June 1962

Bell Laboratories RECORD

Thermoelectric Devices and Materials

Symbolic Logic: The Propositional Calculus

Quick-Connect Clip Terminal

Human Factors and Modern Communications

Computer Synthesizes Human Speech

THE BELL LABORATORIES RECORD is published monthly by Bell Telephone Laboratories, Incorporated, 463 West Street, New York 14, N. Y., J. B. FISK, President; K. PRINCE, Secretary; and T. J. MONTIGEL, Treasurer. Subscription: $2.00 per year; Foreign, $2.95 per year. Checks should be made payable to Bell Laboratories Record and addressed to the Circulation Manager. Printed in U. S. A.

Bell Laboratories **RECORD**

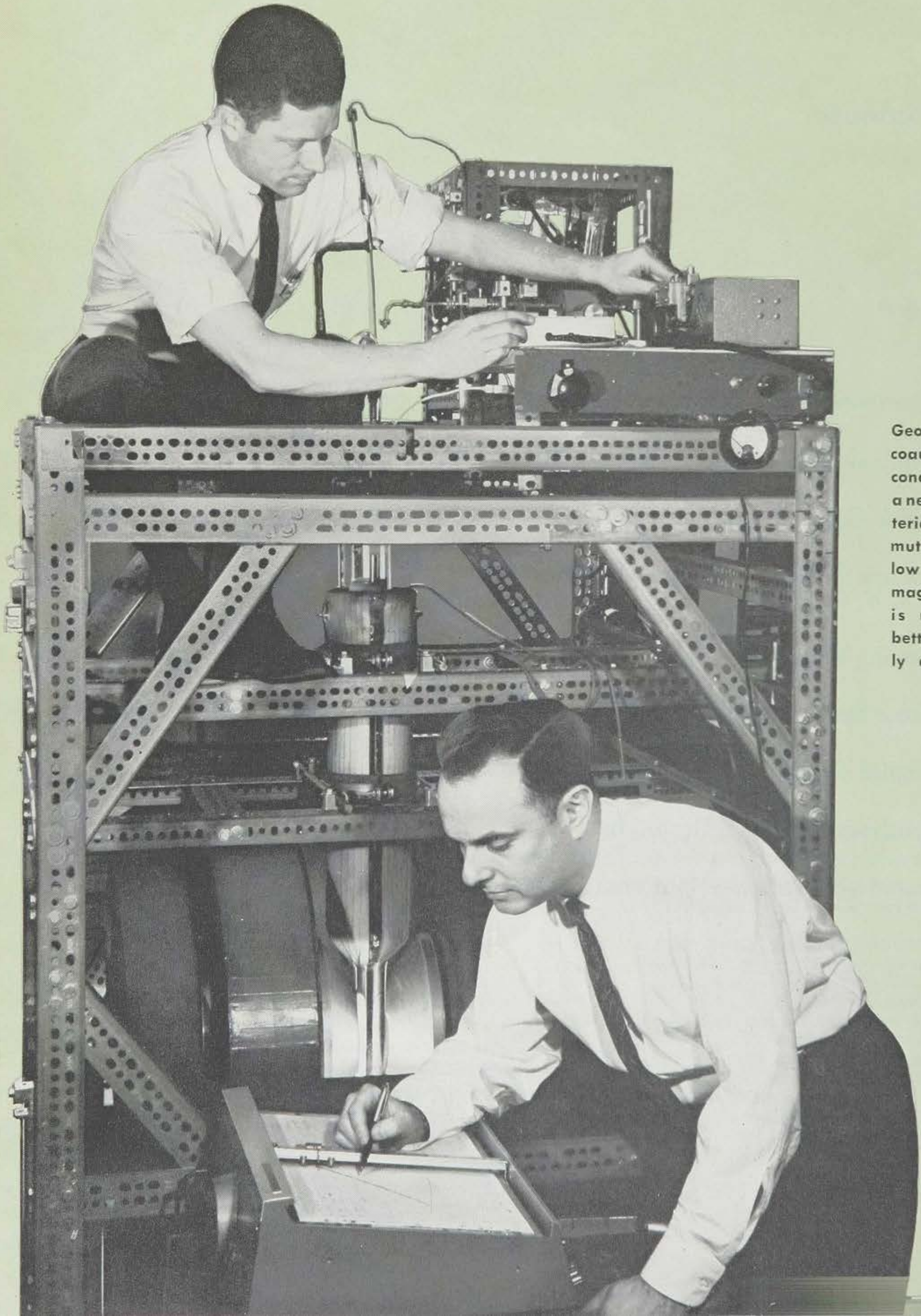
Volume 40 · Number 6 · June 1962

Contents

Cover

Pictures of human speech called "Voiceprints" are as individually distinctive as fingerprints. The six voiceprints on the cover represent the word "you" as spoken by 5 persons. Can you identify the two prints spoken by the same person? (See article on page 214)

Thermoelectric Devices an



George Smith (top) and coauthor Raymond Wolfe conduct experiments on a new thermoelectric material, an alloy of bismuth and antimony. At low temperatures in a magnetic field, the alloy is up to five times better than commercially available materials.

aterials

Based on century-old discoveries, thermoelectric devices may well replace conventional refrigerators and power generators in specific areas. New materials will be the key.

R. Wolfe and J. H. Wernick

A refrigerator less than an inch high silently cools a varactor diode inside a waveguide, resulting in an important reduction in the internal noise of a parametric amplifier. A generator, also operating silently, converts the heat from radioactive isotopes directly into electricity, providing power for the repeater in an active satellite.

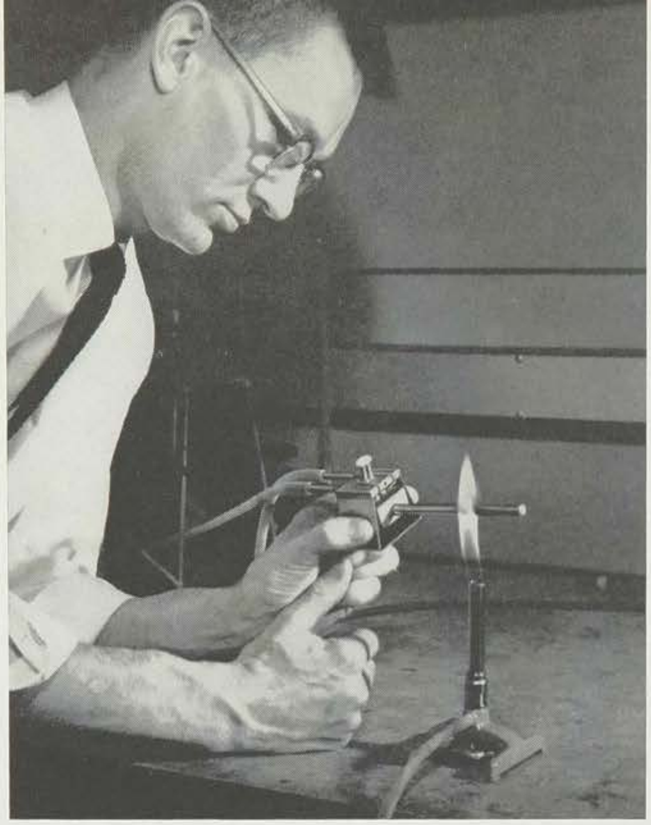
These devices, the first already proven in the Laboratories and the second being considered for future use as an alternative to Bell solar batteries, though seemingly unrelated have one thing in common: both are modern applications of the relatively ancient science of thermo-electricity.

In the refrigerator, the flow of direct current through a circuit composed of two different conductors produces cooling at one junction and heating at the other. This is an application of the Peltier effect, discovered in 1834 and recently made practical by the use of semiconducting compounds instead of metals.

In the generator, a temperature difference between the ends of two joined dissimilar conductors produces a voltage which drives a current around the circuit. This is an application of the Seebeck effect, which was discovered even earlier, in 1821. It is the basis for the familiar thermocouples which have been used as temperature measuring elements in the laboratory and in industry for many years. Again, the understanding of semiconductors and the ability to tailor their properties to meet special needs has changed this thermoelectric effect from a limited laboratory tool to a promising method of direct energy conversion, with theoretical conversion efficiencies now approaching 20 per cent.

One of the primary advantages of both these thermoelectric devices is that there are no moving parts; this provides reliability, noiselessness and freedom from vibration. Other advantages inherent in the devices are small size and weight, and reasonable efficiencies. Their existing large scale counterparts, operating on conventional mechanical technology, have considerably greater efficiencies. However, when these rotating machines are scaled down to small size, their efficiencies drop to very low values. For devices smaller than about one cubic foot, the thermoelectric devices are more efficient than conventional refrigerators and generators.

Some years before the recent improvements in semiconductors had been achieved, a thermoelectric generator was demonstrated at Bell Laboratories. This was the "Thermoelectric Power Pole" invented by W. A. Marrison (RECORD, *October*, 1957). In this device, a telephone repeater was mounted on the top of a hollow pole which contained a tank of propane; when the propane was burned, its heat was converted to electricity by a group of metallic thermocouples to provide power for the repeater. Even with the available metallic thermocouples, with a conversion efficiency of only ½%, Marrison showed that this device was more economical for remote applications than primary batteries, because the tank of propane had to be replaced only once a year to maintain continuous operation of the repeater. The use of



Jack Wagner demonstrates laboratory device which converts heat from flame into electricity; power is then used to freeze moisture in air.

modern semiconductors in a similar generator would increase the efficiency twenty fold. Such a device could then become promising even as a source of stand-by power for microwave relay towers, which require much more power than the pole-mounted repeaters (See RECORD, *July*, 1960).

If propane is replaced by nuclear or solar energy as the source of heat, the unattended life of a thermoelectric generator is greatly extended. Such a generator could then find application in communication satellites, which presently are powered by Bell solar batteries. Thermoelectric generators should be less sensitive to radiation than solar batteries and should be lighter and even more reliable.

One of the most promising applications of thermoelectric cooling (suggested by J. H. Rowen and H. Seidel) is in the parametric amplifier mentioned earlier. In this microwave amplifier, a tiny p-n junction semiconductor device is placed inside the signal waveguide where it is crossed by the pump waveguide. This amplifier is second only to the MASER in its noise performance (RECORD, *May*, 1962). M. Uenohara has shown that its internal noise can be brought even closer to that of the MASER by cooling just the diode inside the waveguide with liquid air. The use of liquid air, however, or other methods of refrigeration, greatly increases the complexity of the parametric amplifier. Liquid air provides more than 350 degrees F of cooling below room temperature. However, the greater part of the improvement in noise was achieved with only 180 degrees F of cooling—possible with a simple thermoelectric refrigerator.

The refrigerator designed for this application consists of two stages; the colder, second stage is a single pair of semiconductor bars, one n-type and one p-type. A small cap which holds the diode to be cooled is soldered onto this "couple". The lower ends of the semiconductor pair in this stage are cooled by a larger stage, about 1½ inch square and ½ inch thick, containing eight couples. This stage is fastened in turn to a brass plate, cooled with running water. When this device is operated in the open, moisture from the air freezes out on both stages. In a vacuum, the larger stage produces a temperature drop of 90 degrees F, and the top of the second stage cools to 183 degrees F below the running water temperature. Inside the amplifier, the region around the refrigerator and the diode is evacuated to eliminate frost and thermal loading, and even though the warm waveguide is very close to the cold cap, the diode is cooled to a temperature of –75 degrees F. At this low temperature, an important reduction in the internal noise of the amplifier is achieved.

Theory of Operation

To understand how such low temperatures can be obtained merely by passing direct current through a simple circuit with no moving parts, or how electricity is produced directly from the flow of heat, we must examine the mechanism of the thermoelectric effects in semiconductors.

If one end of a bar of n-type semiconductor is heated and the other is kept cool, the electrons near the hot end diffuse more rapidly than those near the cool end, because of their extra thermal energy. Electrons, therefore, tend to pile up at the cool end until they produce an electric field which drives electrons back to the hot end. Similarly, in a p-type semiconductor, the positive holes tend to diffuse from the hot to the cool end until an opposing electric field is established, precisely canceling this flow of holes. The thermoelectric, or Seebeck voltage produced is proportional to the temperature difference between the ends. In metals this voltage is typically a few microvolts per degree. In contrast, it can be hundreds or thousands of microvolts per degree in semiconductors. The voltages from both the n-type and p-type bars of semiconductors are cumulative when the bars are joined at their hot ends in a useful device. The two cold ends are then connected by copper wires to a load, and the thermoelectric voltage drives a current around the circuit.

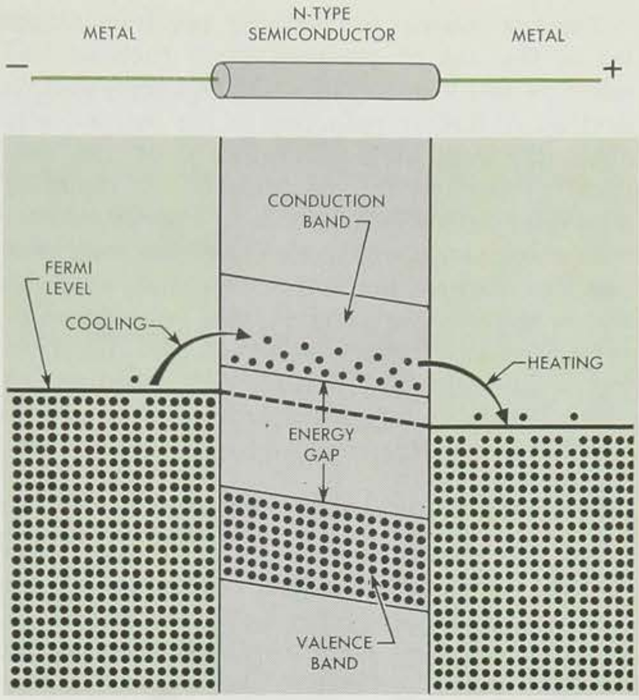
In the Peltier effect, which is basically the inverse of the Seebeck effect, the amount of cooling which takes place when current flows across a junction of two different materials is directly related to the "thermoelectric powers" of the two materials. This effect is also much larger in semiconductors than in metals, and n-type and p-type semiconductors are used in series to enhance the effect even further.

To understand how the cooling effect arises, consider the junction between a metal and an n-type semiconductor. The large number of electrons in the metal *tend* to diffuse into the semiconductor where the electrons are relatively sparse, but this diffusion is prevented by an energy barrier. When current flows from the metal into the semiconductor, the electrons must make an upward jump in energy to surmount this barrier. This extra energy is obtained at the expense of the thermal energy of the material close to the junction. Heat is thus subtracted from this region and the junction is cooled.

