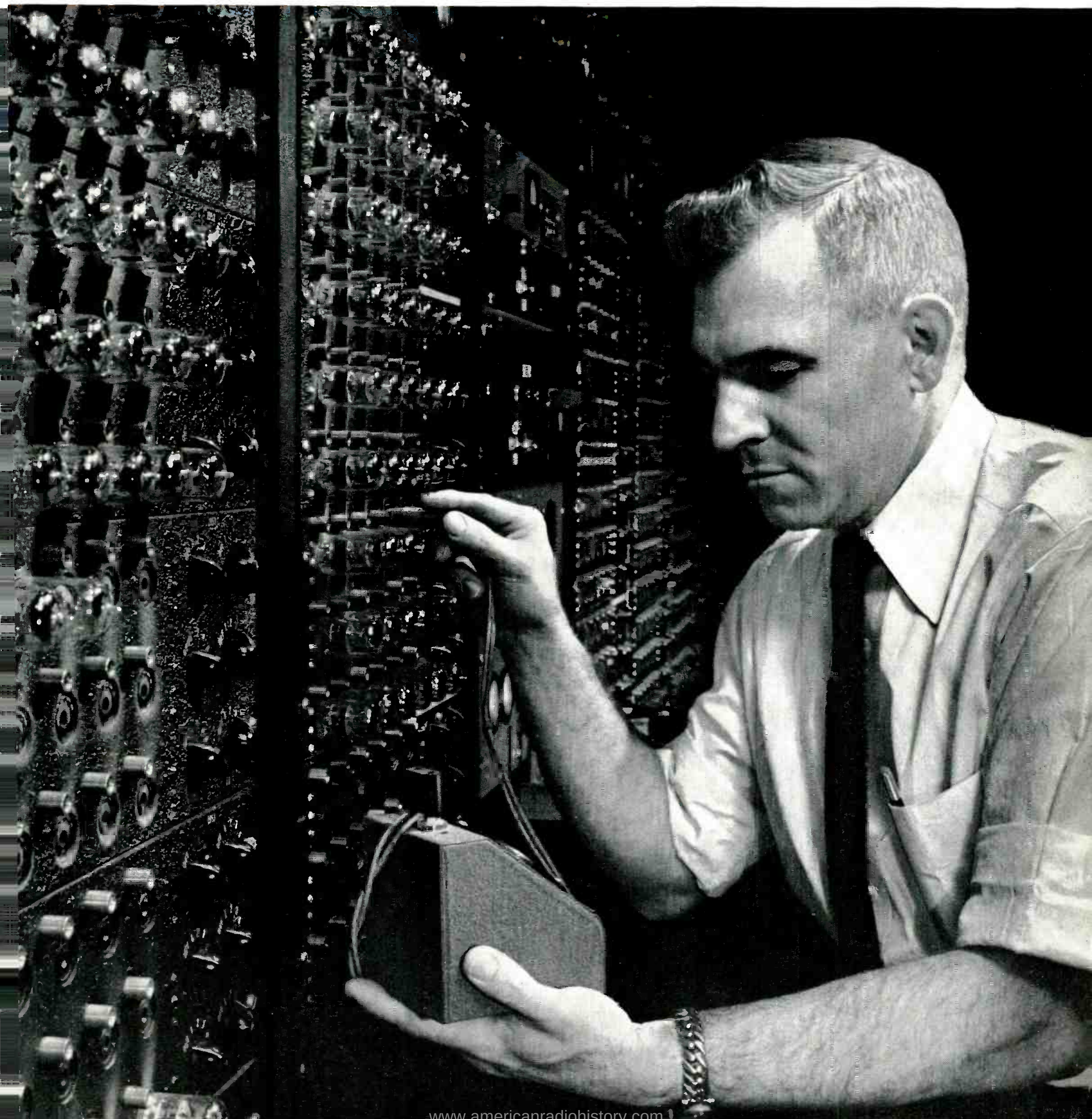
February 1960

Bell Laboratories RECORD



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

Bell Laboratories **RECORD**

Volume 38 • Number 2 • February 1960

Contents

Cover

Life testing electron tubes. D. L. Perry checks current in laboratory models of a new tetrode for TH radio-relay systems. Many tubes have been tested for thousands of hours. *(See page 64.)*

This antenna tower atop a building in downtown Phoenix illustrates the variety of transmission media that serve a modern city. From the top: pole-type mobile-radio antenna, and dish-type antennas for radio-relay systems for television (TD-2) and short-haul toll telephone service (TJ). The TJ system can transmit as many as 720 telephone conversations simultaneously — many times the traffic-handling capacity of the voice-cable lines shown on poles along the street.

Suppose a designer wants to establish telephone circuits between two cities a given distance apart. The problem sounds simple, but for high-quality, economical communications, it requires the consideration of an enormous number of complex technical and economic factors.

L. G. Abraham

The Complexity of the Transmission Network

Telephone service today requires a large and complex network of transmission circuits interconnected through many switching offices. Not only are there many such circuits and switching offices, but there are many different varieties of each. This article considers the complexity of the transmission facilities.

Many people wonder why this network needs so many types of systems. Its size is readily understandable, but why shouldn't there be only one kind of transmission circuit and one kind of switching system adaptable to all circumstances? This article will try to point out the reasons that have produced the existing pattern of transmission facilities, but will not discuss the switching complexity.

In considering this matter, one is reminded of the true story about a carpetbagger who went South just after the Civil War, got into a State Legislature and collected a lot of graft. When finally confronted with his sins, he admitted them and commented: "Sir, when I look back at the conditions that existed then, I am astounded at my own moderation!" In view of the conditions that have existed, it is surprising that the transmission network isn't much more complex than it actually is.

This complexity did not just happen, but stems inevitably from a variety of factors, including: (1) the diversity of circuit lengths, physical environment, quantities needed, and so forth, requiring different solutions to be economical; (2) historical factors which affect the present plant greatly; (3) other services provided in the same network (television, telegraph, sound program, or data); (4) the long life of the facilities used, which keeps older systems in the plant; and (5) to some extent, the desire for diversity along certain routes to protect services against special hazards peculiar to these routes.

Short Haul System	Transmission Medium	Line Frequency Range	Maximum Length in Miles*	Maximum Number of Telephone Circuits	
				Per Route*	Per Unit
2W-VF	Open Wire Cable Pairs	200-3400 cps 200-3400 cps	200 100	12 450	1 1
4W-VF	Cable Pairs	200-3400 cps	500	225	1
C	Open Wire	4.6-30.7 kc	500	60	3
J	Open Wire	36-143 kc	800	144	12
O	Open Wire	2-156 kc	150	300	16
N	Cable	44-260 kc	200	600	12
ON	Cable	36-268 kc	200	1000	20-24
ON/K	Cable	68-136 kc	200	120	12-16
TJ	Radio	10.7-11.7 kmc	200	720	48-240
Non-W.E. Microwave	Radio	5.9-6.4 kmc	150	180	48
P	Open Wire	8-100 kc	25	14	4

*Data in these columns are representative.

How complex is the transmission plant? Transmission facilities may be on open wire, cable pairs, coaxial cable or radio; on these may be transmitted voice frequency, amplitude modulation (carrier), frequency modulation, and soon, perhaps, pulse modulation. Further, these circuits may be combined into groups of from only one or a very few up to 1,860 circuits on one broadband channel each way. One kind of system on a given route may carry 480, 1,800, 3,000, 5,580 or 10,800 circuits, and in the future are waveguide systems with perhaps 100,000 circuits, or the equivalent.

The table on this page shows the major kinds of existing short-haul circuits. A second table shows a similar list for long-haul circuits, in general, good for distances up to 4,000 miles. The numbers are representative only and are not intended to be precise for all situations. In many cases, there are options that could divide even these listings into substantially different kinds of systems. For example, on voice-frequency cable pairs, there are three kinds of inductive loading in common use, as well as nonloaded pairs and phantoms.

To the casual observer, these lists indicate a bewildering array of facilities. So, imagine a Shangri-La that has only two cities, Alpha and Beta, between which telephone service is desired, and that the problem is to design for telephone service between these two points alone. The most economical design for even this group will depend on many factors, including particularly:

(1) The distance from Alpha to Beta.
(2) The physical environment between the two cities: for example, flat plains? or mountains? or perhaps ocean?
(3) The number of circuits needed.
(4) A host of concomitant factors: for instance, the telephone plant already existing on the route and other services such as television that must be accommodated on the same route.
(5) The transmission requirements.

For example, the choice between carrier and voice-frequency is greatly affected by the length of the circuits needed, as illustrated by the graph appearing on page 48. In a general way, this graph illustrates comparative annual costs per circuit mile for 19-gauge voice-frequency and carrier circuits on a fairly heavy route, under various assumptions. The figures are relative only (not in dollars) and do not include common costs such as those for switching, traffic, and allowance for fill.

For very short distances, nothing yet is cheaper than pairs of wires. As the length increases, perhaps larger wires are used and loading is added, but presently it becomes more economical to add a repeater, which costs money, but will permit smaller wires again. As the desired length becomes still greater, larger wires could be used until a second added repeater reduced over-all costs, and so on. The dashed curve on the graph does not show all these details, but the cost per mile for a given kind of two-wire, voice-frequency circuit is roughly constant from the time of the first repeater till the maximum allowable length, from a transmission standpoint, is reached.

But for lengths like, say, 100 miles, K carrier or N carrier usually are more economical, since these put 12 circuits on two pairs of wires by carrier means, thus greatly reducing cable costs per circuit. But they do require fairly costly multiplexing equipment at the carrier terminals, so for shorter lengths, the cost per mile becomes larger, and for quite short lengths, a voice-frequency facility is more economical.

Physical environment also makes a lot of difference. For example, the distance from Florida to Cuba is only about 180 miles, ideal for TJ or TD-2 radio on land. But across the Straits of Florida, 25-30 mile radio-repeater spacing is impracticable, so over-the-horizon radio is used. This route also illustrates one aspect of the frequent need for additional services mentioned earlier. A submarine cable might have been a competitor if only telephone service had been needed (there actually are older cables here), but television service also was needed, so over-the-horizon radio was the only practicable answer at the present time.

In general, any given system has a lot of cost factors which are largely determined by the maximum number of telephone circuits needed. If the maximum circuit need were decreased, a cheaper total system could be devised, using fewer and less expensive repeaters, less complex terminals, less power, and so on. But the cost per circuit would be greater!

Existing plant along the route is often another important influence on the optimum choice of new circuits. If an unfilled system of any kind is available, adding circuits to it is likely to be very economical. If there are radio-relay towers and associated equipment along the route, adding another radio system in a different frequency range may be very economical. Or, if there is an existing voice-frequency cable, converting to N carrier or K carrier may be the best solution.

The requirements for the transmission characteristics are listed in the table on page 48, and these requirements also affect the cost and optimum choice. For example, if it should be decided to specify 3 db lower noise than present requirements on a coaxial system, reducing the repeater spacing would be an attractive way to reduce noise, since the repeaters are a relatively small part of the total system costs. On a new L1 coaxial system, for example, reducing the repeater spacing from 8 to 7.5 miles would give a 3-db noise improvement and would increase the cost only about 2 per cent.

But on radio-relay systems, reducing the repeater spacing would be a very costly way to decrease the noise. For example, even doubling the number of repeaters would reduce the loss per section only 6 db, and the double number of sections would increase the noise at least 3 db in a long circuit, for a net advantage of not over 3 db. Here, an increase in repeater output power or antenna gain would be a much more economical way to improve noise conditions. Thus, the best method for improving transmission characteristics, and the cost of doing it, differ radically for different types of systems.

