stat., N.Y.C.

LeCraw, R. C., Spencer, E. G., and Gordon, E. I., *Acoustic Losses in Ferromagnetic Insulators*, Conf. Magnetism and Magnetic Materials, Phoenix, Ariz.

Lundberg, J. L., see Hefele, J. R.

Martin, W. M., see Hansen, R. H.

McMillin, D. L., *A Design Concept for an Automated Digital Test System*, Johns Hopkins Univ., Howard County, Md.

Morrison, J. A., and Edelson, D., *Solution of the Space Charge Problem for a Pulsed Townsend Discharge*, Am. Math. Soc., Cambridge, Mass.

Mumford, W. W., *Microwave Noise Figures and Elementary Considerations of Noise Performance*, Sem. Grad. Students and Profs., Univ. Wisconsin, Madison, Wis.

Mumford, W. W., *Some Technical Aspects of Microwave Radiation Hazards*, AIEE and IRE, Lincoln, Nebr.; Colloq. Grad. Students and Profs., Univ. Wisconsin, Madison, Wis.

Nassau, K., see Johnson, L. F.

Nelson, L. S., *Flash Heating and Kinetic Spectroscopy*, Argonne Nat. Lab., Argonne, Ill.

Nesbitt, E. A., and Gyorgy, E. M., *Age-Hardened Gold Permalloy and Gold Perminvar*, Conf. Magnetism and Magnetic Materials, Phoenix, Ariz.

Neumann, P. G., *Cyclic Permutation Error-Correcting Codes*, IBM Research Center, Yorktown Heights, N. Y.

Neumann, P. G., *On the Logical Design of Noiseless Load-Sharing Matrix Switches*, Princeton Univ. Conf. on Log. Design Theory and Switch. Circ., Princeton, N. J.

Paterson, E. G. D., *Quality Control Versus Quality Control Versus Reliability*, Am. Soc. Quality Control, Los Angeles, Calif.

Peck, D. S., *The Uses of Semiconductor Life Distributions*, Conf. Reliability Assurance Techn. Semicon. Specifications, Washington, D. C.

Peter, M., *Paramagnetic Resonance of S State Ions in Metals*, Univ. Calif., Los Angeles, Calif.

Peter, M., *Recent Work on Localized Magnetism in Metals*, National Bur. Standards, Boulder, Colo.

Peter, M., *Recent Experiments on Localized Magnetism in Metals*, Polytech. Insti. of Brooklyn, Brooklyn, N. Y.

Roberts, S. W., *Control Chart Tests Based on Runs and Moving Averages*, Am. Soc. Quality Control, Corning, N. Y.

Rogers, C. E., *The Effect of Association of the Propagating Ion-Pair on Polyisoprene Microstructure*, Am. Chem. Soc., Chicago, Ill.

Ross, I. M., *Solar Cells for Satellite Applications*, Stanford Univ. Symp., Stanford, Calif.

Salovey, R., see Hefele, J. R.

Semmelman, C. L., *Digital Simulation of a TASI (Time Assignment Speech Interpolation) System*, Eastern Simulation Council, Murray Hill, N. J.

Scott, J. W., *Design of Fixtures for Shock and Vibration*, I.B.M. Endicott, N. Y.

Slepian, D., *The One-Sided Barrier Problem for Continuous Parameter Gaussian Processes*, Columbia Univ., N.Y.C.

Slichter, W. P., see Kontos, E. G.

Smits, F. M., *The Performance of Solar Cells in Space Environments*, Northeast Electronics Research & Engg. Meeting, Boston, Mass.

Soden, R. R., see Johnson, L. F.

Spencer, E. G., see LeCraw, R. C.

Terry, M. E., *Modern Statistics and the Electronic Computer*, Am. Statis. Assoc., Philadelphia, Pa.

Treves, D., *High Resolution Kerr Effect and Weak Ferromagnetism in Orthoferrites*, IBM, Yorktown Heights, N. Y.