Similarly, when electrons pass from the semiconductor into the metal, they drop downward in energy as they pass the junction and the excess energy is released in the form of heat. In a p-type semiconductor, the effects are analogous, but the heated and cooled ends are reversed.

If the right materials are used in an elementary thermoelectric cooler, the temperature at the cold end can be reduced far below freezing if the warmer end is kept at room temperature. These materials must have a very special combination of properties. Most important, the thermoelectric power must be large to produce a large cooling effect—the chief reason for using semiconductors instead of metals. Second, the electrical resistivity must be low, otherwise the normal resistive heating will be so great that it overbalances the cooling effect. Third, the thermal conductivity must be low to maintain a large temperature difference between the ends of a short bar of semiconductor. These three requirements are related in such a way that a single "figure of merit," Z, determines the usefulness of any material in a thermoelectric refrigerator. Z is equal to the square of the thermoelectric power, divided by the product of the thermal conductivity and the electrical resistivity.

The temperature drop which can be achieved with an individual thermocouple is directly proportional to Z. This same factor also determines the efficiency at which heat is converted into electricity in a thermoelectric generator. Here



Simplified drawing shows energy levels in metals and semiconductors in thermoelectric cooling. The average energy of electrons carrying current in a metal is close to the Fermi level, while in the semiconductor it is up in the conduction band. With the current flowing from left to right, the average electron makes an upward jump in energy when it crosses the junction, absorbing thermal energy. At the other junction, the electrons jump downwards in energy, releasing heat.

too, the thermoelectric effect must be large to produce the required voltage. The resistivity must be small so that the electrical power will not be dissipated in the semiconductor itself. The thermal conductivity must again be low to minimize the wasteful flow of heat through the device.

These material requirements are conflicting. For example, a high thermoelectric power is obtained only in very pure semiconductors. Low resistivity, on the other hand, results from making the semiconductor very impure. A compromise must be reached, and the best figure of merit is obtained by doping to a level of about one impurity atom for every thousand atoms of semiconductor. At this doping level, some heat is carried by the same electrons or holes which carry the electrical current, but most of the thermal conductivity of the semiconductor is due to the vibration of the atoms in the crystal lattice. This lattice thermal conductivity is much lower in compounds containing heavy atoms than in the elemental semiconductors silicon and germanium, because heavy atoms vibrate much less actively.

The low thermal conductivity requirement has led to the use of semiconductors such as lead telluride and bismuth telluride in thermoelectric devices. A further reduction in the thermal conductivity, with little deterioration of the electrical properties, can be achieved by replacing a sizable fraction of the atoms in a semiconductor with other atoms which are chemically very similar. For example, the best commercially available n-type material for refrigeration is prepared by replacing about one-quarter of the tellurium atoms in bismuth telluride with selenium. (A pinch of iodine or silver iodide is added to achieve the required n-type conductivity.)

Disordered Semiconductors Useful

Another approach, which leads to even lower thermal conductivities, is to make use of the "disorder" which is inherent in the atomic arrangement of some semiconductors. One excellent example, silver antimony telluride, which was invented at the Laboratories (RECORD, *October*, 1961), has a random arrangement of silver and antimony atoms. It also includes moderately heavy atoms and does in fact have the lowest thermal conductivity ever measured in a crystalline inorganic compound. Reports from various laboratories indicate that this material and its alloys with related compounds are the best available p-type semiconductors for use in thermoelectric generators which operate in the temperature range from 400 degrees to 930 degrees F.

Recently, the Laboratories' search for improved thermoelectric materials has been extended to include semi-metals. These materials have properties which are intermediate between those of metals and semiconductors. They have equal numbers of electrons and holes (in overlapping conduction and valence bands), and the associated negative and positive thermoelectric powers normally tend to cancel each other. In some cases, however, one type of carrier dominates the other and a useful n-type or p-type material results.

The best known semi-metals are bismuth and antimony. Most alloys of bismuth and antimony are also semi-metals, but in the range of compositions containing 5 to 40 per cent antimony, a small energy gap has been observed at very low temperatures. Materials in this range of composition and temperature are, therefore, semiconductors, although their properties near room temperature are very similar to semi-metals.

In fundamental studies of some of these alloys at our Laboratories, G. E. Smith observed certain electrical peculiarities which indicated unusual thermoelectric properties. Careful measurements at low temperatures showed that the alloys had very high figures of merit. This was essentially a rediscovery of these alloys as thermoelectric materials. They had been investigated as long ago as 1913, long before the superiority of semiconductors was appreciated. However, Smith used single crystals of high purity in his work, and found that the electrons dominate the thermoelectric power in these alloys. In fact, in a particular orientation, the low temperature behavior is such that these materials have the highest figures of merit ever measured.

The best commercially available materials have figures of merit near 3 (in units of 10^{-3}/degree C) at room temperature, dropping off to 1 unit at the temperature of liquid air. In the bismuth-antimony alloys, the highest Z at room temperature is only 1.8. At liquid air temperature, however, Z rises to 5.2 units.

The most recent experiments on these alloys have resulted in still higher figures of merit. In an alloy of 88 per cent bismuth and 12 per cent antimony, the room temperature Z has been raised to 3 units, comparable with the best available materials. At about — 340 degrees F, Z has been raised to a new high of 8.6 units. These improvements were achieved by placing the specimen in a magnetic field perpendicular to the current flow.

A familiar effect of a magnetic field on metals and semiconductors is the increase of the electrical resistivity. Less familiar is the increase of the thermoelectric power in a magnetic field. Both of these effects are greatly enhanced in semimetals due to the cooperative action in a magnetic field of the oppositely charged electrons and holes.

In the bismuth-antimony alloys, as the magnetic field is increased the figure of merit rises because of the increased thermoelectric power. In higher magnetic fields, the resistivity becomes so large that Z goes through a maximum and then drops to smaller values. This maximum is almost three times greater than the zero field figure of merit at some temperatures. The field required to maximize Z near room temperature is 17,000 oersteds, and a large laboratory electromagnet must be used. However, at low temperatures the field required is only a few hundred oersteds, and can be supplied by a small horseshoe magnet!

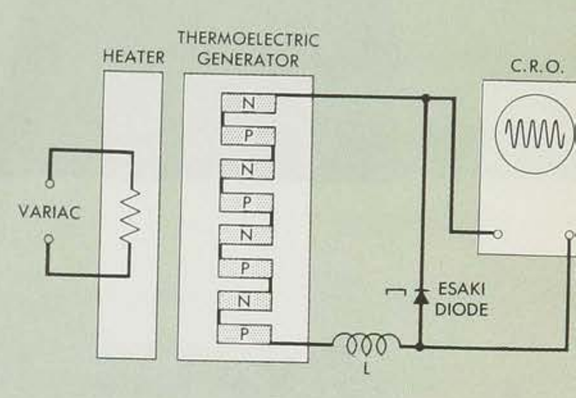
Further improvements in the properties of thermoelectric materials will lead to more efficient devices which may replace many conventional refrigerators and generators. For small scale, specialized applications, particularly in electronics, available thermoelectric materials and devices are already proving their usefulness.

SPECIALIZED APPLICATIONS OF THERMOELECTRICITY AT BELL LABORATORIES

A number of highly specialized devices based on thermoelectric principles have been built at Bell Laboratories. A representative selection is described and illustrated below; many other equally ingenious applications will undoubtedly be forthcoming at an early date.

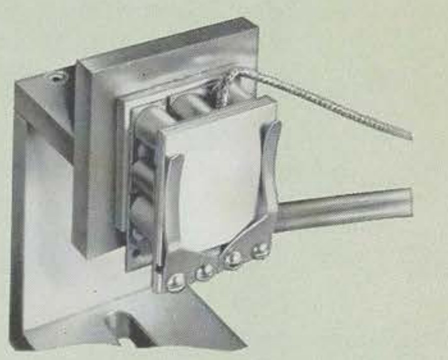
BIAS FOR ESAKI DIODES

Application: Thermoelectric generator to provide dc voltage to bias Esaki diodes into the negative resistance region of their current-voltage curves. The heat source is a simple resistive heater, powered by alternating current. The generator converts ac to very smooth dc, and provides the low impedance required in Esaki diode circuitry. (Suggested by H. K. Gummel, Semiconductor Device Laboratory; designed by R. Wolfe.)



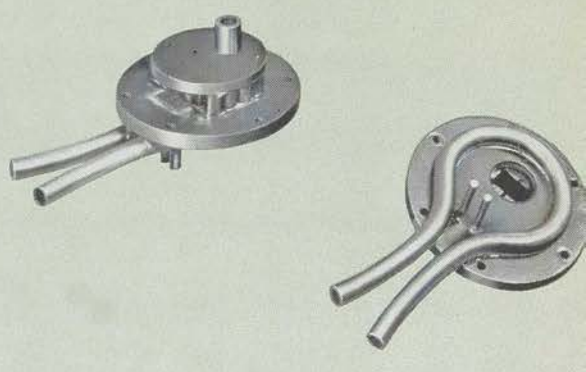
LABORATORY REFRIGERATORS

Application: Thermoelectric refrigerators for use in a large variety of laboratory studies, e.g., in cooling solar cells for studies under simulated space conditions. Similar refrigerators have been used to maintain specimens at fixed low temperatures for investigations of structure by X-rays, infrared reflectivity studies (shown at right) and experiments on the effects of high energy radiation on semiconductors. (Designers: J. P. Griffin and J. S. Wagner, Solid-State Device Laboratory.)



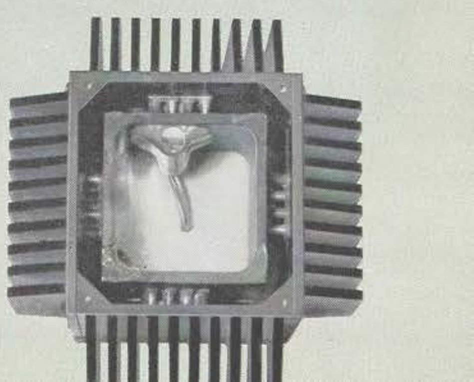
OPTICAL MASER COOLER

Application: To cool the ends of a ruby rod in an optical maser. A pair of specially designed refrigerators has been constructed which fit against the ends of the ruby rod and cool it to —22 degrees F during experiments on optical amplification. (Suggested by J. E. Guesic; designed by J. P. Griffin, J. S. Wagner, and R. Wolfe, all of Solid-State Device Laboratory.)



QUARTZ CRYSTAL OSCILLATOR TEMPERATURE CONTROL

Application: To maintain quartz crystal oscillators at a constant temperature near room temperature or well below, in contrast to conventional ovens. Chambers have been built which maintain temperatures within a few thousandths of a degree. Lower over-all temperature levels increase long term stability. A special purpose chamber has also been built which scans through a wide range of temperatures to determine at which point a given oscillator operates most efficiently. (Designers: W. D. Beaver and H. S. Pustarfi, Components and Solid-State Device Laboratory.)



Symbolic Logic: The Propositiona

The genius of Aristotle first isolated logic as a subject for investigation. Much of everyday human thinking is strongly emotional in character, often efficient and valid, and quite beyond the reach of argument. Below this level, however, is a stratum of thought which appears peculiarly inviolate to all men, where only factual assumptions, and not deductive processes, seem open to doubt. It was this domain that Aristotle preempted, and in it he wrote a book whose authority brooked no question for two thousand years.

It was not until the middle of the nineteenth century that new and vital approaches to logic were made. The most far-reaching was the work of the Irish mathematician, George Boole. In 1853 he published his celebrated book, *The Laws of Thought,* in which mathematical symbolism, long applied in the realm of numbers, was effectively applied in the domain of rational thought.

Beginning at about this time the winds of fundamental mathematics were blowing from many quarters. The foundations of arithmetic, the theory of groups and of sets, a meticulously rigorous theory of functions—all these were being vigorously formulated and investigated. This interest has persisted for a century and has effectively revolutionized mathematical thought. This article will deal with what is in a sense the most basic of these new disciplines—the structure that lies at the basis of mathematical logic. The development of the subject will be purposely somewhat haphazard, and very little further will be said about mathematics itself. However, it is a short step from here to the very foundations of that science.

The Propositional Calculus

The natural approach to symbolic logic begins with the "Propositional Calculus." Single letters of the alphabet such as p, q, r, are used to stand for single propositions, or sentences. The letter p, for example, might represent a simple declarative sentence such as "The sun is shining," or it might perhaps stand for a more complex sentence. In ordinary English, complex sentences are fashioned out of simple ones through the use of "connectives" such as "and," "or" and "if". In the Propositional Calculus not only the simple sentences themselves are symbolized, but also the more common connectives. The symbols for these connectives and the ways they are used are shown at the top of the opposite page.

From simple sentences and these connectives quite complex propositions can be built up. It is the business of the Propositional Calculus to provide a systematic way of analyzing such complex propositions for their truth or falsity. Here an important distinction must be made. Consider the proposition:

$$(p \supset q) \equiv ((\sim p) \cup q).$$

This says, in words, "The statement 'p implies q' is the same as the statement 'either p is false or q is true'." That is, either statement implies the other. A little thought will convince the reader that this proposition is true in a rather extraordinary way: its truth is completely independent of the factual truth or falsity of the component statements p and q. Such a statement is called "logically true" or "tautological." Shortly, rules will be given whereby it can be

Calculus

D. P. Ling

Symbol	Name	Use	Meaning
$\sim$	Denial	$\sim p$	"not p" (p is false)
$\cap$	Conjunction	$p \cap q$	"p and q"
$\cup$	Alternation	$p \cup q$	"p or q"
$\mid$	Disjunction	$p \mid q$	"neither p nor q"
$\supset$	Implication	$p \supset q$	"if p then q" or "p implies q"
$\equiv$	Equivalence	$p \equiv q$	"p is equivalent to q" ie $(p \supset q) \cap (q \supset p)$

systematically determined whether a complex sentence is logically true or only "conditionally" true.

Before explaining these rules, it is perhaps well to point out that not all of the connectives of the table are logically independent. Thus, the proposition discussed in the last paragraph can be taken as *defining* the connective "$\supset$" in terms of the connectives "$\sim$" and "$\cup$". In fact, it is actually possible to get by with a single connective, the sign "$\mid$" of disjunction. Thus $(\sim p) \equiv (p \mid p)$ and $(p \cap q) \equiv ((\sim p) \mid (\sim q)) \equiv ((p \mid p) \mid (q \mid q))$. We shall not, however, confine ourselves to such a Spartan regimen.

The sentences used so far to illustrate this article are all fairly easy to analyze within the ordinary terms of everyday thought. To take an analogy from elementary algebra, if we are told the sum of two numbers is seven, and the first of the numbers is three, we are quite capable of determining the second number as four, without writing $X + Y = 7$, $X = 3$, therefore, $Y = 4$. However, all of us have in our schooling dealt with algebraic problems which would have been insoluble save for the crutch of the algebraic formalism that was taught to us.