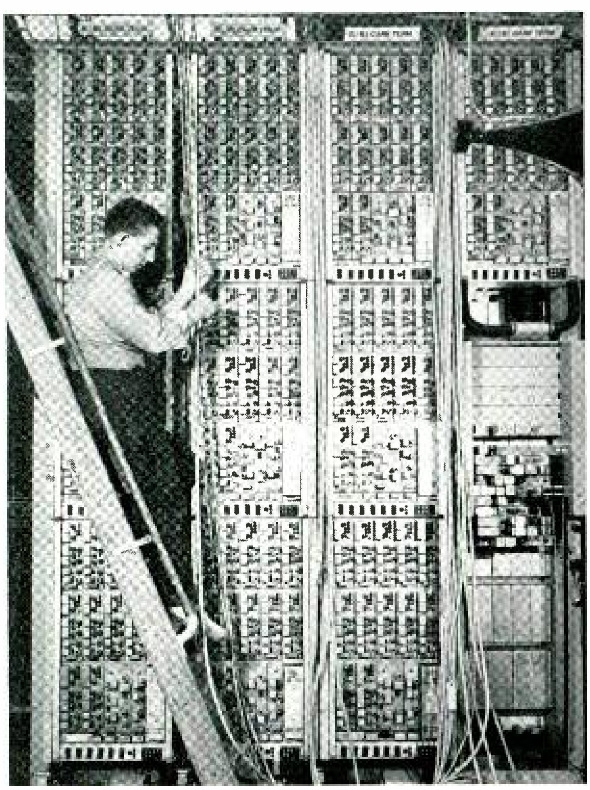
Long Haul System	Transmission Medium	Line Frequency Range	Representative Number of Telephone Circuits	
			Per Broadband	Per Route
K	Cable Pairs	12-60 kc	12	720
L1	Coaxials	64-3096 kc	600	1800
L3	Coaxials	308-8320 kc	1860	5580
TD-2	Radio	3700-4200 mc	600	3000
TH	Radio	5925-6425 mc	1800	10,800
O/H*	Radio	800-2200 mc	36-120	120

*Over the horizon

Similarly, the precise specification of all the other transmission requirements also affects the cost of the optimum system from Alpha to Beta and the choice of the precise system to use.

But when the optimum system has been determined for this imaginary country, it probably will not be the optimum system for next year and the year after. In fact, the optimum choice may well be quite different when the next several years are considered simultaneously. It is clear that providing transmission service between Alpha and Beta is not so simple after all!

Moreover, if Alpha and Beta were floated over and set down in the United States, there would be other circuits needed from Alpha through Beta to Gamma, and from Beta through Alpha to Zeta, and to intermediate points. Some circuits might be switched at either or both ends to other circuits, and some might be used only between the two terminals with different loss and noise requirements. An "optimum" design for each such circuit group, considered separately, would be different and the space between Alpha and Beta could be a hodge-podge of different repeater spacings, transmission media and many other factors. Some of these would interfere with other systems. It would be much more economical to cut back to one or a very few systems for this section, with perhaps no one group using "optimum" facilities for it alone.



An N1 carrier terminal installation. Extensive terminal equipment such as shown here makes carrier transmission costly for very short hauls.

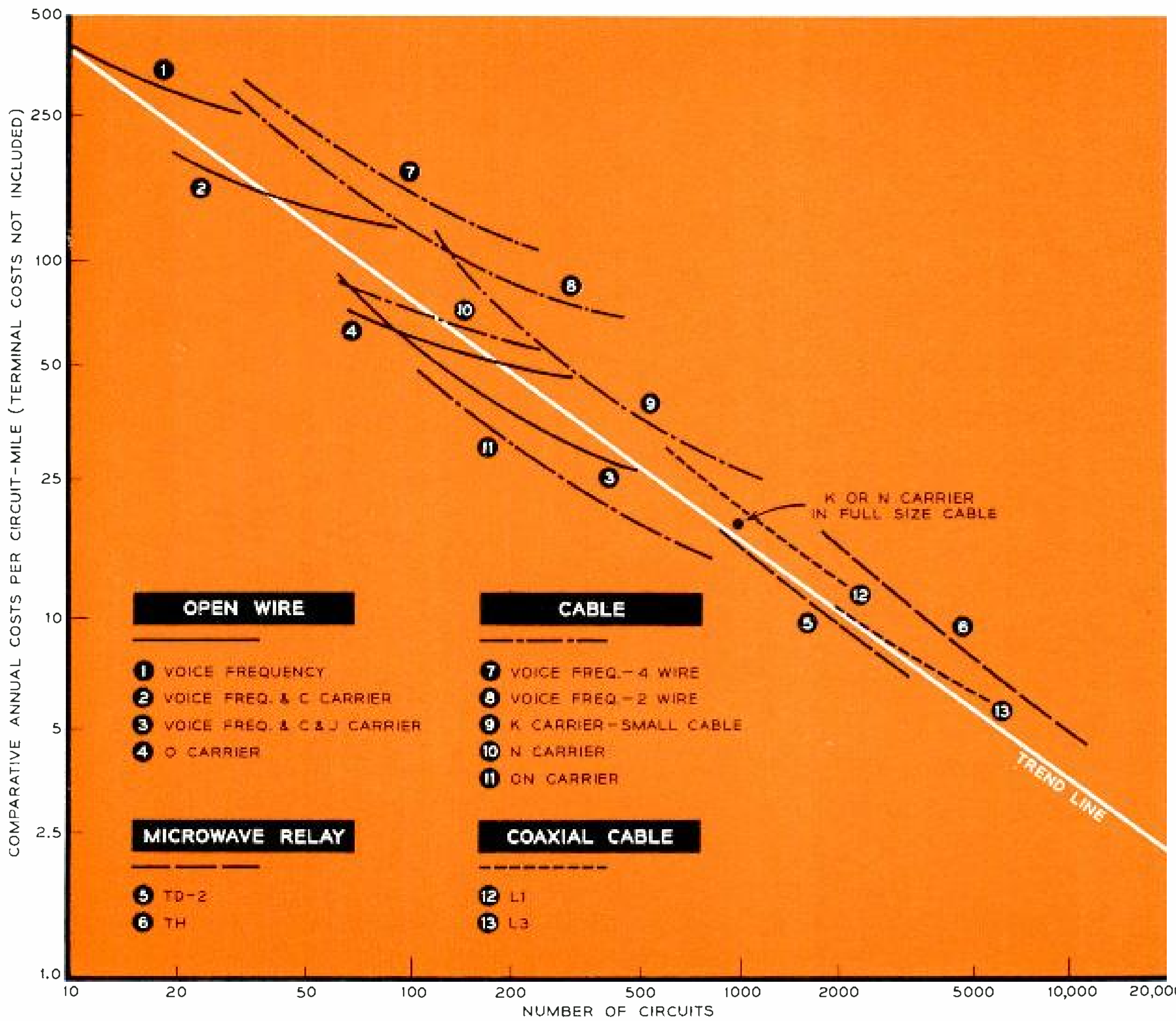
Over the United States, with circuit groups having all their different lengths, physical environments, circuit cross-sections, and other variables, there could be hundreds or even thousands of different "optimum" systems. But if all these were used, the over-all cost of the actual plant would be astronomical. Manufacturing would have to be on a per-job basis, so the advantages of mass production would disappear. Each system would have different limits, different maintenance methods, and different repeater spacings; maintenance forces would be inflexible and essential literature would be voluminous.

This does not mean that there should be only one kind of facility for everything, however. Voice-frequency systems are needed for very short circuits, and long-haul facilities — good for 4,000 miles — are also necessary. And so much of the mileage is in short-haul circuits that it pays to have special kinds of economical facilities good for only a few hundred miles. In addition, particularly in the short-haul field, the geographical conditions, size of route and concomitant factors require some diversity in available types of facilities.

The facilities being installed nowadays in considerable numbers represent a composite judgment as to the minimum number of types that will keep the over-all plant quite economical, without getting the plant so complex that the advantages of standardization are lost.

In addition to the inevitable complexity arising from the factors so far discussed, there is an added complexity in the existing plant due to historical factors. A most important aspect of this is that new routes generally start small and grow slowly at first. In such cases, the most economical facility changes with time. Even if the future growth of a route could be exactly predicted, it would usually be economical to install a light-route facility first, and later supplement it with a large-capacity system when the larger number of circuits were needed.

After one system is installed, it may not pay to remove it from service before the end of its useful life and replace it with another theoretically more nearly optimum system, since you can't recover the installation cost. In addition, the equipment may not yet be paid for by depreciation reserves. So this growth results eventually



Comparative annual circuit costs (not in dollars) *vs. number of circuits. Curves for various systems are about "optimum" for their particular applications, and are closely spaced about "trend" line.*

in different kinds of facilities working in parallel along one route, whereas if you were building it new for the present load, there might be only one kind of facility.

Exceptions to the rule about removing old systems from service do occur, however — for example, when voice-frequency pairs can be unloaded and used for K carrier or N carrier, with more circuits per pair to reduce line costs. Another exception is when L1 coaxial equipment, allowing 1,800 circuits in an 8-coaxial cable, can be replaced by L3 equipment permitting 5,580 circuits in the same cable. In both cases, a large part of the investment can be more efficiently used by the new system.

Another historical factor is that some of the present systems have been available only a relatively short time. For example, commercial radio-relay systems were first available in 1950, so any circuits installed before that time used some other method, say coaxial. And now both kinds of systems work in parallel, sometimes along approximately the same routes.

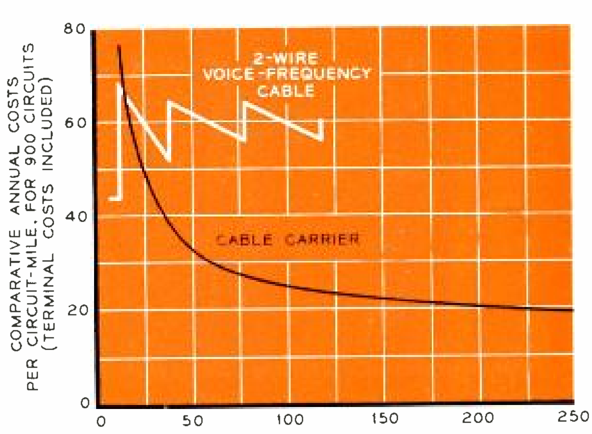
Another historical effect is that costs have changed greatly with time. For example, large quantities of copper and lead are used in coaxial systems, but relatively little in radio-relay systems. The price of copper and lead has increased greatly in the last 15 years, so the coaxial systems that gave such great savings then are now relatively less attractive. But where most of the copper and lead (in cables) is already installed, it is very economical to convert the old L1 to an L3 system.

Another historical factor is that new services are now wanted. This suggests new — wider band, say — facilities to provide services not needed some years ago. When it can be done economically, these new facilities should also be installed to be adaptable for future new services.

Finally, some diversity has advantages and tends to argue for different kinds of facilities along a given route. The results of war, storm, earthquake or other violent emergency are much less likely to take out two kinds of facility than either one separately. And two different systems often can be planned to take two slightly different routes and provide economical service to intermediate points between large centers.

And, fortunately, when there are a reasonable number of different kinds of facilities, not much of the imaginable economy of having an "optimum" facility for each circuit group is lost, as may be illustrated by the graph on page 47. This shows the comparative annual cost of line facilities for different numbers of circuits, excluding such other costs as those for multiplex terminals, switching, traffic and fill, and makes other detailed assumptions.

Each facility now being installed is approximately "optimum" for the maximum number of circuits which it can provide and for the geographical and other conditions for which it is most suitable. These optima points are so grouped near the main trend line from 10 circuits to 20,000 circuits that it is clear that an absolute optimum at any point could not be much cheaper than the available facilities. At short distances and small numbers of circuits, corrections would be necessary in these considerations to allow for terminal costs, circuit lengths, and other factors; but these would not invalidate the general conclusion.



Over short routes, two-wire, voice-frequency pairs are economical; for longer routes, cable carrier system is preferable. Costs are comparative only, not in dollars, *and ignore many other economic factors besides the cost of the circuits.*

TRANSMISSION CHARACTERISTICS	
Net Loss	Average and Deviations
Interference	Noise, Crossmodulation, Tones
Bandwidth	Upper and Lower Cutoff
Distortions	Amplitude, Delay
Distractions	Echoes, Crosstalk
Reliability	

So far, the discussion has been largely concerned with long-distance facilities. Similar factors have affected the local plant, though to date less spectacularly. However, negative-resistance repeaters are now being used in large numbers, and repeaters for local transmission were a rarity even 10 years ago. Line concentrators are also changing local plant facilities.

To summarize, the complexity of the present telephone plant is necessary to provide economically for the large numbers of circuits required under many different kinds of conditions in the Bell System. Nevertheless, it has been possible to hold this complexity within bounds and still obtain nearly minimum theoretical cost in each case and to take advantage of large-scale manufacturing economies.

Still further increases in available kinds of facilities may be expected in the future, particularly for very short routes and for the very heavy concentrations of long-haul facilities envisioned for the future. For example, new short-haul carrier facilities should be introduced extensively in the local plant. And pulse-code modulation systems promise to produce economical carrier circuits for very short lengths.

New services over telephone circuits, such as data transmission, may lead to added complication. On transoceanic submarine cables, TASI and perhaps other band-conservation techniques may save a great deal of money. As long as the present growth in total plant continues, such changes are inevitable and should not cause too great complexity, compared to any other method that will provide the desired service at about minimum cost.