Van Uitert, L. G., *Energy Transfer Between Cation-Antipyrene Aggregates in Their Rare Earth Antipyrene Salts*, Sixth Internat. Conf. on Coordination Chem., Wayne State Univ., Detroit, Mich.

Wertheim, G. K., see Herber, R. H.

THE AUTHORS

R. Sokoler

R. Sokoler, author of "A Low-Speed Data Set for High-Speed Business," was born in New York City. He received his primary education in New York and his B.S.E.E. degree from the University of California at Berkeley in 1957. He joined the Laboratories in 1957, and received his M.E.E. degree from New York University in 1959. Since joining the Laboratories, he has been engaged in the exploratory and final development of data transmission terminals. As a contrast to his engineering background, he relaxes with the nontechnical art of wood carving. Some of his acrobatic figures in wood have been shown at exhibits presented by the Murray Hill Arts and Crafts Club. He is a member of Eta Kappa Nu, Tau Beta Pi, Phi Beta Kappa, and an associate member of Sigma Xi.

S. Geller, a native of New York City, obtained an A.B. degree in mathematics and chemistry from Cornell University in 1941. During World War II, he worked for the U. S. Army as civilian, enlisted man and officer, then returned to Cornell in 1946, where he obtained a Ph.D. in Physical Chemistry in 1949. He spent another year doing postdoctoral work at Cornell and in 1950 joined the E. I. DuPont Company in Waynesboro, Virginia. In 1952 he joined Bell Laboratories, specializing in studies of crystal structure, with emphasis on crystal chemistry studies and the relation of the properties of crystals to their structures, which he discusses in this issue. He is one of the American co-discoverers of ferrimagnetic garnets, and took part in work which led to the discovery of niobium-tin, an intermetallic compound used in a superconductor electromagnet. He is a member of the American Crystallographic Association, American Physical Society, Mineralogical Society of America, Summit Association of Scientists, Sigma Xi, and Phi Kappa Phi.

S. Geller

Fred J. Singer, a native of Robinson, Colo., obtained his B.S.E.E. degree from the University of Washington in 1920. Subsequently he was an instructor in electrical engineering at the University of Wisconsin while obtaining his Masters degree in E.E. He joined AT&T in 1922, and transferred to Bell Laboratories in 1934. Prior to World War II, he planned data communication systems, including the voice frequency telegraph and TWX. During the war, Mr. Singer concentrated on development of the global radioteletype and other military systems. Since the war, he has engaged in the planning and development of a variety of

F. J. Singer

switching and signaling systems for Bell System DDD and private line services. He is presently executive director of the Switching Systems Engineering Division of the Laboratories. Author of "Compatibility in Telephone Communications" in this issue, he holds 33 patents, is a registered P.E., a Fellow of the A.I.E.E. and a senior member of the I.R.E. He is also a member of the Board of Examiners of the A.I.E.E.

R. M. Riley, co-author of "Laboratory for Ocean Cable" in this issue, is a native of Independence, Missouri. He attended Park College and received an A.B. degree in 1943. From 1943 until 1946 Mr. Riley served as radar and sonar officer aboard submarines with the U.S. Navy. He received an M.S. degree from the University of Minnesota in 1948. Mr. Riley was an instructor in mathematics and mechanics at the University of Minnesota for two years and Iowa State College for one year. In 1949 he joined Bell Telephone Laboratories in the Outside Plant Department and graduated from the second CDT class in 1952. He worked on the development of new cable from 1955 to 1961. He is a member of I.R.E. and the Mathematical Association of America. Mr. Riley is currently

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R. M. Riley

J. W. Phelps, co-author of the article "Laboratory for Ocean Cable," is a native of Bellevue, Neb. He joined the Laboratories in 1951 after attending Omaha University and later Iowa State University where he received a B.S. degree in Electrical Engineering. Except for brief assignments in the transmission systems and switching apparatus areas, his work has been in the outside plant laboratory. He was concerned at first with the electrical protection for outside plant equipment. He now supervises a group working on the development and handling problems of ocean cable. Mr. Phelps is a member of Tau Beta Pi and Eta Kappa Nu.

J. W. Phelps