So it is here. It is easy to see that $((p \supset q) \cap p) \supset q$ is logically true. But how about the statement $(p \cap (\sim r)) \cup ((p \cup q) \supset r)$? Is this true for all truth values of p, q and r? If not, for which set of values is it true and for which is it false? Translating the statement into equivalent English connectives is not much help. Clearly, some sort of formal machinery is needed to aid the ordinary processes of thought.

The simplest machinery is a truth table. Simple propositions such as "p" or "q" are thought of as taking on one of two possible "values": F (false) or T (true). For each connective a table can be set down specifying the truth or falsity of the complex proposition in terms of the truth or falsity of its component simple propositions. The table below shows the truth tables for the table of connectives. Thus for denial the truth table says that "not p" is true only if "p" is false, and the table for alternation says that "p or q" is true except when "p" and "q" are both false. By and large, these tables accord with ordinary English usage. Perhaps it is surprising to learn from the table for implication that it is true that a false statement implies any other statement, true or false; but this is merely a reasonable convention. Under alternation, it will be seen that we adopt the "either or

Denial		Conjunction			Alternation		
p	$\sim p$	p	q	$p \cap q$	p	q	$p \cup q$
F	T	F	F	F	F	F	F
T	F	F	T	F	F	T	T
		T	F	F	T	F	T
		T	T	T	T	T	T

Disjunction			Implication			Equivalence		
p	q	$p \mid q$	p	q	$p \supset q$	p	q	$p \equiv q$
F	F	T	F	F	T	F	F	T
F	T	F	F	T	T	F	T	F
T	F	F	T	F	F	T	F	F
T	T	F	T	T	T	T	T	T

$(p \cap (\sim r)) \cup ((p \cup q) \supset r)$

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
p	q	r	$(\sim r)$	$p \cap (\sim r)$	$(p \cup q)$	$(p \cup q) \supset r$	X	$\sim X$
F	F	F	T	F	F	T	T	F
F	F	T	F	F	F	T	T	F
F	T	F	T	F	T	F	F	T
F	T	T	F	F	T	T	T	F
T	F	F	T	T	T	F	T	F
T	F	T	F	F	T	T	T	F
T	T	F	T	T	T	F	T	F
T	T	T	F	F	T	T	T	F

both" interpretation of "or".

These elementary truth tables can be extended to cover more complex propositions. For example, let us pose a riddle in the manner of Lewis Carroll. The following proposition is asserted to be *false:*

"Either the sun is shining and I fail to carry my umbrella; or else I carry my umbrella if either the sun is shining or the sea is rough."

Is the denial of this statement true for all truth values of its component sentences, or for only some, and if so, for which? To tackle the riddle methodically, let "p" represent "the sun is shining," "q" represent "the sea is rough" and "r" represent "I carry an umbrella." Then the statement asserted to be false is

$$(p \cap (\sim r)) \cup ((p \cup q) \supset r).$$

Let us give this statement a name, say X, so that X is asserted to be false, and consequently $\sim X$ is asserted to be true.

We can analyze X, and its denial $\sim X$, piecemeal as in the table at the top of this column. The eight possible sets of truth values for p, q and r are listed in columns (1), (2) and (3). Column (4) is derived from Column (3) by using the truth table for denial. Column (5) is derived from (1) and (4) by using the truth table for conjunction. Column (6) we derive from (1) and (2) by alternation. Column (7) comes from (6) and (3) by implication. X, itself, in column (8) is derived from (5) and (7) by alternation. Finally, in column (9) we compute from (8) by the table for denial, the denial of X. The analysis shows that $\sim X$ is true in only one entry: that of row 3. Thus it can be concluded from the assertion of $\sim X$ that the weather is foul ashore and afloat and that I forgot my umbrella.

Very often the purpose of such an exercise is not to answer some specific question, but merely to determine under what conditions some complex proposition is true (or false). If a proposition is true for all sets of truth values of its components, it is said to be a "tautology" (or "logically true"). (If it is everywhere false it is a "contradiction" or "logically false.") Tautologies are logically interesting, but factually devoid of meaning in that their truth tells nothing about the truth or falsity of the p's, q's, and r's of which they are composed. For example, the assertion X of the table opposite, tells us little about p, q, and r, since X is true for almost all values of these variables. X is perilously close to being a tautology. On the other hand, the assertion $(\sim X)$ is rich in factual meaning: it specifies p, q, and r uniquely.

Now patently, all this is pretty simple stuff and can hardly be said to penetrate very deeply into the mysteries of thought. Nevertheless, there is quite a lot that deserves to be said about it. So before going on to more esoteric matters, we will briefly explore two avenues of considerable interest.

Axioms for the Sentential Calculus

The first is the axiomatic approach to the sentential calculus. Mathematicians like to wrap a subject up with a minimum of definitions and assumptions. This instinct is not purely aesthetic —it permits them to analyze with greater ease and clarity the more difficult and penetrating questions they may choose to ask. For example, we might ask whether the formal system we have been examining—the Propositional Calculus—is consistent or not. That is, can we find some (presumably complicated) sentence P such that both P and $\sim P$ are logically true. It is difficult to attack such a question until we have made our logical system a little more definite than it is now; that is, until we have formalized or "axiomatized" the system.

Since this discipline is the "calculus of sentences," (Sentential Calculus is synonymous with Propositional Calculus) the first thing to be done is to define an "admissible sentence." Admissible sentences are either letters, p, q, r, etc., or combinations of such letters formed by the proper use of the connective symbols. Without defining exactly what we mean by "proper use," it is sufficient to indicate that we wish to include $(p \cap q) \supset r$ as an admissible sentence, but to exclude $p \cup \supset \sim$. Observe that no attempt is made to assign a "meaning" to our strings of symbols. The only requirement is that they be "legitimately" constructed.

The next step is to lay down certain "axioms" —sentences which are to be accepted as true. These are chosen with some care to lead to the logical system which thus far we have been exploring informally. A suitable set of axioms is the following:

Axiom 1. $(p \cup p) \supset p$

Axiom 2. $p \supset (p \cup q)$

Axiom 3. $(p \cup q) \supset (q \cup p)$

Axiom 4. $(p \supset q) \supset ((r \cup p) \supset (r \cup q))$

Looking at these statements from our old informal point of view, e.g. where "$\cup$" meant "or," it is easy to see that they are indeed logically true. From our present point of view, however, the axioms are merely acceptable strings of undefined symbols which we *postulate* to be true.

The next requirement is some way of deriving from these four true sentences further sentences that can be regarded as true; in other words we need a "Rule of Inference." Only one Rule of Inference is required and it is a particularly simple one:

"If p is true, and $p \supset q$ is true, then q is true."

In our informal interpretation of symbols, these axioms and rules certainly accord with our intuitive understanding. Some interpretation is required, however; it is certainly the intent that p and q be interpreted more broadly then as the 16th and 17th letters of the English alphabet. They are supposed to stand for any two admissible sentences. We clearly need a "rule of substitution" that says we may substitute for a letter, say p, in a sentence any more complex admissible expression, provided we make the same substitution for *every* appearance of p in the sentence. For example, if $p \supset (p \cup q)$ is true, then I am allowed to conclude that $(r \cup s) \supset ((r \cup s) \cup q)$ is also true, where I have substituted $(r \cup s)$ for each appearance of p in the original sentence.

Finally, we require certain further assumptions called Rules of Connectives. These say that certain sentences are to be regarded as completely equivalent and can be freely substituted one for the other. (All these rules really do is define $\supset$, $\cap$, and $\equiv$ in terms of $\sim$ and $\cup$.) They are:

Rule 1. $p \supset q$ is equivalent to $(\sim p) \cup q$. (We noted this equivalence in our earlier informal discussion.)

Rule 2. $p \cap q$ is equivalent to $\sim(\sim p \cup \sim q)$.

Rule 3. $p \equiv q$ is equivalent to $(p \supset q) \cap (q \supset p)$.

Symbol	Name	Use	Meaning
$\sim$	Denial	$\sim p$	"not p" (p is false)
$\cap$	Conjunction	$p \cap q$	"p and q"
$\cup$	Alternation	$p \cup q$	"p or q"
/	Disjunction	p / q	"neither p nor q"
$\supset$	Implication	$p \supset q$	"if p then q" or "p implies q"
$\equiv$	Equivalence	$p \equiv q$	"p is equivalent to q" ie $(p \supset q) \cap (q \supset p)$

Harking back to our verbal interpretations of the connectives, we can see that these equivalences are plausible ones.

From the Axioms and with the procedural rules that have been set down, all the theorems of the sentential calculus can be derived. A simple example will give the flavor of what a proof is like. We wish to prove that the sentence $\sim A \cup A$ is a theorem, i.e., is logically true. The proof is as follows:

Step 1: $(A \cup A) \supset A$
(Axiom 1, with A substituted for p.)

Step 2:

$$((A \cup A) \supset A) \supset \left\{[(\sim A) \cup (A \cup A)] \supset ((\sim A) \cup A)\right\}$$

(Axiom 4, with $A \cup A$ for p, A for q, $\sim A$ for r.)

Step 3: $((\sim A) \cup (A \cup A)) \supset ((\sim A) \cup A)$
(Steps 1 and 2 and the Rule of Inference.)

Step 4: $A \supset (A \cup A) \supset (\sim A) \cup A$
(Rule of Connectives 1, applied to the left member of Step 3.)

Step 5: $A \supset (A \cup A)$
(Axiom 2, with A substituted for both p and q.)

Step 6: $(\sim A) \cup A$
(Steps 4 and 5, with the Rule of Inference.)

Why all this formal machinery when the logical truth of Step 6 could be established in half a minute with a truth table? There are several answers. First, the formalism exposes the stripped-down structure of the sentential calculus—the minimal machinery required to make it tick. Second, it allows the logician to ex-

Denial "positive and negative"		Conjunction "multiplication"			Alternation "addition"		
p	~p	p	q	p∩q	p	q	p∪q
0	1	0	0	0	0	0	0
1	0	0	1	0	0	1	1
		1	0	0	1	0	1
		1	1	1	1	1	1

plore more recondite questions connected with this calculus—for example, the question of its consistency. It turns out, happily, that the calculus can be proved to be free from inconsistencies. This is a good thing since a single inconsistency would shatter the logical structure completely. This is not hard to show. Let us assume as *premises* that for some particular sentence, A, both A and ~A are true. Then we may reason as follows:

Step 1: A
(Premise)

Step 2: ~A
(Premise)

Step 3: (~A)⊃((~A)∪B)
(Axiom 2 with ~ A for p and B for q.)

Step 4: (~A)∪B
(Steps 2 and 3 with the Rule of Inference.)

Step 5: A⊃B
(Step 4 with Rule of Connectives 1.)

Step 6: B
(Steps 1 and 5, with the Rule of Inference.)

We have thus proved the perfectly arbitrary statement B on the basis of our two premises. The same proof could have been used to prove ~B. Thus, on the basis of our two premises, we have proved *every* statement and its denial! Consequently, a single inconsistency would mark the total collapse of the logical structure.

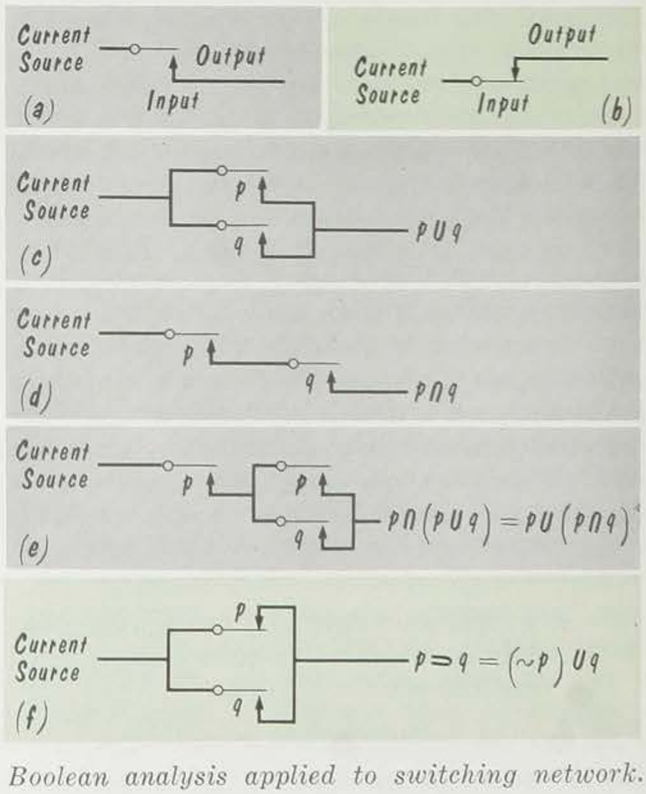
Leaving behind the formal machinery of the sentential calculus, we will explore briefly the second avenue of interest opened up to us by this discipline. This will lead us to a new kind of algebra, and an associated arithmetic. To this end, only the symbols ~, ∩, and ∪ will be retained and these will be associated with the notions, respectively, of "negative" (minus), "multiplication" (times) and "addition" (plus). Thus p∩q becomes an algebraic expression "p times q," and p and q play the role of numerical variables in the expression.

What sorts of numbers will we allow to be substituted for the p's and q's of our algebraic expressions? Earlier, they had only the "truth values," T and F. We shall now identify T with 1 and F with 0 and allow our variables to have only one or the other of these two numerical values. Thus our new arithmetic has only two numbers in it. We can reinterpret the truth tables for the connectives in terms of this arithmetic as in the table opposite. Denial is mathematically interpreted as positive and negative, and conjunction and alternation are respectively a multiplication and an addition table.

Boolean Algebra

All this looks fairly normal in terms of ordinary arithmetic except for the final entry in the "addition" table which does not accord with our customary notion of addition. This is not a matter for surprise since this is not "ordinary arithmetic." It is "Boolean arithmetic" (after George Boole) and the associated algebra is "Boolean algebra."

The algebraic expressions of Boolean algebra



Boolean analysis applied to switching network.

can be evaluated numerically with this new arithmetic just as ordinary algebraic expressions can be evaluated numerically by the ordinary arithmetic. For example, we may ask, what is the value of $(\sim p)\cap(p\cup q)$ for $p = 0$, and $q = 1$. Then our various tables tell us that $\sim p$ is 1, $p\cup q$ is 1 and the product ($\cap$) is 1. This calculation corresponds precisely to the computation of one row of the truth table for the logical sentence in question.