Any automatic equipment required to make logical decisions and remember what it does needs some kind of control. The experimental Electronic Switching System uses for this purpose a unit called "central control." This versatile device directs the logic and memory so vital to the proper operation of electronic switching.

G. G. Drew

A Central Control for ESS

In modern telephone switching systems, the concentration of control circuitry has increased as the variety and speed of services has grown. Crossbar systems, for example, furnish rapid control in the form of "markers"—devices that can establish thousands of calls per hour. The newer Electronic Switching System (ESS), developed at Bell Laboratories, has extended this concept. Here, high-speed electronic devices have permitted designers to concentrate complex control functions in a versatile unit called "central control."

A fundamental objective in ESS has been to keep to a minimum the number of control functions any of the system units can perform. Laboratories engineers have done this to reduce circuit complexity in several units, and concentrate control in one central unit where it could be used more efficiently. Even central control, which has been assigned more functions than any other ESS unit, has been greatly simplified by transferring almost all intricate, sequential-circuit functions to a "stored program" of data.

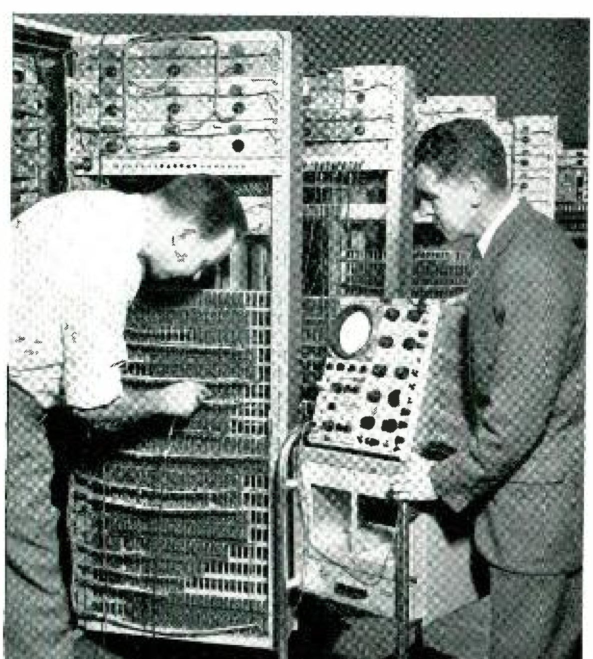
Central control is the nerve center of ESS. It controls the actions of all other major system components and interprets responses from them. To understand the advantages of such an arrangement requires a study of each of these major components. Therefore, we will briefly review each unit and the role it plays in establishing telephone calls.

Requests for service are detected by the "scanner" — the eyes and ears of ESS (RECORD, *May*, 1959). Just as an operator watches for switchboard lamps to light and listens for audible signals, the scanner detects on-hook and off-hook conditions of lines and trunks. Central control tells the scanner which line or trunk to look at, and the scanner, in turn, tells central control whether or not the line or trunk is busy.

The "signal distributor" is one of the muscles of ESS — it causes something to happen within the switching office. For example, a signal is sent to a distant central office, or to an operator's lamp, by a relay in a trunk circuit Thereafter, central control transmits the trunk number, or address, to the signal distributor, along with information as to whether the relay in the trunk should be operated or released. The signal distributor then takes over and directly controls the relay.

The "switching network" may be considered another "muscle" in that it takes action that can be felt outside ESS. This network establishes and removes talking and ringing connections between customers. Incidentally, this muscle has some intelligence, for it can seek an idle path when central control tells it to connect two specific points on opposite sides of the network. Furthermore, it will tell central control whether the attempt has been successful or if all paths are busy, or if one of the network terminals already has a connection to it. Further action is then up to central control.

Short-term memory in ESS is provided by the "barrier-grid store," an electrostatic storage device characterized by its high speed of operation and random mode of storing (RECORD, *December*, 1959). Like some other ESS units, it receives from central control an address telling it where some action should be taken, and an order telling it what the action should be. The orders can be: (1) "read and write 1," (2) "read and write 0," (3) "read and regenerate," or (4) "read and change." On any order, the barrier-grid store transmits to central control, a signal indicating that 1 or 0 was read at the specified location.



G. W. Maymon, left, and the author test terminals on the wiring side of a central-control cabinet.

The brains of ESS are embodied in an operational program stored on photographic plates in the "flying-spot store" (RECORD, *October*, 1959). The operational program consists of a sequence of instructions transmitted to central control one at a time. The flying-spot store is also controlled by central control, from which it receives one of two orders. One order is "advance to the next instruction," the other is "transfer to a specified location." In the second case, an address must always accompany the order.

The Importance of Sequence Control

The flying-spot store always responds by sending central control either an instruction or some translation information on a customer's line or a trunk. It is the high rate of instruction processing and the carefully planned sequence in which instructions are executed that allows one central control to handle all of the traffic and call conditions encountered in a busy telephone office.

The progress through the operational program, instruction by instruction, is controlled by a clock. The period of this clock depends on the operating speed of the slowest unit in the system. Nevertheless, only a few microseconds elapse between clock pulses. On each clock cycle a new instruction is transmitted from the flying-spot store to central control.

Central control must interpret each instruction it receives from the flying-spot store, and prepare those parts of itself that will be involved in the execution of the instruction before the arrival of the next clock pulse. At the same time action is taken on one instruction, a new one is received from the flying-spot store. This overlapping type of operation permits faster execution of instructions. It can only be used, however, if the clock pulses are short with respect to inherent delays in the sequence of registration, interpretation and preparation required for each operating cycle of central control.

An instruction is a binary-encoded word consisting of 19 bits, all sent simultaneously as pulses from the flying-spot store to central control. Here they are registered (or remembered) in transistor "flip-flops" for one operating cycle. A twentieth bit is transmitted as a "parity" bit to detect errors in the instruction. If an error exists, detection circuitry associated with the instruction register tells central control not to execute the instruction. This circuitry then calls into play an error-correction circuit which uses five additional bits sent along with each instruction to correct itself. After correction, central control proceeds with the execution of the instruction in the normal manner.

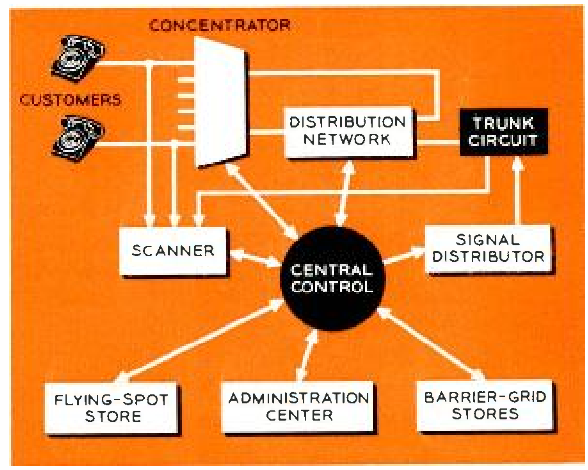
An instruction consists of two parts. The first is the "what to do" part, and the second is the "where" or "to whom" part. There are about 70 different types of instructions central control can interpret, but these are the only instructions that can be used as parts of the operational program. They tell central control such things as "write 1 in the barrier-grid store," "read the scanner," or "transfer the contents of register A to register B." The information telling "where" to write 1 in the barrier-grid store, "which" line or trunk should be scanned and "which" registers are A and B is contained in the second, or address, part of the instruction.

Since central control receives an instruction in coded form, it must decode or translate it to activate those leads that will establish circuit conditions required to execute the instruction. To perform this task, central control uses an instruction translator directly connected to the outputs of the instruction register. It is here that the "what to do" part of an instruction is interpreted. Some 200 outputs from the translator extend to all parts of central control. For any one instruction, however, only a small number of the leads will have active conditions placed on them.

"Flip-Flop" Registers

A large portion of central control consists of flip-flop registers. These are used primarily for very short term, high-speed storage of addresses associated with those in the scanner, barrier-grid store, or switching network that involve a telephone call. These latter addresses are related to telephone calls in process. Most registers consist of 16 transistor flip-flops having "parallel access." This means that the flip-flops are set or reset in various combinations all at once. Similarly, the outputs of all 16 flip-flops are simultaneously available as signals on 16 pairs of leads. Most registers are for general use, but a few have been assigned specific control functions.

Communication between one central control flip-flop register and another, and to parts of ESS external to it, has been provided by a common bus system. Sixteen bits at a time may be transmitted from one central-control register to another, or to the barrier-grid store, the flying-spot store, the signal distributor, or the switching network.

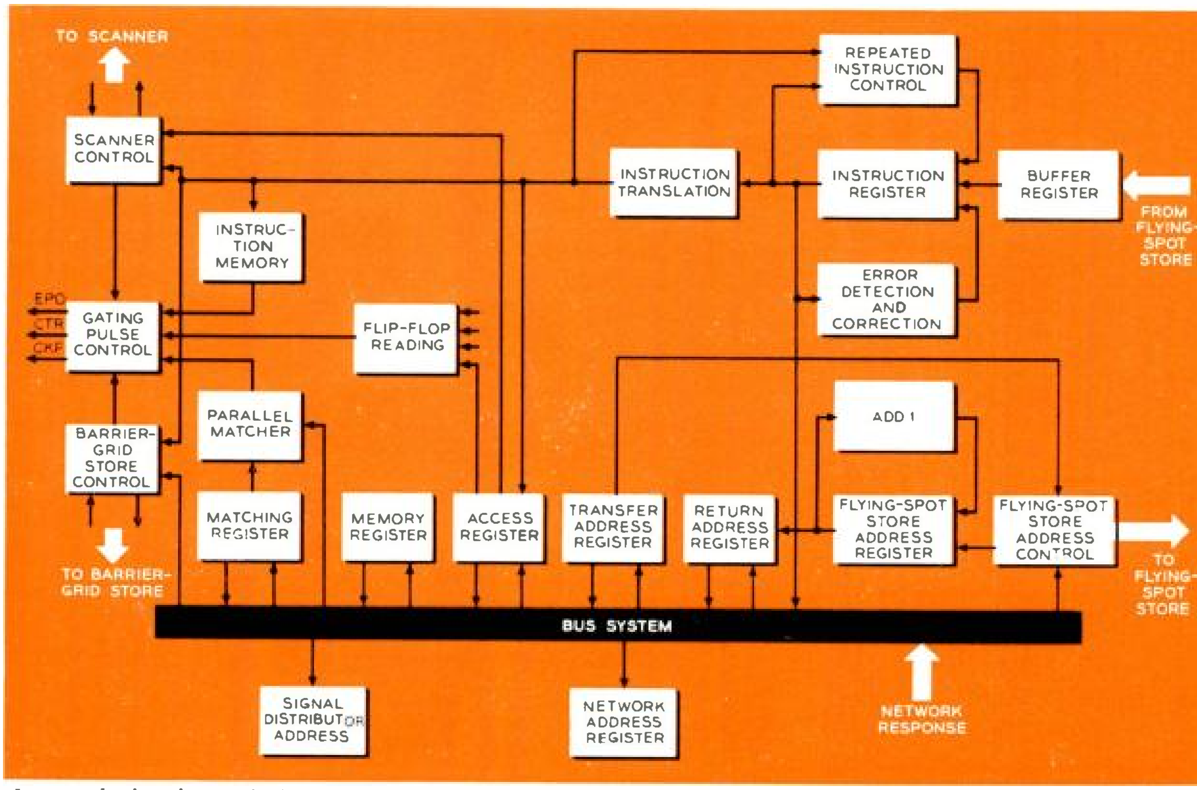


No major device in ESS can carry out its functions by itself. Each needs the help of central control, which communicates directly with all major units, issuing commands and receiving responses.

In most cases, the information on the bus leads is an address at which some action is to be taken. A common bus can be used because the information in only one register is transmitted in parallel over the bus during one clock cycle. As indicated in the block diagram on page 52, some central control registers may transmit information to, and also receive information from, the bus. Most special-purpose registers, however, communicate in only one direction.

Let us follow the sequence of events when an instruction from the flying-spot store tells central control to transport information via the bus from one register to another, or from a register to another ESS unit. First, the instruction is registered in the instruction register. Second, it is translated in the instruction translator, causing two leads to become active. One of these sends the signals from the transmitting register to the bus system. These signals will remain on the bus as long as the instruction remains in the instruction register.

The bus leads go many places. One place is a set of "AND" gates associated with the receiving register. A lead from the translator partially activates this set of AND gates which can connect the bus leads to the receiving register. A clock pulse is generated after the above conditions have had time to become established. This pulse, combined with the electrical conditions on the bus representing information, and a signal that the bus should be gated to the specified register causes the flip-flops of the receiving register to be set or reset in accordance with the output of the transmitting register. The clock pulse causes a new instruction to enter the in-



Internal circuitry of the central control for the Electronic Switching System. A bus arrangement permits information to be transmitted both within central control and to certain external units.

struction register and a similar cycle then begins.