Boolean algebra is in some respects rather like ordinary algebra, but in other respects the two are markedly different. Thus $\sim(\sim p) = p$ is true in Boolean algebra, and its analog $-(-x) = x$ is true in ordinary algebra. However, in Boolean algebra $p \cap p = p$ whereas it is certainly not true that $x \cdot x = x$.

Again, $p\cap(q\cup r) = (p\cap q)\cup(p\cap r)$ agrees with $x \cdot (y + z) = x \cdot y + x \cdot z$. However, $(p\cup q)\cap(p\cup r) = p\cup(q\cap r)$ is a true theorem of Boolean algebra, while the analog of this theorem $(x + y) \cdot (x + z) = x + y \cdot z$ is certainly not true in ordinary algebra.

Boolean algebra is useful in probability theory and the theory of sets. However, its major practical application is in the theory of switching networks—a connection first pointed out by Claude Shannon.

Application to Switching Networks

The basic notion is that the individual relays of which a switching network is composed are "binary" (two-state) devices which are either open (state 0) or closed (state 1). They are in this respect like our Boolean variables p, q, and r.

In a typical relay, see (a) in the drawing on page 200, a contact arm is maintained normally open (by a spring, say) when the input is inactivated (state 0). Current is unable to flow from the current source to the output, which is itself then in state 0. When the input is activated (state 1), a solenoid-operated magnet pulls down the contact arm to closure with the output lead and current flows in the output (state 1). In this kind of relay, if the input is p, the output is likewise p. A "back relay" (b) in the drawing on page 200 operates somewhat differently. Here the contact is held closed when the input is inactivated and pulled open when the input is activated. In this case, if the input is p, the output is $\sim p$.

Relays like these can be compounded in various series-parallel arrangements, and the output of a particular arrangement will depend in a more or less complex way on the various inputs of the individual relays. Specifically, the output will be

Symbol	Name	Use	Meaning
$\sim$	*Denial*	$\sim p$	"not p" (p is false)
$\cap$	*Conjunction*	$p\cap q$	"p and q"
$\cup$	*Alternation*	$p\cup q$	"p or q"
/	*Disjunction*	p / q	"neither p nor q"
$\supset$	*Implication*	$p\supset q$	"if p then q" or "p implies q"
$\equiv$	*Equivalence*	$p\equiv q$	"p is equivalent to q" ie $(p\supset q)\cap(q\supset p)$

a Boolean algebraic expression in its various inputs, and the behavior of the switching network can be analyzed by the methods of Boolean algebra and arithmetic. Conversely, these methods can be used to design switching networks having certain desired properties.

In the drawing on page 200, (c) shows a simple parallel arrangement of two relays whose inputs are p and q respectively. The output is the Boolean "function" (i.e. expression) $p\cup q$. This algebraic statement simply means that current will flow in the output if either p or q is activated. The circuit for the Boolean expression $p\cap q$ is shown in (d). Current can flow only when both p and q are activated. In a slightly more complex example, (e), the two inputs marked p are assumed to be electrically tied together so that both are in the same state at the same time. From (c) and (d), we can deduce that the output ought to be $p\cap(p\cup q)$ and an earlier example in the Boolean algebra tells us that this is the same as $p\cup(p\cap q)$. As a final example, (f) is the circuit for logical implication $p\supset q$, which it will be recalled is identical with $(\sim p)\cup q$.

The major part of the work currently being done in symbolic logic is apt to be quite abstract and, in general, aimed at elucidating the foundations of mathematics. However, as our brief detour through the Boolean algebra shows, its field of application is steadily widening. It is a useful tool wherever complex problems of logical analysis present themselves in engineering, in computing or in the physical, biological or social sciences.

The present article has taken us only a part of the way through the story. A second, and concluding, article on Symbolic Logic will appear in the next issue of the RECORD, where the more esoteric matters promised earlier will be discussed.

To provide business telephone service, Bell System installers connect over 100,000 wires each working day. A new quick-connect clip terminal has now been developed which reduces this effort to a simple push of a hand tool.

W. Pferd

Quick-Connect Clip Terminal

The most time-consuming task a craftsman faces while installing a telephone is placing and connecting the wires which run from the protector block to the telephone set cord. This task becomes particularly laborious in key telephone systems, where 25- and 50-pair cables are used. Since the advent of the CALL DIRECTOR Telephone and other new business telephones, there has been a very rapid increase in the number of more complex new installations and additions to service. To provide this type service, Bell System installers must connect over 100,000 wires each working day—skinning insulation, placing the wire on a terminal and tightening the nut of a screw fastener. Obviously, the total endeavor is time consuming and costly.

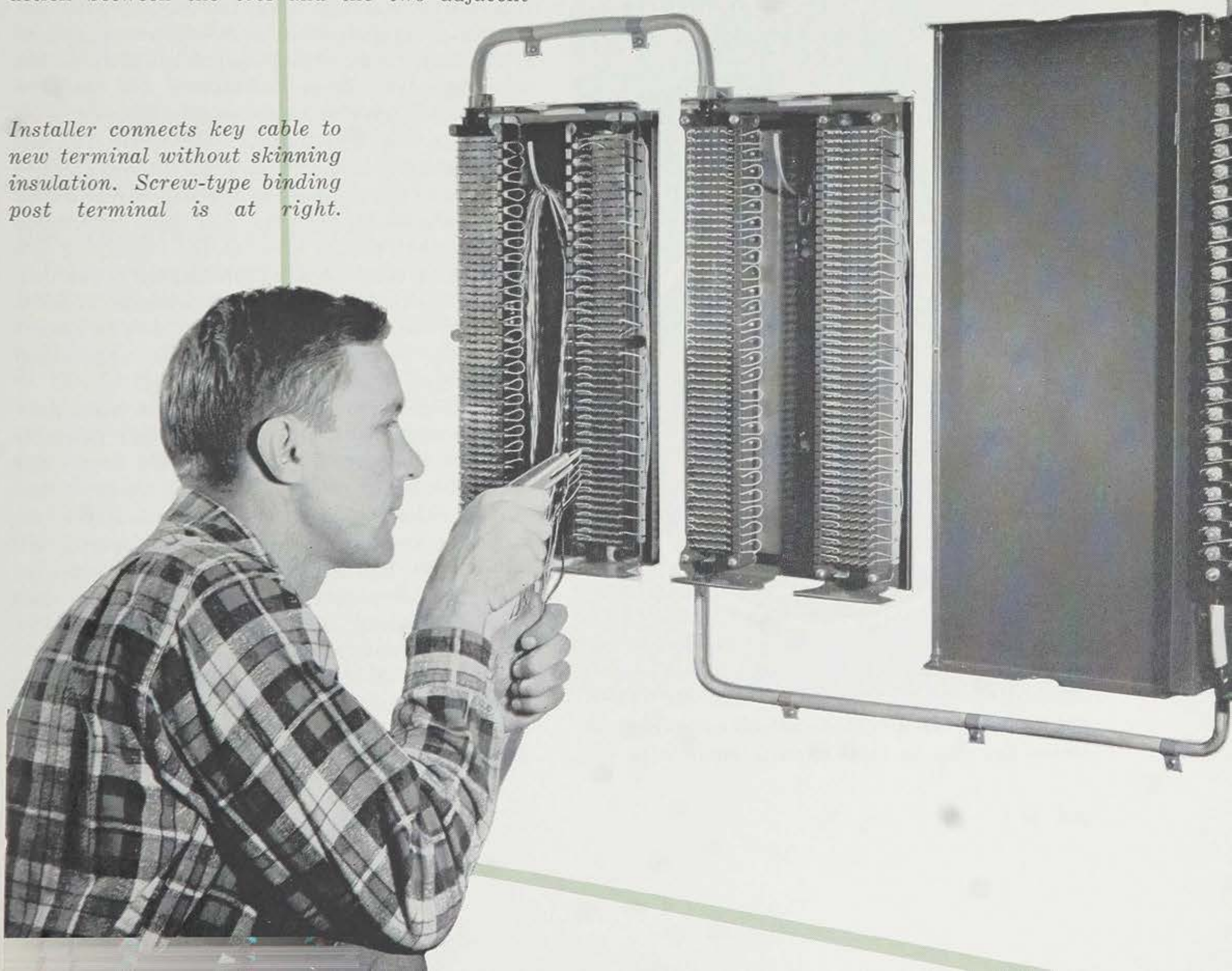
In fact, the increasing task of installation and rearranging, measured both in charges and in time on customer's premises, clearly established the need for quick-connecting devices which significantly reduce this effort and expedite the provision of service. A recent survey of terminating apparatus failed to disclose any device which satisfactorily met the particular requirements for station apparatus. To satisfy this need, a new quick-connect terminal has now been developed which meets installation needs more quickly than did the older binding-post distribution box and screw-terminal connecting blocks. Additionally, the terminal is smaller and less costly than previous terminals. An assortment of connecting block designs incorporating this terminal has been developed, and these are now available. One of the new connecting blocks, the 66A2-50 type, is shown being used by an installer on the opposite page. Because the connecting blocks are easier to use than previous equipment, and because of the wiring convenience to the installer, savings of over $2,000,000 yearly are forecast.

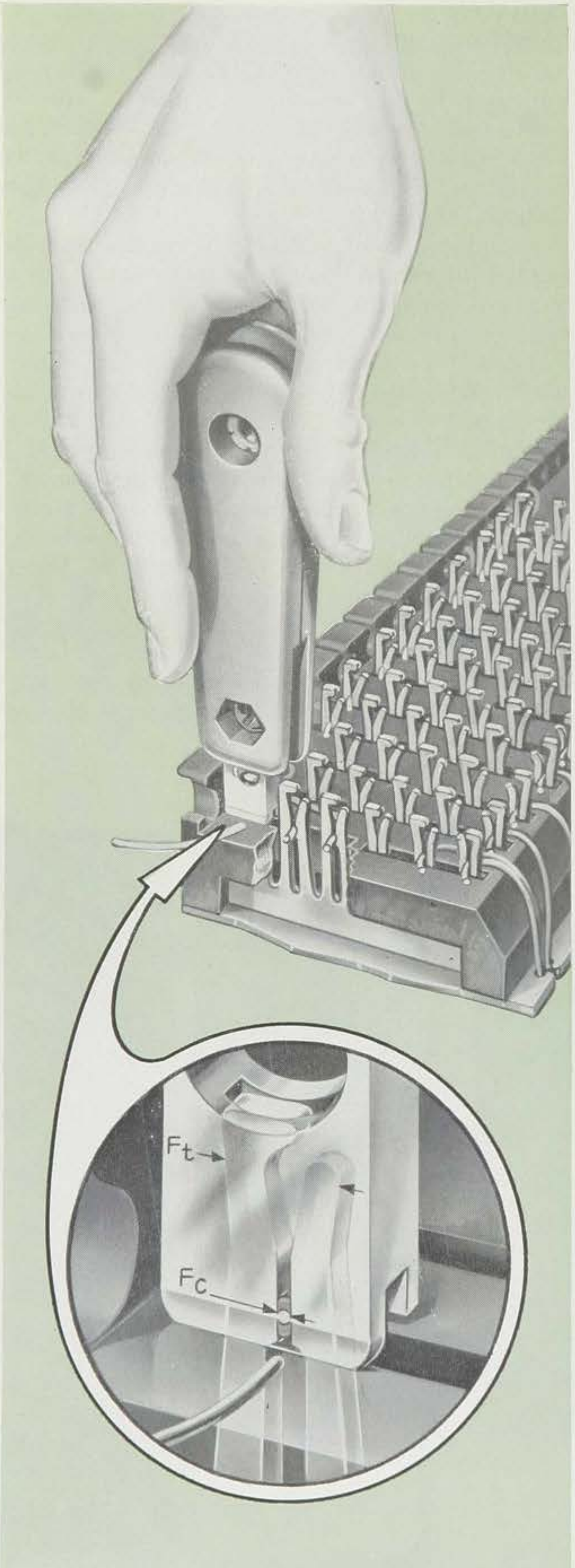
The older 30 and 31 type binding post connecting blocks, which have been in use for over 30 years, provide good contact reliability but are easily broken and require extra care when used to connect more than two cables. These blocks are a reference in comparing speed to make connections and serve as a standard in analyzing installer actions. On analysis, the installation procedure for terminating solid wire to binding-post assemblies breaks down into two major actions on the part of the installer: sorting wires and making connections. The sorting operation requires that the craftsman know both the color coding and the terminating point for each wire. The ease of connecting the wire is determined by the dexterity of the installer and by the design of the connecting device. With conventional terminals, three steps are necessary to make a connection—skinning, placing and tightening. Over the years, the job of removing the insulation has been the major obstacle to speedy operation. When plastic insulation became available, development of a terminal to which unskinned wires could be connected with a simple thrust of a hand tool appeared to be feasible.

The clip terminal shown on the next page was designed to meet this objective. The dimension across the top of the terminal and the distance between the inner side walls of the tool are held to close limits. During connection, interaction between the tool and the two adjacent cantilever beams of the terminal produce the required contact force to crush the plastic insulation as the wire slides between the beams. The terminal works like a clothespin, and is able to connect 18 through 26-gauge solid wire. This simple design is inexpensive, small, and readily manufactured. Above all, it provides a stable electrical connection.

During preliminary studies of various possible configurations and methods of manufacture for a new quick-connect terminal, different compositions of wire and sheet stock were considered as material for the device. Since the new device would replace the low-cost brass screw-type binding post, the cost of raw materials and reproducibility in manufacture became important factors, because both influence costs significantly. Sheet phosphor bronze, worked on a high-production punch press, offered several advantages. For example, it is a relatively inexpensive material with adequate electrical conductivity. Also it has the excellent spring characteristics needed in a quick-connect terminal. The terminal could be manufactured to close tolerance by punching and shearing operations. The punch press method

Installer connects key cable to new terminal without skinning insulation. Screw-type binding post terminal is at right.





Inset shows the forces developed on wire, insulation and clip as connection is made with tool.

of manufacture also made production of great quantities of terminals of a single basic design practical. This capacity will be valuable, since the estimated production rates for all the varieties of connecting blocks using the terminal will require over 300 million terminals yearly.