The action just described executes what is called a "non-decision" type instruction. This class of instruction tells central control to do something — don't ask any questions, just do it. A second general class of instructions is called "decision"-type instructions. These always ask questions, although they may also tell central control to do something at the same time.

"Decision" Instructions

The purpose of asking a question is to obtain information upon which a decision can be based. The answer to any question is expected to be only one of two things. For example, the response to a decision-type instruction — "read the barrier-grid store" — can only be 0 or 1. Also, the scanner can only tell central control whether a line is on-hook or off-hook. Or, the response to a "match" order can only be an indication that two numbers either do or do not match each other.

In response to a decision-type instruction, central control takes one of two alternative actions. First, it may ask the flying-spot store for the next adjacent instruction in the operational program. Second, it may tell the flying-spot store to transfer to an entirely different part of the program. These actions are brought about when central control transmits either an "advance" or "transfer" signal to the flying-spot store. The location or address in the flying-spot store to which a transfer is to be made must accompany a transfer signal.

The process of carrying out a decision type instruction consists of two parts — first the question is asked, and second the decision is made whether to advance or transfer. This is done in two operating cycles. For example, a decision instruction may be "read and regenerate the barrier-grid store at a given address and transfer if the reading is 0." Implied in this instruction is the statement: "advance if the reading is 1."

At the end of the first operating cycle, the barrier-grid store receives the address and the order, "read and regenerate." About half way through the second cycle it pulses back to central control an answer, which is registered by a flip-flop. This information is then transmitted to a gating-pulse control where diode logic determines what kind of signal should be sent to the flying-spot store at the end of the second cycle.

At the end of the first cycle, however, a new instruction enters the instruction register, destroying the information upon which a decision must be based. For this reason, designers provided an instruction memory which remembers, for an additional cycle, those parts of an instruction needed to make a decision.

The gating-pulse control will generate one of two clock pulses. If the response from the barrier-grid store does not result in a transfer, an "execute-present-order" signal sends an advance pulse to the flying-spot store and also executes the instruction currently in the instruction register. If, however, the barrier-grid store reads a 0, a conditional-transfer clock pulse is generated. In this case, a transfer pulse goes to the flying-spot store along with a previously determined address in the transfer register. Thus the data currently in the instruction register is not used.

All decision instructions involve readings from the barrier-grid store, the scanner, various flip-flops, or matching operations. Therefore, the parts of central control contributing information to the gating-pulse control, or decision-making logic, are the barrier-grid store control, the scanner control, the flip-flop reading circuit, and the matching circuit. The last permits information on the bus leads to be matched against data in one of the memory registers. Thus an address of up to 16 bits in any register which has access to the bus may be compared with a predetermined number.

Engineers in the "Morris Laboratory" area of the Whippany location of Bell Laboratories perform tests on the circuitry of the central control.

Checks on Information Transfer

In going through the operational program, central control should know in what stage it is at any time. For this reason, the address register in the flying-spot store has, at all times, a record of the location of the instruction currently in the instruction register. On every flying-spot store transfer, the same address gated to the store is gated to central control's address register for the store. Thereafter, each time an advance pulse goes to the flying-spot store, its address register adds one to the count.

Another action that takes place during transfers in the flying-spot store is one in which the address in the flying-spot store's address register is transmitted to the return-address register. This is the address *from* which the transfer is made. It permits the free use of "subroutines" in the operational program. If a subroutine would be advantageous during a sequence of operations in the program, the flying-spot store "jumps" to the location at which the subroutine is stored and performs the operations called for there. Then it can jump again to the address stored in the return-address register. This brings the flying-spot store back to the point in the main sequence it left to perform the subroutine.

In addition to instructions on the operational program, the flying-spot store also contains translation information on customers' lines, trunk locations, and call routing. This is brought into a central-control register through the instruction register. Since this type of information would confuse the instruction translator, however, a sequence-control circuit in central control inhibits any output from the translator. It also shuffles the translation information from the instruction register to a memory register under its own control, and controls the process of error correction.

The versatility and high speed of central control, combined with its flexible and powerful operational program, permits all of the basic telephone-call functions to be performed rapidly and accurately. The nucleus of an electronic switching system, it is probably the busiest unit in an ESS office. It is certainly one of the most efficient.

Stringent requirements for electron tubes—especially for new long-life tubes to be used with underseas cables—require precise control of the chemical composition of nickel employed in cathode structures. Metallurgical research has produced nickel cathode materials of such high purity that undesirable thermionic characteristics associated with certain impurity levels have been largely eliminated.

K. M. Olsen

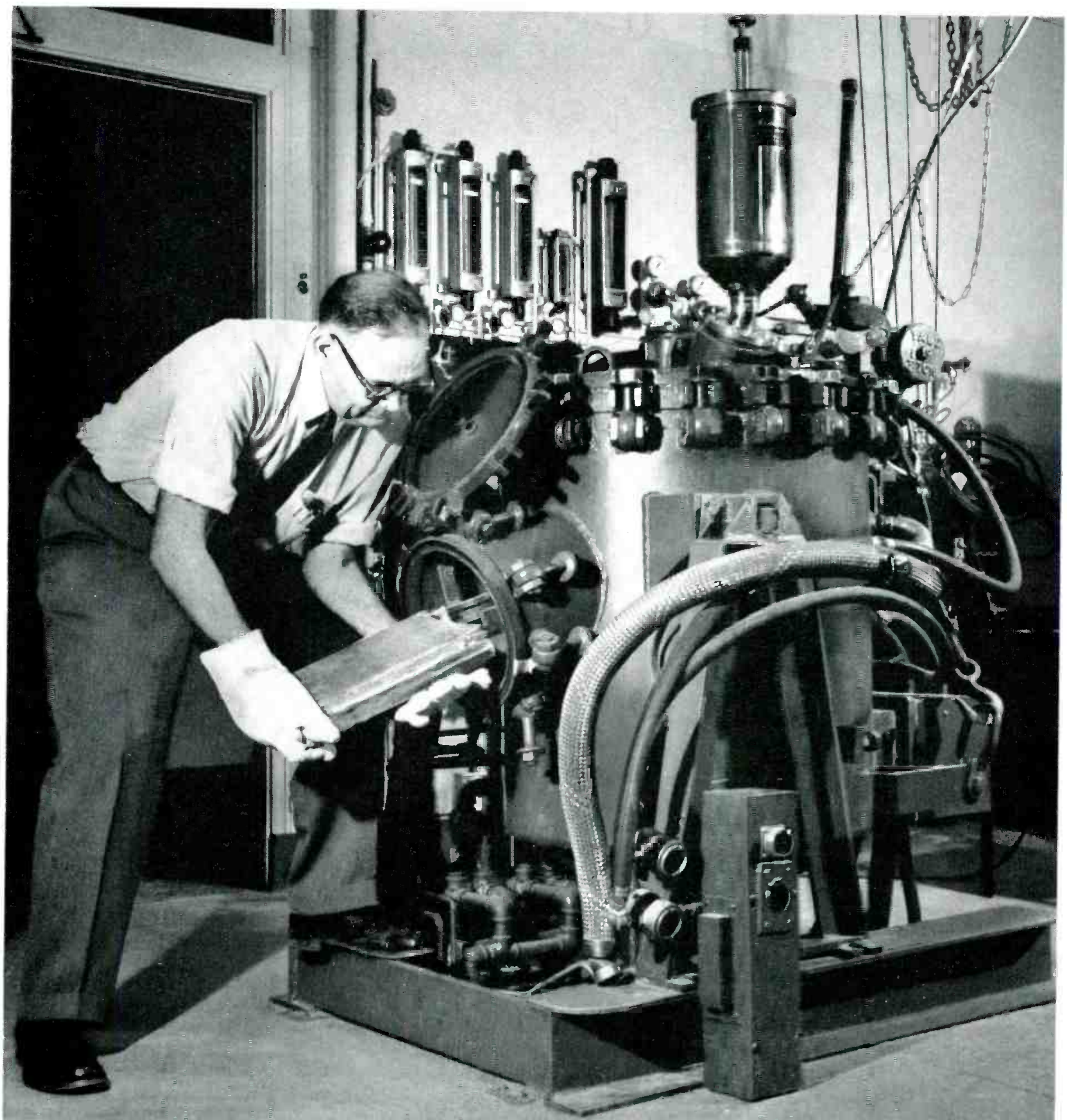
HIGH-PURITY NICKEL

A great many of the vacuum tubes used in the Bell System contain oxide-coated cathodes which, on being heated, emit electrons. These cathodes usually consist of a specially selected nickel base, to which a mixture of barium, strontium and calcium oxides has been applied.

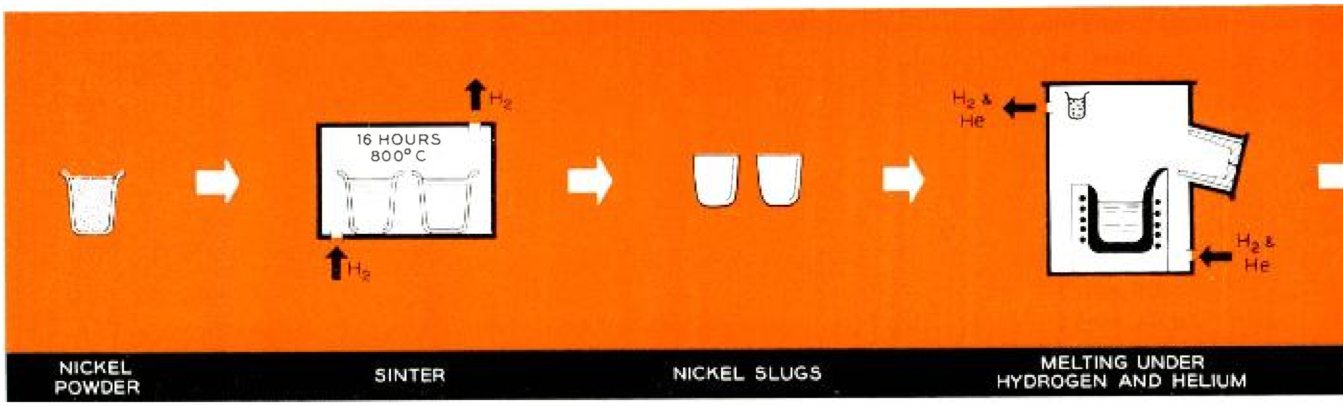
The composition of the nickel base material is an extremely important factor in the quality of the vacuum tube. Studies at Bell Laboratories and elsewhere have shown that, to a large extent, impurities in the nickel determine the level of electron emission and the length of time a given emission level can be maintained. As little as 0.01 per cent by weight of such impurities as magnesium, carbon and silicon markedly influences emission properties. Impurities are not necessarily objectionable, however. In fact, pure nickel alone has poor emission characteristics, and specific amounts of beneficial impurities are required to obtain the desired properties.

A critical research appraisal of the effect of each impurity element on cathode emission has not been successful heretofore, mainly because of the lack of high-purity nickel. There have been many attempts to prepare such materials in which the few hundredths of a per cent of the added impurity element was the sole major constituent. The main difficulty has been that sound ingots of nickel are difficult to prepare unless "de-oxidizing" or "de-gassifying" elements — such as magnesium, manganese, silicon or carbon — are added to the molten nickel before casting. If these additions are not made, the resulting ingot will usually be "gassy"; that is, the ingot will contain a myriad of bubbles produced by the evolution of gases as the casting solidifies. An additional obstacle to maintaining high purity is contamination of the nickel from the crucible during the melting and during the long process required to fabricate the ingot into cathode structures.

Impurities from these sources, as well as those present in the raw material, produce nickel with a composition that may vary over rather wide limits. For this reason, the suitability of a certain melt or lot of commercial nickel for a particular cathode application can only be determined by a "prove-in" vacuum-tube life test. Acceptance or rejection of the lot is based on performance of the nickel cathode in the test. Until recently, this empirical procedure has been adequate for locating nickels to satisfy most cathode requirements. However, new designs of vacuum tubes are placing more stringent performance and life requirements on the cathode. This is especially true in the new submarine cable tube, which must have long life and must operate at higher fre-



P. H. Schmitt removes an ingot of high-purity nickel from the controlled-atmosphere melting furnace.



quencies and greater bandwidths than the tube now in transoceanic service. These new requirements have further emphasized the need for improved cathode nickels whose impurity content is rigorously controlled.

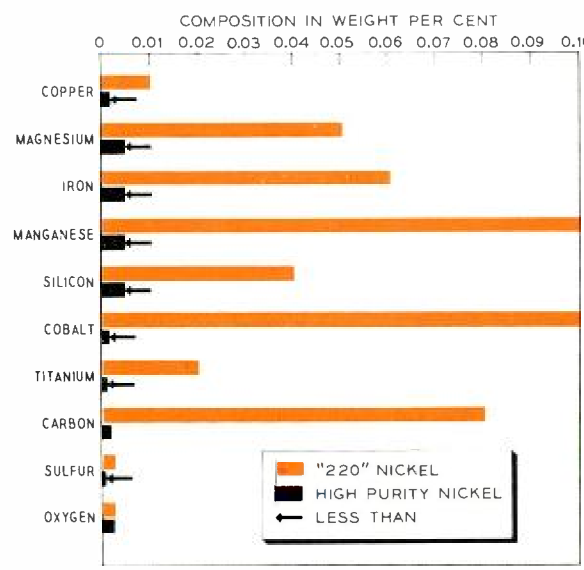
This article describes the metallurgical work which has successfully produced over 1500 pounds of high-purity nickel containing controlled additions of desired elements. Thus, there are now available for the first time high-purity nickels for fundamental research studies, and also new cathode materials for evaluation in the development program directed toward the new submarine-cable tube.

A survey of raw materials revealed that a powder made by the Mond Company of England was the purest nickel that was commercially available. Selected 1000-pound lots of this material were obtained through the cooperation of the International Nickel Company. A typical analysis shows an impurity concentration of 0.004 per cent iron with all the other impurities at 0.001 per cent or less, except oxygen (0.2 per cent) and carbon (0.07 per cent). The relatively high oxygen and carbon contents are not considered objectionable, since they can be reduced to a satisfactory low level by heat treatment in hydrogen.

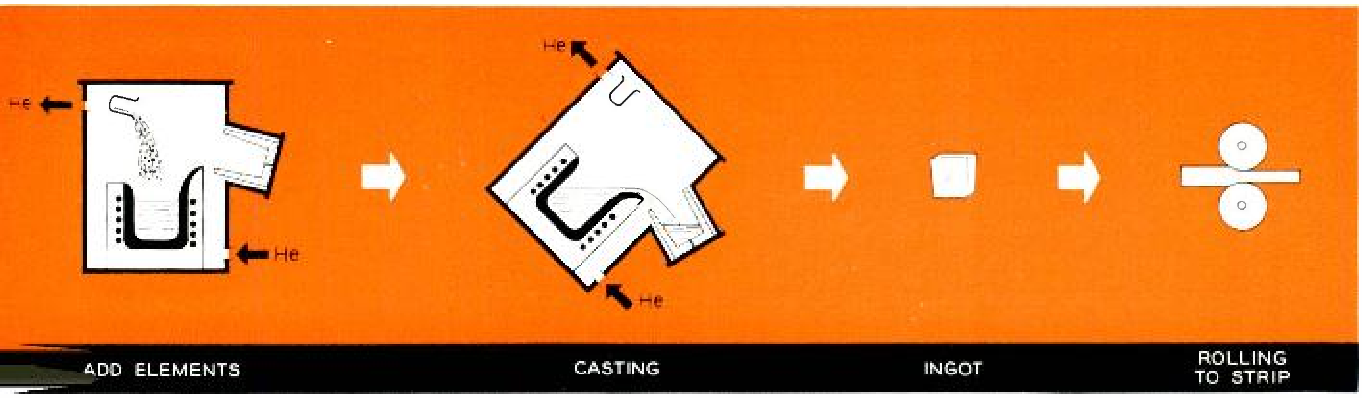
A special controlled-atmosphere furnace has been successfully used in preparing high-quality, soft magnetic alloys, and for this reason it was also used in the work on nickels. This furnace is equipped to permit melting and casting under a great variety of conditions—in wet or dry hydrogen, in inert atmospheres, under partial or atmospheric gas pressures, under continuously flowing atmospheres, in vacua of about one mm of mercury, or under any desired sequence of atmospheres. Past experience also indicated that minimum contamination from the crucible might be expected if a crucible of magnesium oxide was used. An induction coil operating at a frequency of 1920 cycles is used for heating and melting the nickel in the crucible.

Attempts to melt the powdered nickel or compressed bars of the powder resulted in gassy ingots. No improvement was obtained by melting under hydrogen, vacuum, helium, argon or various sequence combinations of atmospheres. However, further studies indicated that sound ingots could be prepared if the carbon and oxygen content of the powder were reduced to sufficiently low levels. This suggested that it would be beneficial to pre-treat the powder before melting.

The procedure eventually developed enabled preparation of sound ingots without using additives: the nickel powder was sintered to form nickel slugs by a wet hydrogen treatment at a low temperature for a long period of time. This



Color bars show impurity levels of a good commercial nickel. Black bars show greatly decreased concentrations in nickel made at the Laboratories.



step, carried on at 800°C for 16 hours reduced the oxygen content and lowered the carbon from about 0.07 per cent to about 0.007 per cent. The sintered slugs were then melted down in dry hydrogen in the controlled-atmosphere furnace. During melting, a steady flow of hydrogen was maintained at 20 cu. ft. per hour. After a 10-minute period to allow the molten charge to reach a stable temperature of about 1500°C, the dry hydrogen was purged from the furnace with dry helium, and all gases were removed by evacuation. Next, dry hydrogen was reintroduced for 15 minutes to effect a further reduction of the small residual quantities of carbon and oxygen in the melt, and the hydrogen was then purged again with helium and subsequent evacuation. Helium was then reintroduced to establish a flow of 20 cu. ft. per hour at a pressure of one atmosphere.

If high-purity nickel with no addition is desired, the molten charge is at this point poured into an alundum-coated steel mold. Careful processing into strips will provide a nickel of exceptional purity as shown in the bar graph. Bars are also shown for a commercial grade of cathode nickel to illustrate the marked difference in impurity content. The purity is such that no single element is present in amounts exceeding 50 parts per million (0.005 per cent by weight).

On the other hand, if nickel containing other elements is desired, the additions are made at this time, using a hopper device actuated by external controls. After allowing 3 to 5 minutes for complete solution of the added elements, the molten charge is poured into the ingot mold. Ingots produced in this manner weigh 26 pounds and are 1½ inches thick.

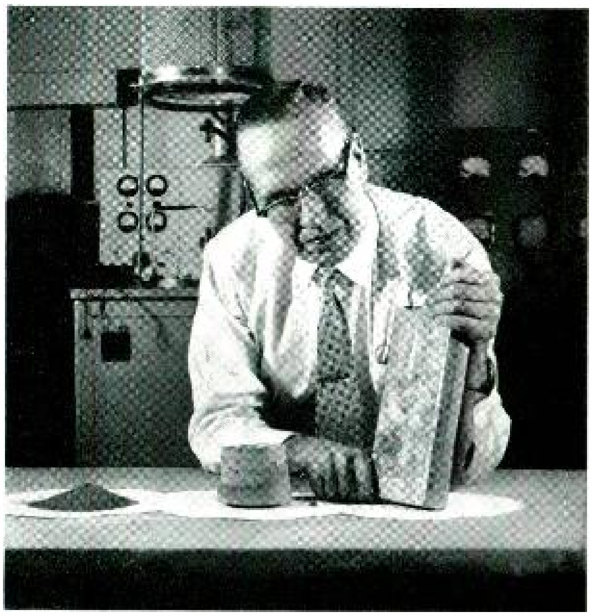
Careful processing controls and good housekeeping practices are required to avoid contamination during fabrication of the ingot into strips. The ingots were hot rolled in air at 1000°C to a thickness of ½ inch and the surfaces were then machined to remove the oxide scale. Cold rolling was employed to reduce the thickness further to 0.08 inch. The strip was then annealed at 800°C in hydrogen. After annealing, the strip was cold rolled to 0.020 inch, annealed again, and finally rolled to finished strip having a thickness of 0.003 inch. A clean Inconel tube was used for the annealing treatments. Special rolls were reserved for rolling, and pure kerosene was used as a lubricant during rolling to minimize contamination from this source. Lubricants and other surface contaminants were carefully removed prior to each anneal.

With these procedures, it has been possible to fabricate strip material from ingots of nickel containing added elements and still maintain the degree of purity shown in the bar graph.

Nickels containing low-concentration, single additions of silicon, titanium, magnesium, manganese, boron, zirconium, cobalt, carbon, and oxygen were prepared for research studies. For the development studies of cathodes in the new submarine-cable tube, high-purity nickel strip containing the following additives was prepared:

- aluminum 0.03 and 0.1 per cent (by weight)
- magnesium 0.03 and 0.1 per cent
- tungsten 0.02, 2.0 and 4.0 per cent
- tungsten 2.0 per cent with magnesium at 0.02 and 0.03 per cent
- tungsten 4.0 per cent with magnesium at 0.02 and 0.03 per cent

Very promising results have been obtained for the nickel — 2 per cent tungsten material both with and without the addition of magnesium. Cathodes constructed with these nickels have shown encouraging life expectancy and stability of electron emission on tests which have been running for more than 15,000 hours.



Nickel powder, left, and sintered slug, center. At right, author holds ingot of high-purity nickel.

The significant results of the submarine-cable tube evaluation have led to a similar study of high-purity nickel cathode materials by the Electron Device Development group at the Allentown, Pa., Laboratories location. Early life-test results using several types of standard W.E. Co. vacuum tubes also indicated that good emission properties are obtained in cathodes of high-purity nickel containing 2 per cent tungsten and 0.025 per cent magnesium. Pilot production of tubes using this new material is under way at the W.E. Co. Allentown plant, and field trials are to be run on these commercially produced tubes. In addition, arrangements have been made with the Metals Manufacturing Division of the W.E. Co. at Hawthorne, Illinois, to undertake a development program aimed at large-scale production of this high-purity cathode material.

Metallurgically, these new nickel materials represent another interesting case of how materials should be prepared for fundamental studies. In the past, and to some extent even today, the nature of complex metallurgical structures and their associated properties could only be studied by more or less "cut and try" methods. However, Laboratories experience — especially with semi-conductors used for transistors — has shown the value of first refining the base material to the purest state possible. Then by adding other elements systematically, research can arrive at a quantitative understanding of precisely why materials behave as they do.

In a few years, transistorized digital computers will dominate electronic computing. Engineers at Bell Laboratories have made significant contributions to the wane of the electron-tube computer by the development of the small, yet versatile and reliable "Leprechaun" transistor computer and its predecessor, TRADIC.

LEPRECHAUN

The modern computer, despite the almost mystical powers sometimes attributed to it, is nevertheless only a tool — an extension of man's abilities. Computers extend man's ability to do mathematical calculations by enabling him to solve complex problems very rapidly and extremely accurately. Until recently, however, these computing tools had to be very large to be versatile, and this led to the serious disadvantage of immobility. The tool could not be taken out on the job, so to speak.

An obvious answer to this problem of immobility was the use of transistors in the design of electronic computers. In 1951, Bell Laboratories undertook for the Air Force an investigation of the feasibility of using transistors in a digital computer. The computer was to be used for performing the computations required by a modern bombing and navigation system.

This exploratory development program, known as TRADIC (TRansistorized Airborne DIgital Computer), was divided into several phases. In the first phase, a feasibility computer was built — the first transistorized computer to go into operation. This pioneer solid-state machine is

J. A. Baird

COMPUTER

known simply as the TRADIC Phase I Computer (RECORD, *April*, 1955; *September*, 1958).

The second phase, beginning in 1954, was divided into two parts: (1) the design and construction of a TRADIC Flyable Model, and (2) a research and exploratory development program which has been called TRADIC Computer Research. This portion of the program has been aimed broadly at exploiting the capabilities of new solid-state devices for airborne computers. One of the important results of this computer research program has been the second TRADIC Feasibility Computer, named "Leprechaun."