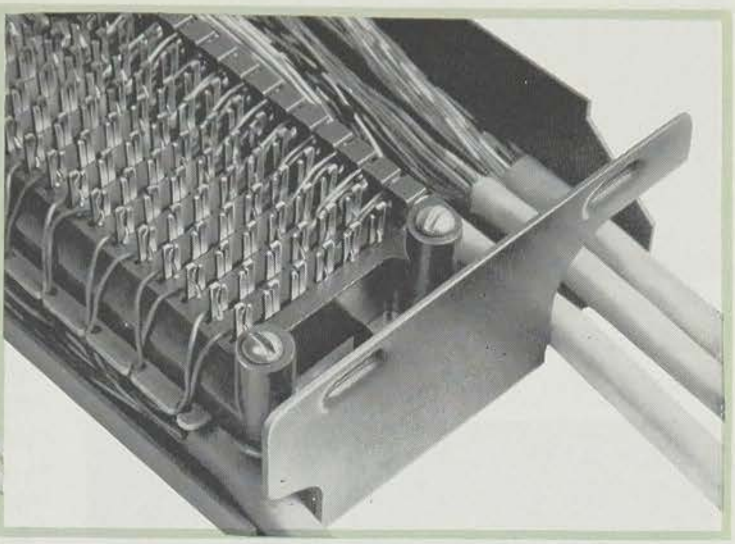
New Plastic for Terminal Mounting

The mounting for the terminal also presented challenging design problems. After evaluating many other plastics, injection molded acetal resin (such as Delrin) was chosen because of its relatively low cost, electrical properties, resistance to low temperature shock, and hardness. The last characteristic is very important, since the block serves as an anvil when excess wire is cut off by the connecting tool. The high strength and resilience of acetal permits the assemblies to withstand the rough handling and dropping experienced in field use. The low water absorption rate of the plastic aids in maintaining high volume resistivity. The material is ideally suited for a connecting block where good electrical properties are required in conjunction with excellent mechanical properties. In this regard, the material used in the new block is far superior to that in the older binding post terminal.

A new connecting block for station wire distribution, designated the 66A2-25, which permits joining six inside wiring cables, is shown on the opposite page. These connectors are designed for cross-connecting and bridging inside wire cables. In use, distribution cable from the key telephone apparatus is connected without slack to a column of clips. Cables to telephones which may be subsequently changed are then connected through the fanning strip to the remaining five columns of clips. A six-cable capacity was considered adequate for all but exceptional installations. Where the connecting block is to be mounted within the business office, an attractively styled snap-on enclosure is provided.

For 25-pair cable installations a container holding one connecting block is used. This assembly is coded 66A2-25. An assembly of 2 blocks and container, coded 66A2-50, is available for larger 50-pair cable installations. These containers consist of a sheet-steel base and cover, styled and finished to harmonize with the surroundings. They provide proper space for storing the slack wire and permit easy mounting plus quick removal and replacement of a snap-on cover.

The over-all design of the new connecting blocks and containers resulted from development work at the Murray Hill and Baltimore locations of Bell Laboratories, as well as production con-



The 66A2-25 connecting block permits joining six inside wiring cables. Closeup shows actual clips.

sideration by the Western Electric engineers at Baltimore and field studies in six operating telephone company areas. Since the advantages anticipated in using the terminal derive from simplified repetitive work operation, human engineering factors were also carefully evaluated during these studies. The terminals, when mounted row-on-row in the block, had to be readily accessible and convenient. Laboratory tests to establish the spacing between terminals to permit orderly wiring plans dictated the block design. These tests also indicated that connections could be made with the clip terminal in from one-half to one-third the time required with conventional binding post connectors. Subsequent tests confirmed the laboratory results, and showed the new design to be extremely easy to use.

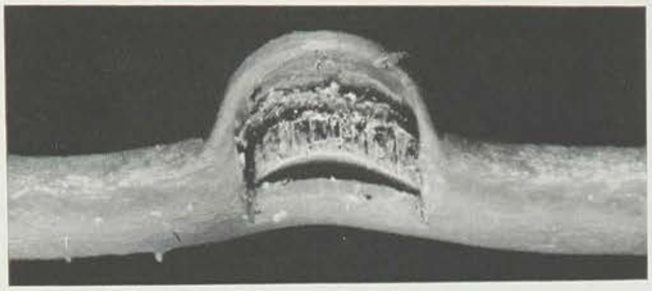
One Wire Connection per Clip

To insure reliable connections, only one wire is connected to each clip. A wire change can be made as quickly as a new installation, by merely pulling the unwanted wire out of the terminal in the direction of the clip opening and re-inserting a new wire with the hand tool. Because an individual terminal is used for each wire, connecting or removing any one wire does not disturb other connections. This also permits orderly wiring and provides adequate space for wire manipulation.

A craftsman making a connection positions an unskinned wire around the hook on one of the adjacent cantilever beams of the terminal and pushes it down with the hand tool, designated the 714B. When the wire is forced into the terminal, the beam ends deflect outward and make contact with the inner walls of the tool. The terminal beams are thus loaded as end supported cantilevers. As shown on the opposite page, a tool force, F_t, is imparted at the ends of the beams and a contact force, F_c, is developed to crush the insulation on the wire. This force is effective even at temperatures below freezing, when the insulation hardens and the effective diameter of the insulation increases. As the insulated wire advances, the beams are progressively deflected, increasing the contact force and compressing the insulation until it shears. Continued movement of the wire further increases the contact force, scraping the bare copper wire against the inside walls of the beams. This action dislodges any corrosive films present on either the beams or the wire. The final contact is made over rectangularly shaped areas on each side of the wire. (Typical contact areas on 24-gauge polyvinyl chloride "D" wire and bare wire are shown on page 206; they measure approximately 0.015 x 0.045 inches on each side of the wire.) The craftsman then makes a final push, which forces a knife edge on the tool to cut off the excess wire against the plastic block. Tool cut-off is permissible for wire up to 22 gauge.

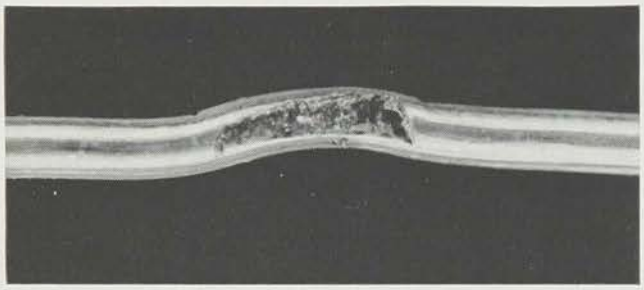
The tool bit is double ended; if the wire is not to be cut off, the opposite end is used simply to force the wire into place. This procedure is used when wire cables are to be looped through the terminal block, a wiring plan which permits minimum installation time for two telephones.

Connecting without cut-off is also employed when terminating 20 gauge steel JKT and 18, 19, and 20 gauge copper wire to avoid reduced blade life. After positioning these wires around the hook on the terminal, the excess is cut off with a wire cutter. The connection is then made by pushing the wire into the terminal with the looping end of the tool.



Contact area on 24-gauge, PVC insulated wire.

Contact area on 24-gauge bare copper wire.



Following installation, there must be sufficient force to maintain reliable contact during subsequent wire movement caused by the installer as he continues his work. However, there must not be so great a force as to prevent purposeful removal of the wire. This contact force must also prevent the separation of the wire and clip due to the buildup of contaminating films, and to maintain a gas-tight connection. A contact force of nominally 5 pounds, exerted on 26-gauge wire, meets these requirements. The contact force increases for larger diameter wire, reaching 12 pounds on 18-gauge wire. These forces, coupled with the large deflection of the beams, produce a terminal with great elastic reserve; the device can thus withstand considerable handling while still performing satisfactorily.

The large beam deflection naturally produces high stress in the clip beams, as well as a resultant compression in the wire. The possibility of a gradually progressing snipping-off action on the wire by "scissoring" over a long time has been thoroughly explored. For 24-gauge wire, only a ¼ mil reduction in wire diameter is expected in 20 years due to the relatively low contacting pressure; during the same period, the clip beams will relax only 1½ mils because of the stress relaxation characteristics of phosphor bronze. Tests show that these changes are not large enough to be troublesome.

Because of the various processing and storage conditions, insulating films of different thicknesses are always present on the surfaces of the copper wire and the beams of the phosphor bronze clips. Clean metal-to-metal contacts result from the rubbing actions of the copper wire on the beams during the connection stages mentioned earlier. The action is as effective on old tarnished clips as on new parts. Studies of the resistance of aged terminals and connections have indicated a long life for the clip terminal. Laboratory-induced oxide films as thick as those occurring on phosphor bronze details in industrial atmospheres after 20 years are easily ruptured. Copper sulfide films, greatly in excess of those expected during normal service, are also easily ruptured by the high contact force. These exposure tests have been performed under temperature cycles from 0 degrees to 140 degrees F and under dry and humid atmosphere. The results of these and other electrical tests on 24-gauge PVC "D" inside wire are summarized below and are consistently good.

Because of the favorable results experienced in the laboratory and field with the early development models, plans for an accelerated program to provide large quantities of the connecting blocks were begun even while some testing was still under way. The potential savings in using the clip terminal were so great that Western Electric was authorized to proceed with plans for full

Table shows results of electrical and other tests.

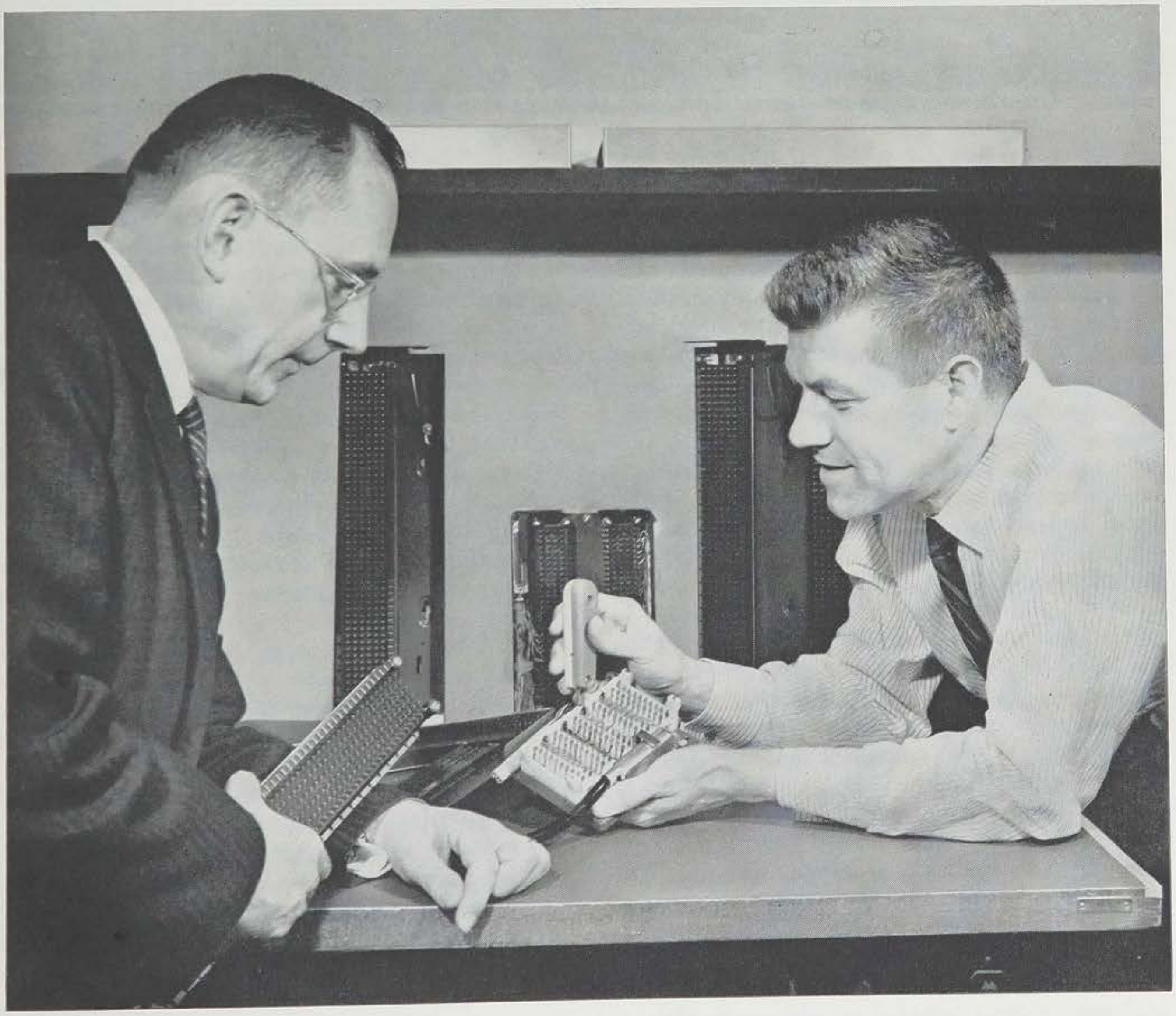
TEST	RESULTING CHANGE
1. Initial Contact Resistance	$\overline{X} + 3\sigma = (0.5 + 1)$ Milliohm
2. Oxide Film Contamination	Less Than 1 Milliohm Increase
3. Sulfide Film Contamination	Less Than 1 Milliohm Increase
4. Environmental Cycle	Unchanged After 6 cycles
5. Two Year Severe Industrial Exposure	
Undisturbed	No Change In Resistance
Disturbed 5 times	Average Increase—5 Milliohms
6. Aging of Plastic	Satisfactory Connections
7. Low Temperature Utility	Satisfactory Connections
8. Vibration Test	No Change In Resistance

production. Connecting blocks and containers for 25- and 50-pair cable were made available in limited quantity during the latter part of 1961. Since then, field experience has been overwhelmingly favorable and has prompted the adaptation of the clip terminal to solve other connecting problems. The terminal offers distinct advantages wherever 20- to 26-gauge plastic insulated solid wire is used and additionally, can be used to quick-connect any bare wire of 18 gauge or smaller.

To take advantage of the quick-connect features of the clip terminal in various applications, other sizes of connecting blocks have also been developed. For connecting distribution cable to the new 759A PBX, a connecting block coded 66E1-32 provides a 2-clip multiple for use with cables having as many as 32 pairs. Also a 25-pair, 6-clip multiple connecting block, coded 66B1-25, is mounted in the 300 type key telephone units to permit rapid connecting of distribution cable. A 66E3-25 assembly for connecting plug-ended telephones to inside wire cable will be available shortly, as will a six-pair connector for residence telephone use. Application of the terminal to central office main frames and outside plant distribution is being studied.

Some of the different designs incorporating the new connector are shown below, and it is expected that this new, quick-connect device will soon find additional uses. The low cost of these terminals, their ease of use and proven contact reliability fulfill the requirements for a major new terminating device.

P. P. Koliss (left) discusses new designs of connecting blocks using the clip connector with author Pferd.



Specialized personnel at Bell Telephone Laboratories are studying the human factors in modern telephony—man's communication needs, abilities and limitations.

J. E. Karlin

Human Factors Engineering and Mode

Effective communications engineering requires some basic knowledge about the telephone user's properties, namely, his communication needs, abilities, and limitations. The user's needs help determine what new systems should be considered and his abilities and limitations help dictate how the system should be built. The study of these user communication properties is the subject of human factors engineering and research.