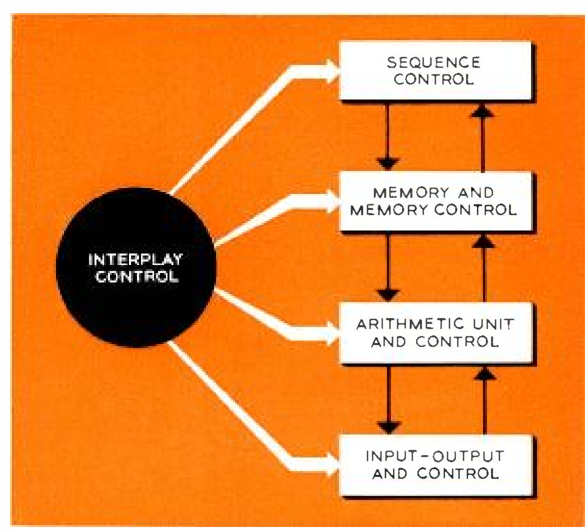
At the time the Phase I machine was completed, the computer art and the solid-state art were both advancing very rapidly. New junction transistors with excellent switching properties gave promise of circuits that would operate at lower powers and would require fewer auxiliary components than the point-contact transistor circuits used in the first TRADIC. Also, new magnetic materials and new high-speed, high-current transistors opened up the possibility of designing memory units that are compact yet able to store relatively large amounts of data.

On the basis of these promising devices, the computer research program was directed toward the development of basic computer circuits using junction transistors, and storage units of the magnetic-core type controlled by transistors.

Interest in storing a lot of data in magnetic cores was twofold. First, it could answer such technical questions as, how large a memory (how many cores) can be switched by transistors? And second, if a relatively large-capacity memory could be built, it might uncover some of the problems associated with the storage of computer programs for performing bombing and navigation calculations.

Earlier basic computer circuits, designed on the "building-block" principle, used germanium diodes to perform the logic or switching function of the computer, and used point-contact transistors to amplify and reshape signals as they passed through the computer. Newer, alloy-junction transistors made good switches as well as amplifiers, and a number of groups at the Laboratories began to explore the possibilities of using these transistors for both purposes.

While this investigation was in progress, the Philco Radio Corporation announced the development of a complete set of very simple computer building blocks. These circuits used only resistors and one type of transistor. They called this development "direct-coupled transistor logic" (DCTL). The techniques suggested here, especially the extreme simplicity of the basic



Block diagram showing the major elements of the Leprechaun computer and their relationship to each other. Interplay control is essentially the master control unit of entire computing system.

circuit, seemed to be well suited to the design of airborne computers.

Despite the simplicity and adaptability of DCTL, successful operation of the circuits depended heavily on the specification of an appropriate transistor. Considerable effort was therefore directed toward establishing a sound theoretical foundation for two fundamental concepts: transistor specifications and the resulting rules for logical design of the computer.

The most important reason for adopting and developing DCTL circuitry was to try to realize maximum circuit reliability. DCTL could help do this by reducing power requirements and by minimizing the types of components. As usual, however, advantages do not come without some accompanying disadvantages. DCTL circuits operate at very low voltage, but at relatively high currents. When these high currents are switched among many transistors and in complex patterns, the voltages generated in the interconnecting ground circuits can produce unwanted signals (noise).

The Noise Problem

The point at which noise signals enter the system depends on the relative physical location of the transistors being switched. And the switching pattern is a very complex one, depending on such things as the actual numbers being processed by the computer. This meant that an analytical approach to the noise problem could give only a first-order solution. Limited laboratory experiments in noise analysis indicated that it would be necessary to test circuits containing almost as many transistors as an entire computer to get a true picture of the noise problem.

This conclusion prompted military systems engineers and the Air Force to give serious consideration to the construction of a complete computer. Such a computer could test jointly the use of a small-sized, large-capacity, magnetic-core memory, and the use of direct-coupled transistor logic for computing and control. The fact that Bell Laboratories had a contract to develop the bombing and navigation system for a new tactical bomber provided the clinching argument.

The proposed computer would provide fundamental information for the design of the new bombing and navigation system, and would furnish a tool on which the problems of programming and system organization could be studied. But basically, the experimental computer was to be designed with features which would make it useful for programming studies and for the evaluation of computer design techniques.

Leprechaun — the machine which resulted from this decision — is a general-purpose, stored-program, digital computer. It computes with binary numbers, performs operations on the digits of a number in parallel, and in its over-all operation it is asynchronous. This means it has no set time pattern for performing certain operations. Leprechaun can store 1,024, 17-bit words, including a "sign" bit that identifies numbers as positive or negative. An 18th "parity" bit is also stored to check memory operations.

The computer can extract a stored word in 20 microseconds, and it can perform repeated additions of numbers in 40 microseconds. Multiplication requires about 350 microseconds, and division about 430 microseconds.

The computing portion of Leprechaun has about 5,500 transistors, 3,000 resistors, 50 capacitors and 40 delay lines. The memory is made up of 18,000 magnetic cores and about 75 associated transistor circuits. Leprechaun is about the same size as a large console television set — about 15 cubic feet. And it consumes only slightly more power: about 250 watts.

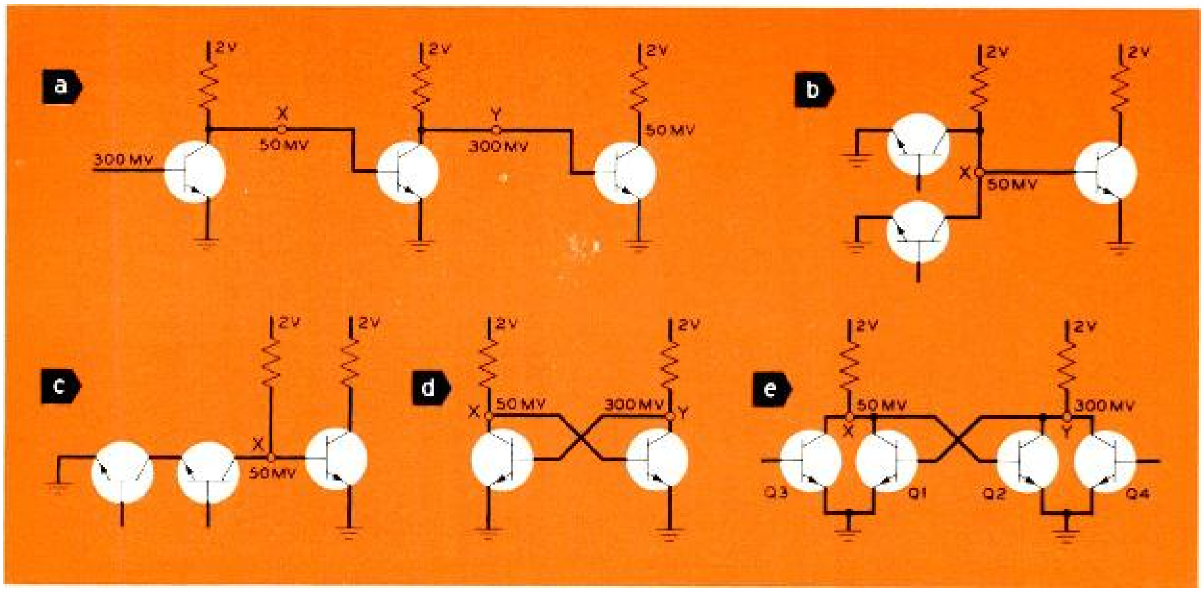
In the large, Leprechaun consists of an arithmetic unit, a memory, an input-output arrangement, a sequence control and an interplay control. The relationships of these units are shown in the block diagram on the preceding page.

Except for the memory and input-output these are not physically separate units. Also, each functional unit has a certain amount of control, which emphasizes the system's asynchronous operation.

The memory and memory-control section includes the core memory and the circuits that furnish access to it. Sequence control keeps track of the program instructions, provides the memory with "address" information, and handles words which have been read from or are being written into storage.

During actual calculations, the numbers are manipulated in the arithmetic unit (and control). Men or other machines communicate with the computer through the input-output arrangement. A master control unit — the interplay control — keeps track of the activities of the other units, and ensures that a section of the computer completes one task before beginning another. It also ensures that a unit will be kept busy until forced to wait for some other unit.

This control unit, and the other units in Leprechaun except for circuits directly associated with the memory, use DCTL. Since the language



Circuit diagrams show how the two voltage levels for "zero" and "one" are achieved (a), and shows the derivation of DCTL circuitry (b through e). Inputs are 2 volts and all resistors are 500-ohm.

of Leprechaun is binary, the circuits must be capable of representing two numbers: zero and one. In DCTL, zero and one are represented by two voltage levels. The lower level is determined by the collector voltage of a heavily conducting transistor, and the higher level by the base voltage of another heavily conducting transistor.

The details of this principle can be explained by reference to the circuit diagrams on this page. The simple circuit at the top (a) shows three transistors connected in tandem with their emitters grounded. If 300 millivolts is applied to the base of the first transistor, nearly 4 milliamperes of current will flow in the collector, and the voltage at point X will drop to about 50 millivolts. When applied to the base of the second transistor, this voltage will cause only a small collector current to flow, and the voltage at point Y will tend to rise toward the applied voltage of 2 volts. But the voltage is prevented from doing so by current flowing into the base of the third transistor. In fact, this current flow prevents point Y from going above the 300 millivolts originally applied.

In Leprechaun, the voltage nearest ground (about 50 millivolts) arbitrarily becomes a "one" and the voltage furthest from ground (about 300 millivolts) is a "zero." The determination and control of these voltages depends particularly on the junction characteristics of the transistor rather than on the design of the circuit.

With these two-level (bi-state) arrangements, computer logic — the manipulation of numbers in the computer — can be performed by connecting the transistors in series or in parallel. In the parallel arrangement (b in the series of diagrams) the voltage at point X will be brought near ground if *either* of the two transistors at the left is conducting. In the series circuit (marked c), point X will be near ground only if *both* transistors are conducting. This circuit imposes more stringent requirements on the transistor, since the voltage drop across the two transistors in series must be low enough to prevent the following stage from conducting. For this reason, Leprechaun was designed to avoid the series configuration in most cases.

Making "Flip-flop" Circuits

"Flip-flops" — circuits which act as "scratch pads" for temporarily holding information, and which can be erased or "reset" — can be made by connecting the output to the input of two of the tandem stages (circuit a) shown in the diagram. This has been done in the center arrangement (circuit d) in the bottom row.

To change the state of the flip-flop by an external signal — in other words, to set or reset it — two parallel transistors (Q3 and Q4 in circuit e) are added. In this arrangement, if the base of transistor Q4 is raised from 50 to 300 millivolts, the flip-flop will change state, and point X will go to 300 millivolts while point Y will go to 50 millivolts. These voltages, which represent bits of information, are then held in the flip-flop until "read-out." If necessary, the flip-flop is then reset.

These DCTL circuits are the basic building blocks for performing the switching or computing functions in Leprechaun. Their configurations are so simple that they make possible some very interesting physical designs.

Physically, the basic package in Leprechaun is the "book." Each book has four "leaves," arranged roughly in the form of a "W." The two leaves in the center are back-to-back with a common "ground plane" 7 inches high by 9½ inches long. On this metal plane, 360 transistors are mounted on each side, in an array of 20 columns and 18 rows. The emitters of all of these transistors are connected to the ground plane, and the base and collector of each transistor are brought out to a pair of taper-pin receptacles.

The two hinged, outer members, one of which is shown in the photograph below, are alike. Each contains 128 transistors with all three terminals — base, emitter and collector — brought out to taper-pin receptacles. Each also includes 252 resistors of 510 ohms with one terminal connected to a 2-volt bus and the other terminal brought out to a taper-pin receptacle. A few resistors have both terminals brought out to taper-pin connectors. The resistors are in the center portion of the outer leaves.

The author, right, and J. A. Githens check the control panel of Leprechaun. A leaf of one of the books, with circuit patching cords installed, is swung out behind Mr. Baird. Memory is on top.

Interconnecting Circuit Elements

Computer circuits like gates and flip-flops are formed by interconnecting the terminals of the resistors and the transistors with taper-pin connectors. The arithmetic unit, for example, is made up by interconnecting resistors and transistors on one of the books. It consists of several registers, an adder and gates for transferring numbers between the registers and the adder. To perform calculations such as addition and multiplication, the control portion of the arithmetic unit causes these gates to operate in the proper sequence. A 17-bit number can be held in a register made up of 17 flip-flop circuits. Gates are made up of circuits similar to b and c in the diagrams discussed earlier.

As mentioned, Leprechaun has a magnetic-core memory. The actual storage element is a small toroidal core of magnetic material, 0.08 inch in outside diameter, and 0.05-inch inside diameter. This magnetic material has two stable magnetic states and can be switched from one to the other by about 350 milliamperes of current in a single turn of wire, or half that in two separate single turns of the proper polarities.

The cores are arranged in a rectangular array, 16 by 64, to form a "memory plane," shown in the photograph on the next page. The complete memory is made up of 18 such planes, placed side by side. A number 18 digits long is stored with one digit in each plane. The first plane, for example, stores the first digit of the words or numbers stored in the array. The total capacity of the memory is 1024 18-digit numbers.