In the early days of telephony, the important needs like better intelligibility and faster service were obvious and the demands of the simple equipment on the user's abilities were slight. Therefore, the human factors research was relatively straightforward and uncomplicated. In modern communications, both the needs and the technological possibilities for satisfying them are multiplying at a rapid rate. This diversity, coupled with increasing competition, cost, and demands on the user's abilities due to more complex equipment, has made it necessary to devise methods for a more profound understanding and for better measurement of man's communication properties. As a result, the number of specialized personnel at Bell Laboratories studying telephone man-machine problems has increased rapidly over the past decade. Human factors specialists are working in several research, development and engineering departments, as well as in groups studying military problems.

How can the user's future communications needs be foreseen? The methods available are still highly qualitative and rudimentary from a measurement viewpoint, yet they have yielded some worth-while results. One method is, simply, to look for any items of dissatisfaction at the points where man is coupled to the machine in the present telephone system. This method has led in various departments to such developments as lighter weight handsets, TOUCH-TONE Calling sets and automatic dialers (RECORD, *October*, 1961). Second, ideas come from studying trends in world conditions. Data transmission and satellite communication are two outstanding results of this method.

After the qualitative methods have suggested a number of ideas for potentially worthwhile services, the idea is evaluated in terms of its future utility to the user. As pointed out in an earlier article (RECORD, *May*, 1954), forecasting the utility of a new service without actual experience with the service is fraught with danger. For example, in one recent experiment, the utility of a message storage device at the Laboratories was shown to have been badly over-estimated by armchair experts. With this device, a user was able to dial a number and record a message in his own voice to be played back to a designated telephone at a designated time. It was assumed that this service would be useful for "busy" and "don't

Laboratories members and customers tested these dial-in-handsets. Both preferred the rectilinear model (foreground).

ommunications

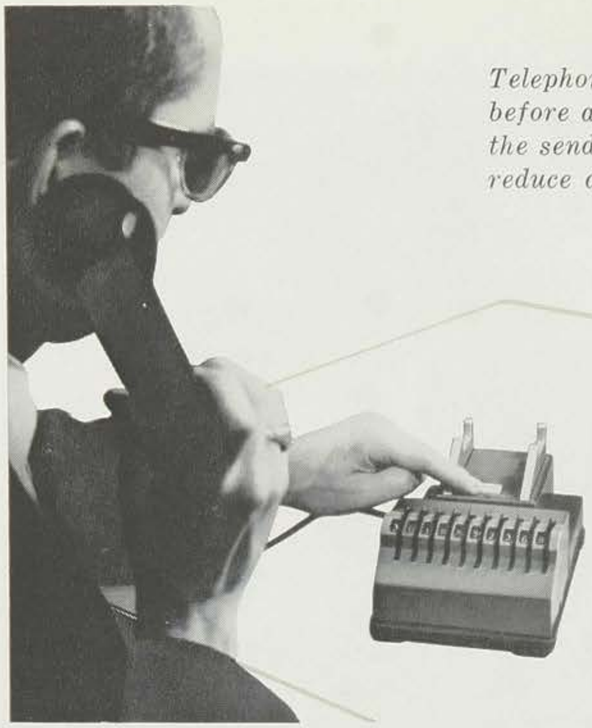
answer" conditions, or for sending the same message to a number of telephones. The results contradicted all the expectations. When the novelty of the service wore off, people used the service less and less. (The experiment also showed the importance of choosing the right sample of users —the project director and his staff required a much longer time for their interest in the service to disappear.) Overlooked in developing the device was the importance of the assurance that the message had been delivered.

In the same way, user interest in a preset dialer such as the one shown on page 210 was also shown to have been over-estimated. The experiment showed that people spent more time setting up the number to be called than dialing it with a conventional rotary dial. They also made just as many errors—in spite of the fact that they could check the number after it was set up.

The importance of appraising projected services through actual use led to the development of Sibyl, a general-purpose machine for simulating new telephone systems and recording data on user reaction under normal operating conditions (RECORD, *November*, 1958). Sibyl has considerable programming flexibility, eliminating the necessity of building expensive equipment to simulate each new system. At the present time, Sibyl is being used to allow some Laboratories personnel to conduct normal telephone calls from their desks over a simulated satellite communication path. Round-trip transmission time over the 90,000 odd miles in a stationary satellite system is about half a second. Echoes become very noticeable with such delays, consequently, suppressors are essential. Since echo suppressors tend to make it difficult for a listener to interrupt, it is necessary to test for the best suppressor arrangement. If tests were made in a test room, using planned conversations, the results would be highly variable. The tests made with Sibyl provide the necessary realism to obtain more accurate information. Much has already been learned about the type of user reaction to be expected with future satellite transmission systems.

Such methods of measuring utility, while not very precise, are useful because the information required about a new service sometimes need be only very general. However, on occasion, it is important to determine more precisely which of two services the user prefers and by how much. The variability permissible in such measurements is considerably less.

Research on a general approach to this problem led to the development of the *isopreference method*, which is still in the exploratory stage but appears promising. It has been used, for example, to map contour lines of equal preference for voice transmission circuits having different speech and noise levels. All the transmission con-



Telephone numbers are preset for checking before automatic dialing is initiated by pressing the send button. This checking did not, however, reduce dialing errors in laboratory experiments.

ditions on any one line of the graph at the top of page 211 are, on the average, equal in preference for a group of listeners and all the conditions on any one line are preferred to those on a lower numbered line. The numbers on two lines can be used to predict the percentage of listeners preferring one condition to another. The contours also show how noise and voice level can be traded off against each other for engineering or economic reasons. This kind of overview will become increasingly important in engineering as the over-all communication network becomes more complex and the requirements more exacting.

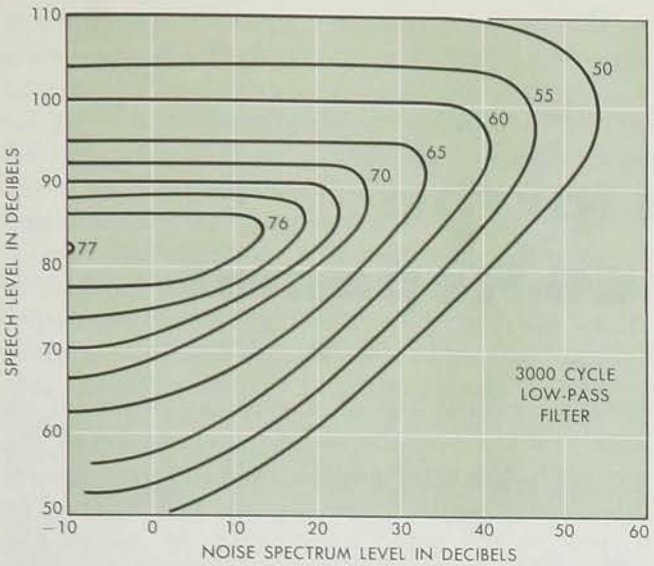
A principal objective of human factors laboratory experiments is the study of communication behavior under controlled conditions. To what extent do these apparently artificial conditions and limited nature of the Laboratories user samples impair our ability to predict user behavior in the field? Over a wide range of telephone equipment and services the impairment is surprisingly small. For example, Laboratories studies years ago showed a user preference for light-weight telephones in line with the continuing trend in the field over the subsequent fifteen years. Laboratory experiments also showed a gain in user accuracy and speed for all-number dialing over letter-number dialing; this has been substantiated in field operation. Experimental results showed that TOUCH-TONE calling is about twice as fast as, but no more accurate than rotary dialing; field trials confirmed both findings. Laboratories users showed a preference, both for appearance and usage, for a rectilinear rather than curvilinear dial-in-handset as shown on page 209. This predicted very closely the subsequent user reaction in a field trial.

Sufficient evidence has been obtained on the relation between Laboratories user and actual customer communication behavior to make it clear that many new services and equipments can profitably be tested without a field trial. Such tests, especially in the exploratory development stages, can economically help "debug" and evaluate the utility, appearance and convenience of new equipment and service. The resulting design then has a higher acceptance probability and can be used with more validity in later product and market trials.

There are some problems with customer telephone behavior which cannot be studied effectively in the laboratory. One problem is the heavy and expensive use of the Information Operator. In this case, a study was made in the field and data were collected under normal operating conditions. Analysis showed some unexpected and interesting results: in two different central offices, for example, about 10% of individual users were responsible for 50% of the calls to Information, as shown on page 211. One institution was requesting an average of 200 numbers a day; one customer requested the same number seven times in three weeks. Studies are now under way in an effort to explore reasons and devise necessary corrective action.

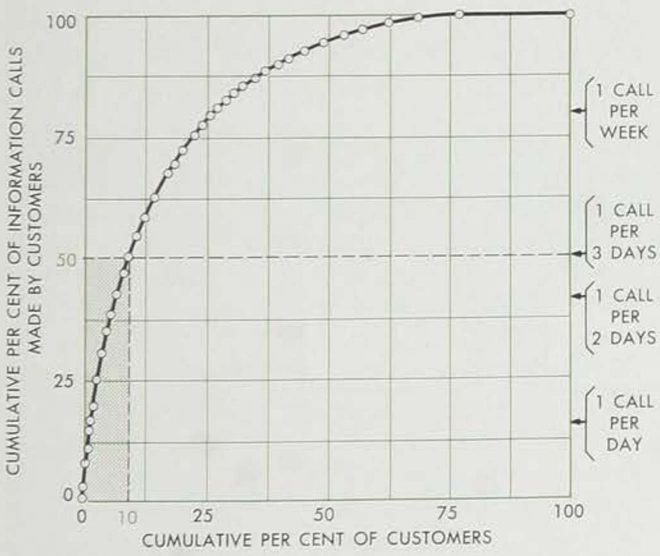
Human Factors and Maintenance

This article has related principally to the *design* of new equipment for customer use. However, the *maintenance* of existing plant equipment and human factors related to maintenance personnel are receiving more and more attention. Studies to date have shown both the seriousness of neglecting the human factor in designing for maintainability and the benefits to be gained from such studies (RECORD, *April*, 1962).



Isopreference contours show which transmission conditions are equally acceptable to listener and the number who prefer one condition to another.

The design of new communication systems is becoming increasingly dependent on a sophisticated knowledge of customer communication properties. Research has led to improved methods for understanding and measuring these properties, but the need for improvement continues as customers become part of an increasingly complex communication machine. With the advent of world-wide dialing, the compatibility of procedures and equipment used by customers in different countries becomes an additional problem. International human factors engineering meetings have already been organized to consider this problem.



A small proportion of users make a disproportionate number of calls to Telephone Information. Data was taken over a 106 day period.

Mercury Tracking System Aids Carpenter Flight

Navy Lieut. Commander M. Scott Carpenter, the second American spaceman to orbit the earth three times, was hurled into space from Cape Canaveral, Florida on May 24, by an Atlas booster rocket. Commander Carpenter's flight, three months on the heels of Marine Corps Colonel John H. Glenn, Jr.'s epic three-orbital trip was, like Glenn's, a National Aeronautics and Space Administration Project Mercury achievement. Western Electric led the industrial team which engineered and built the 18-station worldwide tracking network and provided the communciation with the astronaut through the 140,000 miles of special circuits. Bell Laboratories headed major portions of the Mercury program, including design and installation of the operations control room at Canaveral. Men from Long Lines and most of the associated Bell companies took active part in the project.

The astronaut's capsule dropped into the sea about 125 miles north of Puerto Rico, 200 miles down range from the expected recovery area. Carpenter blew off the escape hatch of the capsule and climbed into his raft. He was joined by two para-rescue men from a C-54 aircraft, who found him in good condition, and waited to be picked up by helicopters.

The 18 stations that comprise the Tracking and Ground Instrumentation System (TAGIS) are connected to the Goddard Space Flight Center in Greenbelt, Md. All types of transmission media are used to provide teletypewriter communication for every station and voice communication for all but six.

From the moment a Mercury spacecraft goes into orbit and recedes from the radar view at Cape Canaveral the successive remote sites of the worldwide network pick up and monitor its operation and position. During the orbital passes, each site receives information from the spacecraft and from the astronaut. These data are transmitted to Goddard Space Flight Center where they are processed by computers and then sent to the Control Center at Cape Canaveral. In this way, a continuous flow of information to and from the Control Center is maintained throughout the entire mission.

The tasks performed by the Laboratories for Project Mercury fall into four categories: equipment design and procurement, equipment engineering, development of operational procedures, and evaluation of the Mercury Range stations.

Testing Equipment for the E6 Repeater

The Bell System's new, transistorized, voice-frequency repeater, the E6, is designed to reduce transmission losses in exchange-area trunks (RECORD, *October*, 1961). To test the performance of these repeaters and to simplify their installation and maintenance, Laboratories engineers at Merrimack Valley developed three new pieces of testing equipment: the 54B test stand, the 54A transmission measuring set, and the 54C return-loss measuring set.

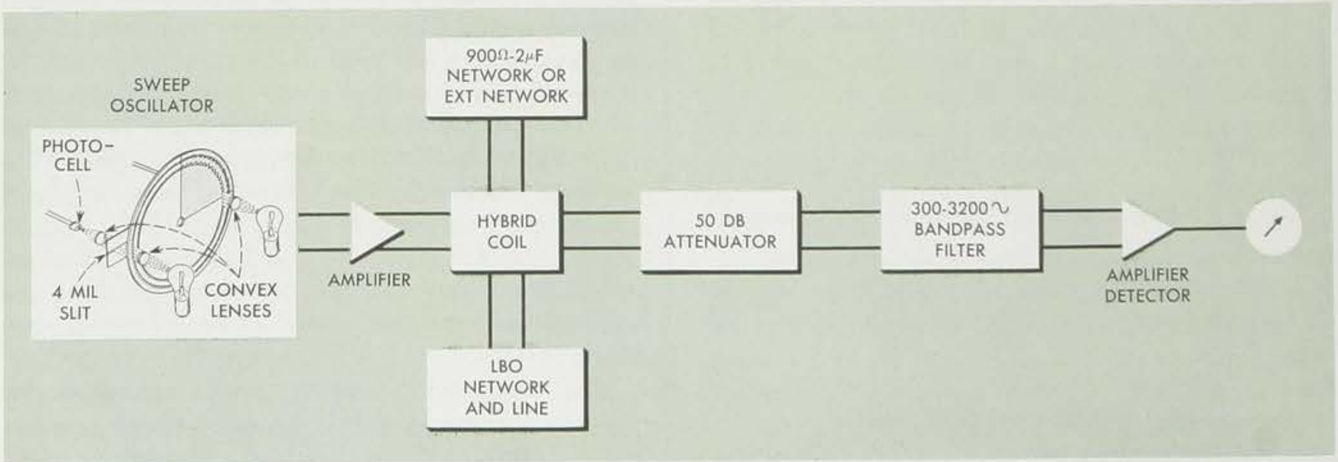
The test stand holds the repeater so that its converter and line-building-out (LBO) networks can be connected to the dc power supply, the lines of the repeater bay, the transmission measuring set, and the return-loss measuring set. It holds the repeater in two positions. In one position, a maintenance man can adjust the screws for the LBO; in the second position, attained by rotating a turret-like frame 180 degrees, he can adjust the series and shunt converter networks.

By operating a switch at the base of the test stand, a maintenance man can make four connections to test the repeater: by turning the switch to the first position, he connects the repeater to the line for normal operation; in the second position, he connects the series and shunt converters of the repeater to the transmission-measuring set to check their individual and combined gains. To measure return loss of a repeater placed at an intermediate position on the line, he turns the switch to the third position and connects the return-loss measuring set to the converter. The fourth switch position connects the return-loss set to the converter to measure return loss of a repeater placed in a terminal position.

A "holding" circuit in the test stand provides a dc path to relays connected at the far end of a line. This permits the relays to be operated and "held" to maintain a dialed-line termination (the "busy" condition of a dialed-line), which is needed in making return-loss measurements. As an added convenience, a pocket in the front of the top panel holds charts for all the cord connections, gain adjustments and LBO adjustments needed for proper installation.

The transmission measuring set is used to obtain the desired gain and image impedance of the series and shunt converters during installation and to check the converter gain and overload point directly from test jacks on the bays after the repeater is installed. With this arrangement, periodic checks can be made quickly, thus minimizing repeater out-of-service time. These tests are also made to determine the over-all repeater gain and transistor reliability with use and aging.

The test set measures gains from 0.5 to 13.5 db.



Schematic drawing of the return-loss measuring set showing sweep oscillator arrangement with which telephone personnel can check LBO network and determine optimum return-loss settings.

It contains a 1000-cps oscillator with an output impedance of 900 ohms, and a 1000-cps, 900-ohm detector. Attenuators and a meter circuit in the set permit the measurement of the gain of the E6 converter unit as a whole or the series and shunt units separately. This measuring technique means that a maintenance man does not have to connect the repeater to the individual line pairs to measure its gain as with the earlier negative-impedance repeaters. The test set has jacks which (with a head set) can be used to monitor in-service circuits before fully inserting the gain-measuring connecting plug which takes a repeater out of service.

The primary function of the return-loss measuring set is to check the LBO network and determine the optimum return-loss setting. The LBO is used to compensate for the varying lengths of cable end sections, office wiring, and different gauges of cable. These adjustments are made against a standard termination (900 ohms in series with 2 microfarads) which is built into the test set and is equal to the image impedance of an E6 repeater. If the LBO adjustments are not properly made, a certain amount of repeater gain may have to be sacrificed to prevent "singing." Adjustments of the LBOs are made by screw connections, as in the case of the converter, which add or remove resistive or capacitive components from the circuit.

The set measures return loss in two frequency bands (500 to 2500 cps or 2000 to 3000 cps) with a self-contained sweep oscillator. Sweep frequencies are used because the relationship between return loss and frequency is highly variable and the over-all shape of a return loss curve is unpredictable for specific cases. A sweep frequency measurement gives an average measurement that is more representative than abritrary single-frequency or group of single-frequency measurements could be.

Sweep frequencies are produced by a light beam modulated by a motor-driven opaque disc which contains two transparent patterns of the wave shapes and frequencies required. This system, shown on page 212, is similar to the sound track on movie film and its associated optical system. The frequencies are entirely dependent on the speed of the synchronous motor and the pattern on the disc; consequently, no frequency adjustments other than the selection of range are ever required. The light beam causes a variation of current in a phototransistor, which is then amplified to the desired level.

A 50-db attenuator and a 20-db scale on the detector meter associated with a high-gain amplifier provide a measuring range from 20-db return gains to 50-db return losses. The return gains are caused by the two-way, or bilateral, amplification feature of the E6 repeater. In such cases, the echo of a signal is amplified twice: once during transmission and once when it is returned. Thus, because of this bilateral amplification, the level of the echo may exceed that of the signal. Determination of whether a measurement is a return loss or gain is facilitated by the use of a red "return gain" scale and a black "return loss" scale on the meter with corresponding colors on the associated attenuator.

E. J. Hurst of New England Telephone and Telegraph adjusts LBO network of E6 repeater.

The 54C set also has some general-purpose return-loss measuring or adjusting applications aside from those concerned with the E6 repeater. It can be used to adjust impedance compensators and precision compromise networks and to measure the return loss of cable pairs. Also, it permits the connection of external oscillators when single frequency return-loss measurments are required, such as in the case of cable irregularity location measurements. Provisions are also made for the connection of external compromise networks when required. The initial cost of the E6 is comparable to that of the older E23, but the ease of installation and adjustment with the use of these test sets and its superior performance make it highly attractive to telephone operating companies.

M. A. Plante and R. D. Powell
Radio Transmission Laboratory

Voice Spectrograms Are Unique Personal Identification

Acoustics scientists have long been aware of the wide variation in human voices. Bell Laboratories scientists now believe that this variation may someday identify people in much the same way as fingerprints do today. L. G. Kersta of the Visual and Acoustics Research Laboratory recently described to the Acoustical Society of America work being done at the Laboratories directed toward "voiceprint" identification.

The voiceprints are actually "pictures" of one word of a person's speech. The pictures reveal the patterns of voice energy in the various levels of pitch—patterns that are quite distinctive and identifiable.

News of Acoustics Research

In tests, voiceprints had been made of the same word spoken by different persons, each person uttering it several different times. Each utterance of the word was voice-printed on a separate card. Then the cards were shuffled, and trained subjects were asked to group the cards representing each voice. In 25,000 decisions, these people made the right decisions more than 97 per cent of the time.

Now Mr. Kersta hopes to prove that an expert, given enough different word samples from an unidentified speaker, could indentify the speaker's voice from millions of others—despite any attempt by the speaker to disguise his voice. "But many more voice samples must be analyzed before we can be certain this is possible," Mr. Kersta said. Such voiceprint identification on a national scale would require the training of experts and the development of an efficient classification system. Voiceprints, Mr. Kersta suggests, can be analyzed and coded by computer. Then the code of an unidentified voice could be matched against those on file.

Even in fingerprint identification, the process is not completely automatic—final identification is made visually by an expert from a number of prints that are similar.

To identify one person from a very large number of other persons, fingerprint experts often need prints of most of the person's fingers—almost certainly more than one or two. Mr. Kersta proposes that much the same technique would be applied to the voiceprint. He suggests that instead of the ten fingers, voice identification might use the ten most commonly used words of the English language: *it, me, you, the, on, I, is, and, a,* and *to*. For instance, on our cover, the same person made the voiceprints in the upper left and lower right.

Voiceprints, sometimes called visible speech, are usually referred to by scientists as voice spectrograms. Oddly, the visible prints disclose fundamental patterns that seem to be more distinctive to the eye than to the ear.

The technique of making spectrograms was invented 17 years ago by a group at Bell Laboratories under the leadership of Ralph K. Potter, former director of transmission research.

During World War II, acoustics scientists C. H. G. Gray and G. A. Kopp suggested that enemy radio voices might be identified by spectrogram in order to detect the movement of units from place to place. Less was known then about voices.

L. G. Kersta speaks into a microphone to make a print of his voice on the spectrograph machine.

And because present techniques were not then available, the type of identification then proposed was very tedious. More is now known about voice, and a new kind of spectrogram was devised by B. F. Logan and A. J. Prestigiacomo of the Visual and Acoustics Research Laboratory in 1960. It gives a "quantized" voiceprint, which resembles a contour map, and which is more adaptable to computers. Use of a computer for analysis, coding and rough identification would be vastly important to a working identification system.

The wide variations in voices is one of the factors that has thwarted many efforts to build a machine that will understand a large variety of spoken words when uttered by many different voices. Current research is aimed toward taking advantage of this variability by associating unique characteristics with each voice.

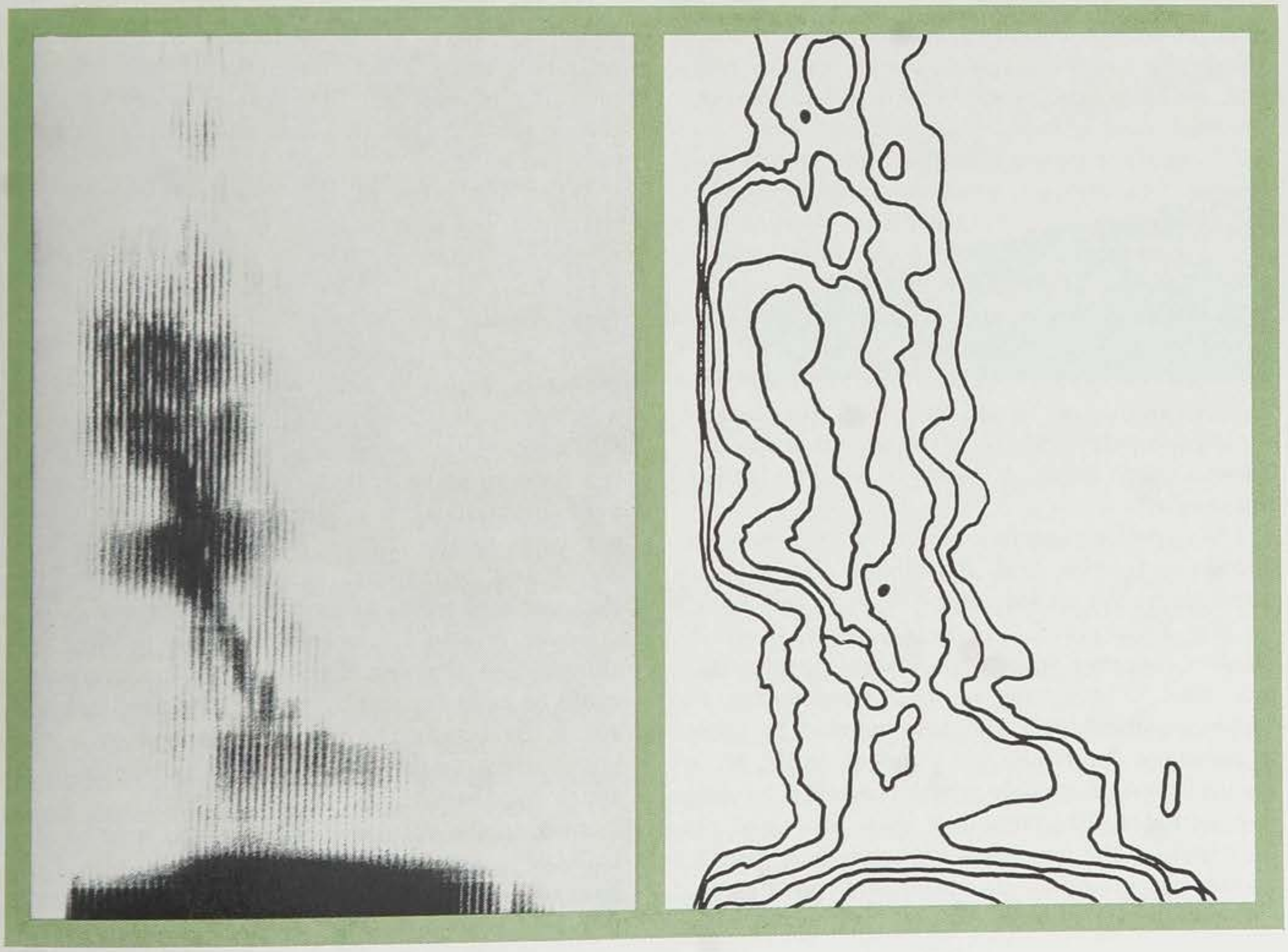
The natural shape and size of a person's mouth, throat, and nasal cavities cause his voice energy to be concentrated into bands of frequencies. The pattern—but not the exact configuration—of these bands remains essentially the same even when a person attempts to disguise his voice by lowering or raising the pitch, speaking in a whisper, muffling the voice, or affecting an accent.

Only a small portion of the pattern is modified by loss of teeth, tonsils, adenoids, or by filling the mouth with marbles. And an operation to alter the throat and nasal cavities permanently would be more difficult than surgical removal of the fingerprints.

It is believed that an adult's pattern is substantially unchanged by age. Mr. Kersta expects to investigate this question by studying samples of speech of broadcasters, entertainers and other voices that have been recorded on many occasions over a period of years.

He believes that voice identification will eventually achieve a degree of accuracy somewhere between the present accuracy of identification by fingerprints and identification by handwriting.

Two forms of the voiceprint are the "bar" form, left, and the "contour" form, at the right. Both of the voiceprints in the photographs below represent the word "you" spoken by the same person.



Digital Computer Synthesizes Human Speech

Two basic approaches to the production of synthetic speech will be presented by John L. Kelly of the Visual and Acoustics Research Laboratory to a seminar in Stockholm next month. Research in this field represents an attempt to understand the basic phenomenon of speech, as well as understanding the necessary elements in the transmission of speech. Such understanding is essential to an efficient approach to telephone transmission in the future.

The two approaches to be discussed at Stockholm aim at the same goal: the generation of speech from an input consisting of *names* of the elementary sounds or phonemes, plus a minimum amount of information on timing, stress, and inflection. The first approach involves a "terminal analog," or a machine such as a vocoder, whose inputs are acoustical parameters, such as pitch, buzz intensity, and formant frequencies. The other approach uses a "vocal tract analog," whose control signals represent articulatory parameters such as the shape of the vocal tract, nasal coupling and tongue position. In either case a set of rules must be worked out to generate control signals from phonetic information.

To compare the virtues of the two approaches to the production of synthetic speech, Dr. Kelly produced computer programs which simulate both the "speaking machines" proposed. He then recorded the output of the computer on audio tape. Tapes of both types of machines will be played at the seminar.

The opposite page is a recording of a tape produced using the first mentioned method—the terminal analog. This machine, proposed jointly by Mr. Kelly and Louis J. Gerstman, is of the tandem resonant type, with several novel principles used. The computer used to simulate the "speaking machine" was programmed to accept in sequence the names, on punched cards, of the phonetic speech sounds which make up an English sentence. The computer then processed this information the way an actual speaking machine would, and produced an output like the output of the speaking machine.

The program had two parts. One simulated the speaking machine; the other consisted of rules, derived from previous research, for combining the individual speech sounds into connected speech and producing control signals for driving the speaking machine. Nine control signals corresponding to voice pitch, buzz intensity, and hiss intensity, plus the center frequencies and bandwidths of three speech formants were continuously generated.