Numbers are "written" into the memory by the transistor circuits which surround the memory planes. These circuits switch the cores to the magnetic state that represents a one or a zero. The words are read out from the memory by simply switching all of the cores in a word toward the zero magnetic state. If a one was stored in a given core, that core will switch and an output due to the change in flux can be detected. If a zero was stored, there is no switch, and no output is detected.

The digits of a number are stored in the same row and column in each of the 18 planes. Half of the switching current for readout is applied to the selected row and half to the selected column, so that only those cores at the selected intersections get enough current to cause them to switch. Numbers are written into memory and read from memory in parallel (simultaneously). A complete cycle of writing and reading requires 20 microseconds.

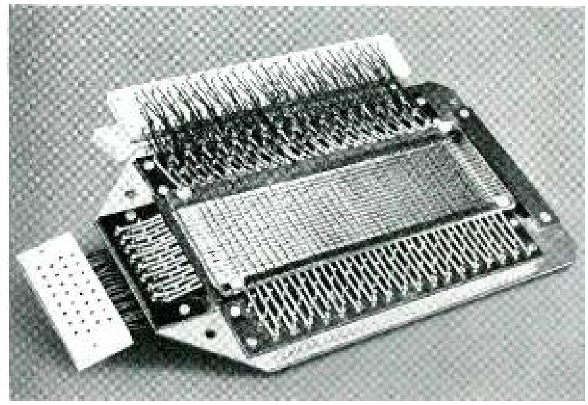
In addition to the memory and arithmetic units, an important part of any computer is the input-output arrangement. Ordinarily, the inputs to an airborne computer would be voltages or shaft positions proportional to some physical quantity, such as air speed or altitude. The outputs would be control signals, voltages, or shafts positioned by the computer. But since Leprechaun was to be used primarily in the laboratory for the evaluation of computer design techniques, programming studies, and as a general-purpose computer, the designers provided it with paper-tape input and output equipment.

The tape has seven rows across it where holes can be punched. A hole represents a one and no hole represents zero. Six of the rows can carry digital information, while the seventh is used for parity, or checking. The information on the tape is "read" by an optical reader. The electrical output from the computer is fed to a teletypewriter punch, which in turn punches the information onto the same type of paper tape.

Input-Output Features

For trouble-shooting, or for other slower-speed output requirements, the output can be typed by an electric typewriter. Conversion equipment has also been built for displaying the output on a cathode-ray oscilloscope. As a secondary method of input, a hand key-punch is provided that can be conveniently used for one, or at the most, a few inputs.

On this input equipment, the programmer punches the program on tapes at a separate tape-preparation unit. The information from the tape, written in a language that Leprechaun understands, is read into the computer and stored in the memory. Words making up the program look just like other numbers, such as constants. The total of program steps, constants and other items stored in memory cannot exceed 1,024. Since instructions are just like data, Leprechaun can modify its own instructions. The 28 basic operations that can be performed by the computer give it a degree of versatility that is more than enough to allow Leprechaun to do the basic weapons-control problem and to make it very useful as a general-purpose computer.



One plane of the Leprechaun memory system. Magnetic cores are at junctions of wires crisscrossing in center. Eighteen such planes, one for each digit and operated by transistor circuits, make up the entire memory system of the computer.

After its completion, Leprechaun was operated under test for approximately 10,000 hours. Most of this time was devoted to an evaluation of the computer. Over 6,000 hours of that time were devoted to special error-checking routines which were designed to check and evaluate errors in computation.

During this operating time, 14 transistors have failed — 2 degraded to the point where they were unusable. The other twelve failed in three separate "events" when related groups of transistors developed shorts between elements, which suggested that the 12 were damaged by transients of unknown origin. Thus, there have been five separate failure events. In addition, 24 transistors have been destroyed during modifications of and additions to the computer. This is one of the hazards of using the machine as a laboratory tool, where frequent changes are allowed.

While operating in the error-detection routine for over 6,000 hours, the machine made a total of about 160 billion operations. Only 22 of these operations were detected to be in error. An error rate of this order demonstrates clearly that although noise and crosstalk must be a design consideration with DCTL, it is not a serious problem. This is one of the important points in the evaluation of Leprechaun.

In April 1959, Leprechaun was delivered to the Air Force and is installed at the Wright Air Development Center at Dayton, Ohio. It is currently being used to solve problems in the evaluation of Air Force weapons systems.

In the exacting art of microwave radio-relay transmission, the over-all capability of a system depends heavily on the high performance of its components. In one of these components, a new electron tube for the TH system, careful attention to subtle design details and judicious integration of tube and circuit have led to a significant advance in tube performance.

T. E. Talpey and N. C. Wittwer

A High-Performance Tetrode for TH Radio Relay

The first installation of a new multi-channel, cross-country communication network — the TH Microwave Radio-Relay System — is scheduled to be placed in service late in 1960, between Denver and Salt Lake City. Intended primarily as a long-haul transmission medium, TH is capable of carrying 1860 simultaneous telephone conversations, or two television programs, on each of its eight two-way, radio-frequency channels. Because of its greatly increased information-handling capacity, the specifications of the TH system are considerably more exacting than those imposed on previous broadband systems (RECORD, *July*, 1957). These requirements have led to the development of many new components with greatly improved performance capabilities.

One of these components, a new electron tube, is a high-transconductance tetrode for the intermediate-frequency (IF) amplifiers. Seven of these tubes provide most of the gain in the TH receivers. This article describes some of the concepts underlying the development of the new tube, and discusses briefly some of the important characteristics. For convenience, we will frequently use the official code of the tube, WE 448A.

The WE 448A is the latest of a series of high-performance tubes that take advantage of the very close element spacings obtainable with frame-type control grids — a construction technique developed at Bell Laboratories (RECORD, *February* 1949; *April*, 1950; *May*, 1954). As this and other design techniques have been improved, it has been possible to design tubes with higher performance characteristics. In most cases, however, the designers have used principles, techniques, and even individual parts which have proved dependable by experience on previous electron-tube designs.

In line with this practice, the 448A uses basically the same control grid, cathode, heater, and mica supports that are used in an earlier Western Electric tetrode, the WE 436A. This use of available parts makes possible a reduction in manufacturing costs and takes advantage of the proven dependability of the 436A input structure.

Before describing the specific design requirements of the new tube, it would be well to outline briefly the general performance requirements of the IF amplifiers.

In TH, the carrier frequencies, which lie between 5925 mc and 6425 mc, are converted at each repeater to an intermediate frequency of 74.1 mc. The IF amplifier must furnish an overall gain of 60 db, with a response curve that is flat to within 0.6 db over a 32-mc frequency band. Included in this amplifier is an automatic gain control (AGC) circuit that maintains the amplifier output at a constant level of 12 dbm, despite variations of as much as 25 db in the input level. In addition to the specific requirements on gain, bandwidth and AGC, the tube for the TH application was required to have a high degree of stability and a relatively long life.

Design Considerations

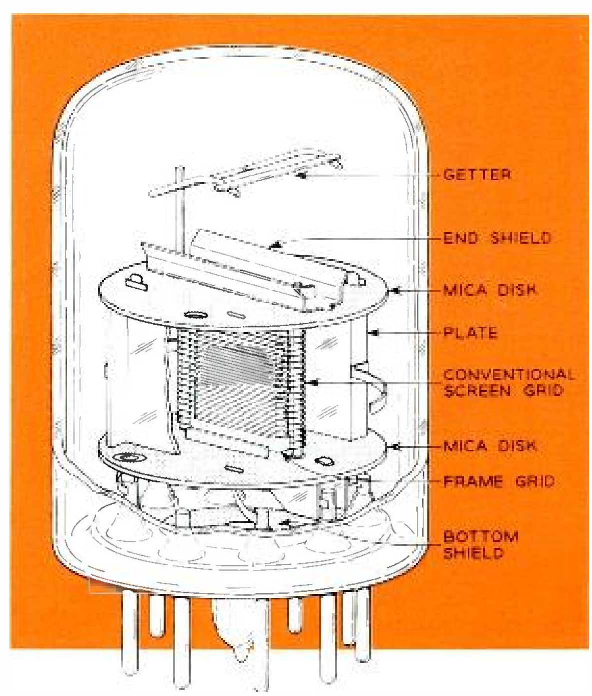
The illustration on this page shows a cutaway view of the 448A. This sketch will be helpful in following the subsequent discussions of tube structure. As the diagram shows, the separation between the screen grid and the plate is much larger than any of the other spacings. Wide spacing makes possible a very low capacitance at the output, since the plate is far removed from the screen grid and the other grounded elements in the tube. Furthermore, the space-charge created by the stream of electrons flowing from the screen to the plate depresses the potential in this region and serves to suppress the passage of secondary electrons between the plate and the screen.

A tube that uses this type of secondary-emission suppression is called a "critically-spaced tetrode," because there is an optimum spacing which yields the best plate characteristic. The plate of the 448A is located near this optimum. As shown in the lower half of the illustration on page 66, the plate-characteristic curves of the 448A accordingly lack the typical secondary-emission dip usually associated with tetrodes.

Power-supply considerations for the IF amplifiers dictated the use of a relatively low (135 volts) screen potential in the 448A. This requirement was met by using a control-grid-to-screen spacing of only 0.014 inch — the minimum which was considered practical in this structure, consistent with adequate mechanical clearances. Since element temperatures above certain values are known to have an adverse effect on tube life, the use of the lowest possible screen-grid voltage in the 448A and the resulting low screen dissipation should also contribute to long life. This prediction is supported by life data taken on development models which have been operating continuously for over 25,000 hours. (*See cover.*)

During the development of the 448A, a careful study was made to determine the optimum arrangement of the basing pins and the leads that connect these pins to the various tube elements. The inductance of the cathode lead was of major importance in this study because at high frequencies the signal voltages developed across the inductive reactance of the cathode lead cause a feedback effect. This effect in turn produces a resistive loading on the circuit connected between the grid and cathode leads. Resistance loading of this type is undesirable since it is frequency sensitive and since the interstage transformer connected to the grid is designed for termination in a constant resistance.

To minimize the loading effects of cathode-lead inductance, it was necessary to design the tube with the lowest possible value of cathode-lead inductance. The arrangement adopted for this



A cutaway view of the WE 448A, showing the frame-grid construction and the other tube elements.

Packaging engineers at Bell Laboratories are using modern components, materials and techniques to effect radical changes in the physical design of electronic equipment. They have recently completed a redesign of certain Bell System networks that will make these units less expensive, more rugged and more reliable than their presently obtainable counterparts.

L. H. Steiff

Redesign of Low-Frequency Networks

In telephone and telegraph transmission, networks are used in prodigious quantities. Indeed, there is hardly an area within the Bell System — from the handset to the central office — which does not make use of networks. In carrier systems, families of networks are used to permit otherwise identical equipment to operate at a variety of frequencies.

Networks are often attached to the equipment with which they are associated. Therefore, a series of standard-sized cans, with standard mounting and terminal arrangements was evolved, and equipment is designed to accommodate these standard-sized cans readily.

It is almost a universal truth that standardization, where feasible, offers production advantages, so about fifteen years ago a method of assembling Bell System low-frequency networks was standardized. At that time, existing components were rather large as compared to equivalent present-day components, and the anticipated demand for some of the "high-demand" types, or codes, was only about four hundred per year. In an endeavor to acquire similar packages and identical production techniques for a wide variety of networks, the design of the low-frequency codes developed into what is now known as the "Stacked Assembly."

The stacked assembly consists of a group of components arranged side by side, wired together, and placed in a standard can of proper size. Where necessary, shims are used between components to fill the can completely. The use of shims enables the can to accommodate a variety of component thicknesses, but the nature of the package dictates that the component length and width be uniform to insure stackability.

To meet this uniformity requirement, inductors, transformers, and inductor-capacitor subnetworks are housed in aluminum cans of the proper length and width, and some capacitor bodies which could normally be quite small, are enlarged to the stackable dimensions.

The stacked assembly has achieved its design objectives — similar packages and identical manufacturing techniques. Although the variety of and demand for networks has increased manyfold, the stacked assembly is still successfully employed in the Western Electric Company Shops.