The speech of the simulated talking machine came out of the computer on digital magnetic tape, and was then converted to a variable magnetic sound track suitable for playing on an ordinary tape recorder.

On the demonstration tape recorded here, the computer "says" simple sentences in a measured monotone voice. Then more natural inflection and phrasing is inserted. This was obtained by specifying the changes in pitch and timing on each punched card.

When the pitch of the sounds is varied, the computer can also be made to sing, as witnessed by the recording of "Bicycle Built for Two"; also a few lines of the "To Be Or Not To Be" soliloquy from *Hamlet* are included.

The samples presented are early results of a research project by Kelly and Gerstman to obtain a better understanding of the nature of speech. Ultimately this knowledge may be useful in devising new ways of transmitting speech efficiently over communication systems. For example, a person may, in the future, be able to sit at a keyboard and by typing, cause a talking machine thousands of miles away to speak for him.

There is also the possibility that talking machines, like the one simulated in the computer, could be built for use by people who are unable to speak. By typing the phonetic symbols on a keyboard they could direct a talking machine to speak for them.

Also, in the future, a blind person may be able to have a speaking machine read to him from books which have been previously encoded on a punched tape.

Tantalum-Sputtered Resistors Improved by Adding Nitrogen

By sputtering tantalum films in a partial nitrogen atmosphere, Bell Laboratories scientists have obtained improved thin-film resistors. The tantalum-nitride technique provides resistors with a stability and reliability formerly available only in the larger and more expensive hermetically-sealed devices. The technique was described recently in a paper presented before the Electronics Components Conference in Washington, D. C. by D. Gerstenberg and E. H. Mayer of the Components Laboratory.

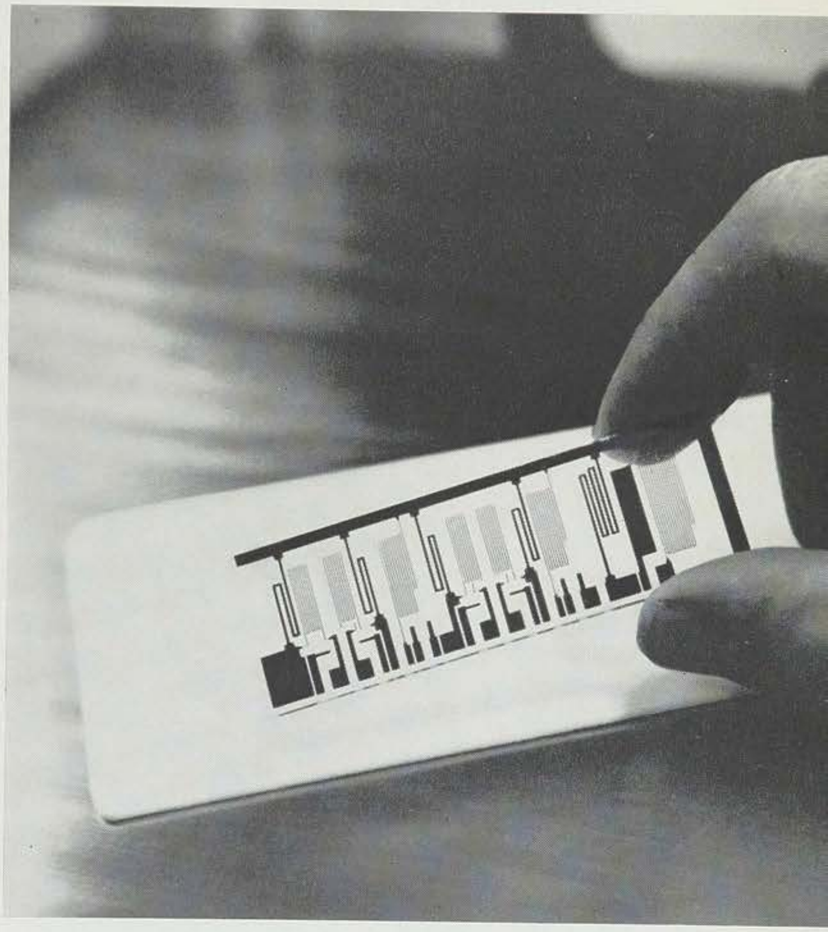
News of Device Development

In "sputtering," ionized gas molecules bombard a cathode of a refractory metal such as tantalum, dislodging its atoms which then redeposit on nearby surfaces. Very precise miniature resistors can be produced on glass or ceramic bases by this technique when used in conjunction with a photolithographic etching process. This process leads to resistors as narrow as 2 mil, as close as 2 mil apart, producing high resistance in a small area.

Heretofore, tantalum devices have been sputtered in an atmosphere of inert gas such as argon (RECORD, *November*, 1958). Traces of certain impurities, like oxygen and water vapor, usually appear in these tantalum films, resulting in resistors with relatively wide variations in resistivity and temperature coefficient.

Small amounts of nitrogen (one to ten per cent by pressure) added to the argon tend to override the accidental impurities, resulting in resistors with much narrower spreads in resistivity and temperature coefficient. In addition to being more stable over wide temperature ranges than their predecessors, tantalum-nitride resistors are more stable over a long period of time. Ordinary sputtered-tantalum resistors, when subjected to a load test for a thousand hours, show changes in resistance of one per cent or more. Tantalum-nitride resistors of the same design, tested under similar conditions, vary less than one-tenth of one per cent.

Like ordinary sputtered-tantalum resistors, the tantalum-nitride devices can be protected with an oxide film, and indeed, it is this "anodizing" of a layer of tantalum oxide that permits the close tolerances to which sputtered devices can be "trimmed." The anodizing technique produces resistors within one-tenth of one per cent of their nominal resistance.



Glass substrate containing tantalum-nitride resistors produced by new technique of sputtering in a partial nitrogen atmosphere.

Because of their minuteness, the way they are constructed, and their reliability, tantalum-nitride resistors will be particularly suitable for use in integrated circuits. Typical applications would be in logic modules in certain types of switching systems, or in certain types of transmission networks.

New Coin Telephone Set Given Field Trial

A new coin phone, designed by Bell Laboratories and produced at Western Electric's Oklahoma City Works, is now on field trial in Norfolk, Virginia. It features a single coin slot, replacing the present three coin slots that have been in Bell System pay phones for more than 50 years. Located in the upper left corner of the housing faceplate, the slot will accept nickels, dimes and quarters. A customer-operated lever also provides for the release of stuck coins.

Another big change is the placement of the handset in the center of the faceplate. This arrangement is similar to that for wall telephones for the home. Other external features are two-tone gray housings, with chrome-finished accessories, and a more attractive display of information card material.

But aside from changes on the outside, the new coin telephone has a number of internal improvements. A notable difference is the replacement of the usual gong and chimes with electronically-generated tones for signaling coin deposits. The coin collecting mechanism has been completely redesigned to offer maximum protection against fraudulent dialing of calls.

The new coin phone also has an improved locking arrangement for the upper housing and cash compartment door—all designed to make it tough for thieves. The cash compartment will house either the standard size coin receptacle or one which will hold 50 per cent more money.

As to its possibilities in the future, the new coin telephone is readily convertible to TOUCH-TONE dialing when it is introduced.

Twenty-four of the new coin phones, made at W.E.'s Oklahoma City Works, were delivered in late January to the Chesapeake and Potomac Telephone Company of Virginia for field testing. The trial is expected to last six months. It is expected the product will be in regular production at Oklahoma City early in 1963, making this the first Western Electric facility to join the Indianapolis Works in the manufacture of telephone sets.

Besides final assembly, Oklahoma City will turn out many of the sub-units for the new coin telephone. Standard dials, handsets, networks and ringers will be shipped from Indianapolis. Output is expected to reach a capacity of 120,000 sets annually. Long range requirements call for over 1,000,000 sets during the first nine years of availability. The demand for the older type of coin telephones is expected to end by 1964.

The new single-slot coin telephone, demonstrated here by a Western Electric employee, was designed at the Laboratories. Its field trial is well underway and production should start late this year.

news in brief

Laboratories Engineers Win Design Award

Laboratories engineers, under the design and development supervision of W. Pferd and P. P. Koliss, won first place in the Industrial Category of the Copper and Brass Achievement Awards Contest. The prize, a bronze trophy and $500, was presented for the development of a quick-connect clip terminal for use in telephone installation. (See "The Quick-Connect Clip Terminal" in this issue.)

The award is given "for the year's outstanding contribution to advancing the use of copper, brass, bronze, or other copper-base alloy through product development, new marketing or production, methods, or metallurgical discovery."

Mr. Pferd, a supervisor in the Telephone Station Equipment Department, who was awarded the prize and trophy for his associates on the project, will donate the $500 prize to Rutgers University's College of Engineering.

Three From Laboratories Named American Academy Fellows

H. W. Bode, W. C. Herring, and J. R. Pierce were elected Fellows of the American Academy of Arts and Sciences last month at its 182nd annual meeting held in Boston. The men were among 110 new members selected for the Academy's highest award. The Academy is comprised of some 1800 national and international leaders in the sciences and arts.

Mr. Bode, vice president of military systems engineering, and Mr. Pierce, executive director of the Research — Communications Principles and Communications Systems Division, were honored in the section of Engineering Sciences and Technologies. Mr. Herring, of the Theoretical Physics Research Department, was one of eight men in the section of physics elected as a Fellow.

Five From Laboratories Given Honorary Degrees

Five Laboratories men received honorary Doctorate degrees this month, including J. B. Fisk, W. O. Baker, S. O. Morgan, J. W. Tukey, and G. R. Frost.

President of the Laboratories, J. B. Fisk was awarded an honorary Doctor of Science degree on June 11 by Colby College, Waterville, Maine. The degree was one of nine honorary degrees awarded at the college's 141st commencement ceremonies. Robert E. L. Strided, president of Colby, conferred Mr. Fisk's degree and read the citation which said, in part: "Your steady rise to the administrative leadership of one of the nation's most remarkable research laboratories is testimony to the technical brilliance of your capacities and to the depth of your insight into the ways in which modern science can be turned to peaceful purposes."

W. O. Baker, vice president of research and patents, received a Doctor of Engineering degree from Stevens Institute of Technology for his contribution to scientific research. Mr. Baker was the guest speaker at the Institute's commencement exercise.

S. O. Morgan received a Doctor of Science degree from Union College. A Union College alumnus class of 1922, Mr. Morgan is assistant vice president for university relations at Bell Laboratories.

J. W. Tukey, associate executive director, Research, Communications Principles Division, received a Doctor of Science degree from Case Institute for his contributions in the field of mathematics.

Western New England College awarded the Doctor of Science degree to G. R. Frost. Mr. Frost, who is demonstrations engineer for the Public Relations and Publication Division at the Laboratories, received the degree for "outstanding service in the field of education."

CDT Graduates Receive Certificates

One hundred seventy four students of Bell Laboratories Communications Development Training Program (CDT) received graduation certificates at Murray Hill June 14. Six CDT students from Merrimack Valley received their certificates the next day during ceremonies at that Laboratory. At graduation exercises in Governor Livingston High School, Murray Hill, N. J., Randolph J. Pilc received the Laboratories' 1962 CDT Fellowship Award.

R. R. Hough, Vice President in Charge of Engineering at the American Telephone and Telegraph Company, was guest speaker at the graduation. J. P. Molnar, Executive Vice President, Development, Design and Systems Engineering at the Laboratories, introduced Mr. Hough.

The CDT certification was conferred by Mr. Molnar. J. N. Shive, Director of the Laboratories Education and Training Center was master of ceremonies.

The Laboratories CDT program, which runs three years and leads to a master's degree for the engineer, is conducted at graduate schools near the Columbus, Merrimack Valley, Winston-Salem, Allentown, Murray Hill, New York, Whippany and Holmdel Laboratories.

Branch Laboratories students spend the first two years of this program on campus completing master's requirements. The third year is spent on Laboratories premises in the study of Laboratories technology.

New York University operates a graduate engineering center with classroom facilities and faculty offices on the Murray Hill premises.

PATENTS

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

Albrecht, J. C.—*Data Storage and Retrieval*—3,030,609.

Baldwin, J. A., Jr.—*Nondestructive Memory Circuits*—3,029,-415.

Chasek, N. E.—*Broadband Radio Relay System in which Signals from Adjacent Repeaters are Compared to Control Gain of Each Repeater*—3,028,489.

Courtney-Pratt, J. S.—*Optical Device for Use in Controlling Light Transmission*—3,030,852.

Dacey, G. C., Lee, C. A., and Shockley, W.—*Semiconductive Device*—3,028,655.

Dimond, T. L. and Wyckoff, A. C. —*Elapsed Time Recorder Stamp Impression Reader*—3,031,135.

Flaschen, S. S. and Garn, P. D.—*Conductors Insulated with Aluminum Fluoride*—3,028,447.

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

Iwersen, J. E. and Nelson, J. T.—*Method for Applying a Gold-Silver Contact onto Silicon and Germanium Semiconductors and Article*—3,028,663.

Jacobson, O. D.—Automatic Wiring Apparatus—3,030,985.

Jacobson, O. D.—*Switching Device*—3,030,451.

Kadri, F. V.—*Current Supply Apparatus*—3,030,589.

Kadri, F. V.—*Power Supply System*—3,031,629.

Lee, C. A., see Dacey, G. C.

Leonard, D. J. and Shennum, R. H.—*PCM Telephone Signaling* —3,030,448.

Marcatili, E. A. J.—*Frequency Separator*—3,031,630.

Mattingly, R. L.—*Directive Antenna Systems*—3,028,591.

Miller, R. P.—*Balanced Transistor Switching Circuits*—3,-030,524.

Nelson, J. T., see Iwersen, J. E.

Saal, F. A.—*Speech Interpolation System*—3,030,447.

Schroeder, M. R.—*Band Compression System*—3,030,450.

Shennum, R. H., see Leonard, D. J.

Shockley, W., see Dacey, G. C.

Treptow, A. W.—*Glass-Metal Seals*—3,029,559.

Von Aulock, W. H.—*Temperature Compensated Gyromagnetic Device*—3,030,593.

Weatherill, P. H.—*Reversible Counting Relay Chain*—3,028,-084.

Wiebusch, C. F.—*Signal Controlled Steering Systems*—3,-027,859.

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Buchsbaum, S. J., *Resonant Interaction of an Extraordinary Wave with a Plasma Column*, Plasma Phys. Div. Mtg., Colorado Springs, Colo.

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Davis, C. G., *Satellite Communications*, U.S. Navy PG School Mtg., IRE, A.I.E.E. and ARS., Monterey, Calif.

Davis, C. G., *TASI*, IRE, Calif. Polytechnic Coll., San Luis Obispo, Calif.

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