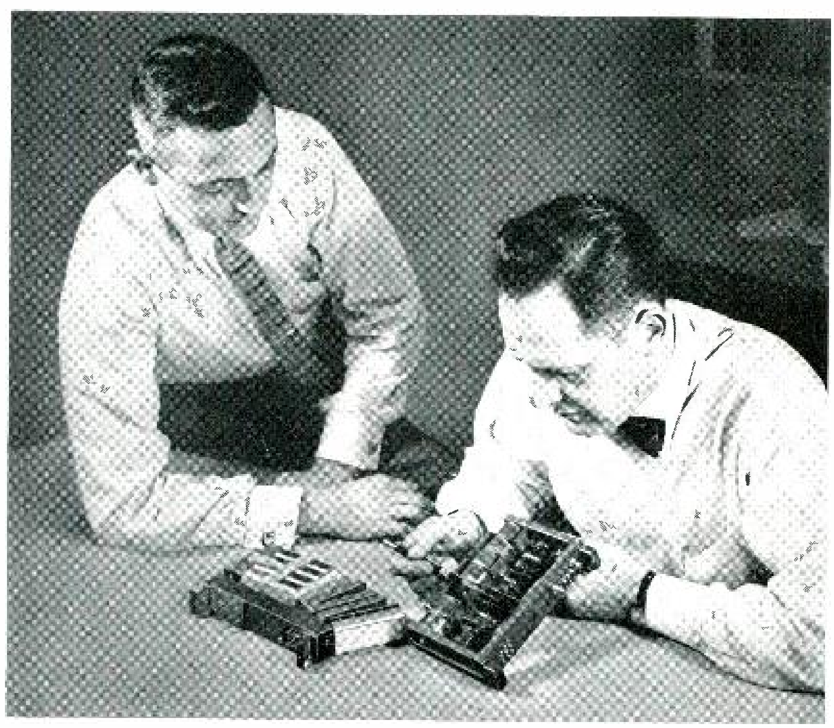
With the advent of modern, miniaturized components and new materials and methods, however, it became obvious that the time for a redesign was at hand. As a result, it was decided to start with the redesign of the 453- and 454-type networks used in the 43A1 Telegraph System. Present demand for these networks is about 50,000 per year. The redesign was agreed upon and carried out jointly by the Western Electric Company and Bell Laboratories at Merrimack Valley, Massachusetts, and is an example of the close cooperation made possible by the existence of the branch laboratory.

The objectives of the redesign were: (1) electrical and mechanical interchangeability with the existing design; (2) lower cost than that of the existing design with no reduction in quality, and (3) the design of standard hardware and techniques that could be employed in the production of other low-frequency codes. Crosstalk requirements for the telegraph terminal are such that any reduction in the can size of the 453- and 454-type networks could not be tolerated. Therefore, miniaturization was not an objective of this redesign.

The task of choosing the proper material and technique rests upon the designer. Literally thousands of materials are on the market, each with its own characteristic properties. Similarly, there is an almost endless variety of techniques which could be employed to hold together the components of an electronic circuit and to give it shape and form. The designer must engineer his selections into a functional package capable of meeting all of the requirements imposed upon it, economic as well as physical.

The redesign began with the premise that modern materials and methods could be used to advantage. After a number of components and materials were investigated with respect to their physical properties, electrical properties and cost, it was decided that the backbone of the structure would be a molded phenolic, U-shaped chassis. Use of this material permitted the replacement of a variety of attached hardware on the existing design with equivalent "molded-in" hardware. For example, attached to the existing design is a connector consisting of a gold-plated coaxial plug, ten gold-plated contact pins, and two guide pins. In the new design, the coaxial

The author, left, and M. Fiore examining the redesigned 454U network. Round components along the left of the new network are inductors and transformers potted in nylon cups. At the left is the standard, stacked-assembly design with uniform cans.



plug and all the pins are molded into the chassis, effectively transforming it into an elaborately shaped connector, capable of housing the entire network. All this is done at a very nominal cost, representing a substantial cost saving compared with that of the stacked assembly. The chassis is shown in the photograph below.

The new design employs a rather unusual technique for mounting all of its pigtail-leaded components. It was proposed by A. Gingrande of the Western Electric Company in connection with his investigation of cost-reduction measures for networks. The leads are cast into a poured epoxy strip, their ends forming terminals. When cured, the epoxy strip becomes a neat, effective mount for these components (*see opposite page*). Its use eliminates the materials and processes usually associated with component insertion, such as terminals, eyelets, and crimping. The strip of components is inserted into a slide in the phenolic chassis and held with two pins.

Inductors and transformers are potted in small nylon cups specifically designed for this purpose. The cups are stacked one upon the other and staked to both sides of the phenolic chassis. The arrangement of the cups and the epoxy strip may be seen in the photograph on page 69, which shows a production model of the 454U network and its redesigned equivalent.

The U-shaped chassis that forms the backbone of the redesigned networks. Coaxial plug and contact and guide pins, upper left, are molded into the phenolic chassis at the time it is formed.

The "canned" inductor-capacitor sub-networks used in the old design are tuned to resonate within very narrow limits of the required frequency. This is necessary to assure operation of the network within its frequency limits. Tuning is accomplished in production by hand-tailoring the inductor to the capacitor with which it is matched. The matched components are then tagged, tied together, and transported to the potting area where they are potted in metal cans. This procedure is both cumbersome and costly.

In the new design, the procedure outlined in the preceding paragraph is entirely eliminated. The new tuning method utilizes two process-adjustment capacitors in addition to the four process-adjustment capacitors used in the current production design. The network is first assembled and connected to a scanning circuit which displays the frequency characteristic on an oscilloscope. A capacitance decade box is then connected to terminals provided for the additional process-adjustment capacitors. Various capacitance values are inserted until the desired frequency characteristic is observed on the oscilloscope. Process-adjustment capacitors are then selected in accordance with the dictates of the decade box, and inserted into the network.

This tuning method permits the assembly of the entire network without hand-tailoring, tagging and tying together of any inductors with their associated capacitors. When one realizes that the majority of the 453-type networks have two such inductor-capacitor sub-networks each, and that the majority of the 454-type have four each, it becomes obvious that the new procedure affords an appreciable cost saving.

An additional advantage, common to about half of the networks, is derived from the use of Mylar capacitors in place of a variety of precision-paper capacitors. The cost of Mylar capacitors is about one-third that of equivalent precision-paper capacitors.

Models were built so that the electrical and mechanical properties of the new design could be evaluated. In selecting a particular code for the model, it was decided that the one most likely to experience difficulty in meeting circuit requirements should be built. The network which operates at the highest frequency is usually considered the one most prone to crosstalk difficulties. The 454U network, which operates at 5.0 to 5.1 kc, was therefore chosen for the models.

The redesigned models met all system requirements and actually surpassed the crosstalk requirement by 10db. When compared to a "standard" network, which is used as a basis of com-

Cast epoxy strip with pigtail-leaded components. Ends of leads are used as terminals. Casting mold, with holes for leads, is shown at bottom.

parison for other networks, the new design offered an 8-db crosstalk advantage.

Physical tests were required to determine the ability of the redesigned models to survive shipment. In the absence of specific shipability tests, the testing group at the Whippany, New Jersey, location of Bell Laboratories contrived a series of tests. The networks were to be subjected to such conditions that it could reasonably be assumed that if they survived these tests, they could be shipped safely. To aid in evaluating the results, the new design and a production-line sample of the existing design were subjected to each test simultaneously. The networks were subjected to a free-bounce test, a shock test, and a vibration test.

Fifteen years of experience have proven that the production-line networks can withstand the rigors of shipment. The redesigned model suffered absolutely no damage in the free-bounce test and in the shock test, whereas the models taken from the production line failed both of these tests; and before failing, the redesigned model endured the vibration test for a considerably longer time than did the production-line model. It was therefore concluded that shipment would not impair the integrity of the redesigned networks.

This case history illustrates some of the problems and the modus operandi of the packaging engineer. As new components and materials are evolved, and as new and more stringent requirements are imposed upon designs, the packaging engineer will play an increasingly important role in the Bell System.

Western Electric Sets Production, Repair Marks

Last year, the Western Electric Company manufactured well over 7,000,000 new telephone sets — the largest number ever made in one year in Bell System history. The new telephone production figure topped 1956's previous high by half a million.

Nearly 3,300,000 general-purpose "500" sets made up a large part of this record total. More than half of the years' new sets were color telephones. In addition, a record 9,000,000 telephone sets were repaired by the end of 1959 — restoring to service some half-million more telephones than were reconditioned the year before.

Western Electric is also producing more varieties of telephone instruments. Wall sets, key sets, and coin collectors, together with the new Princess set and the Call Director telephone, comprised more than half of the 1959 production total.

Volume manufacture of the Princess telephone began at Indianapolis last fall. Initial production is supplying the sets to four market-test areas among the Operating Companies.

Western Electric expects to manufacture over 2,000,000 of these compact new instruments this year.

Popularity of the Call Director among business customers nearly quadrupled its original production program for a total of 71,200 in 1959. This year, according to present plans, some 61,000 Call Director telephone sets will be made.

Western Electric Company's record 1959 telephone production schedule included 2,605,000 wall sets. Shown here is the final assembly area in Western Electric's Indianapolis Works.

NEWS

A.T.&T. President Kappel Reports Successful Year in 1959; Prospects Good For 1960

"The Bell System had a successful year in 1959 and prospects for 1960 are good," Frederick R. Kappel, president of A.T.&T., said in a year-end statement. "By successful I mean that people used more of our services than ever before — quite a lot more; we introduced numerous service betterments and also operated more efficiently; and we made a much-needed improvement in our level of earnings."

Mr. Kappel reported that the increase in Bell telephones in 1959 will be well over three million and may possibly equal or exceed the previous record gain of 3,264,000 in 1946. Long distance conversations are up about 10 per cent over 1958, he said, with the year's total expected to exceed three billion. "By comparison, we handled about two billion long distance conversations five years ago and a billion-and-a-half 10 years ago," he noted.

Among principal 1959 service improvements, Mr. Kappel cited the expansion of direct distance dialing, opening of a second transatlantic cable linking this continent directly with continental Europe, and the introduction of more convenient and attractive telephone instruments. Direct distance dialing greatly speeds up long distance telephone service. About 15 million customers can dial their own long distance calls now, compared with about 8 million at the end of 1958.

"We are giving special attention to the communications needs of our business customers and we expect to step up this effort in 1960," Mr. Kappel also stated.

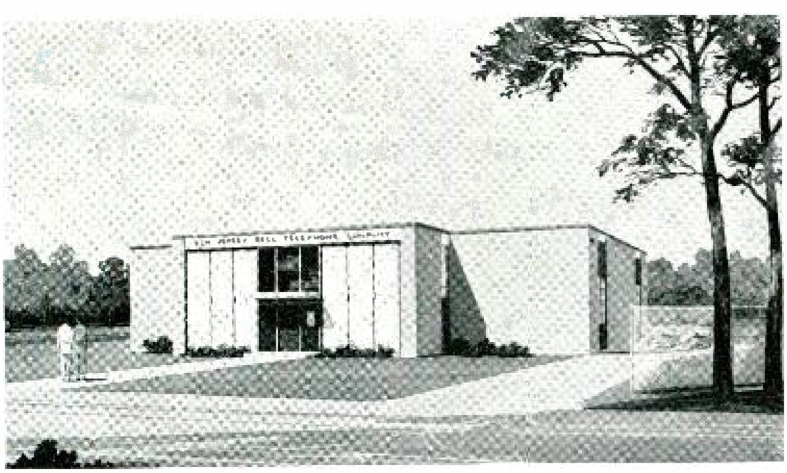
He forecast that next year will bring "continuing growth in service. This means that the Bell Companies will keep on building a great deal of new plant. Construction expenditures for 1959 come to about $2¼ billion, and our program for 1960, as we see it now, will be at least that much and maybe more. For this and later construction requirements, we shall continue to need large sums of new capital."

He expects 1959 earnings "to be consistent with results for the first three quarters and better than in 1958." Long-run earnings prospects, he said, depend largely on two things:

"One is a climate for industry that will give business managers the encouragement and incentives to drive ahead and really perform." He said this "applies full force to business under public regulation.

"The second need is for all Government agencies and regulatory bodies in particular to recognize that the public will get the best service or products at the most reasonable price if they will allow earnings that stimulate top-flight performance."

Mr. Kappel declared that "the evidence is overwhelming that companies that show excellent profit records do the best job for their customers and employees, and as corporate citizens contribute the most to the community."



The New Jersey Bell Telephone Company is building a dial switching office at Murray Hill, New Jersey, on property acquired from Bell Laboratories. In addition to serving residential and business customers in the area, the new installation will replace the PBX dial equipment now located in the Laboratories buildings at the Murray Hill location.

This new equipment will make possible some new features in the telephone service at the Murray Hill location, including in-dialing and out-dialing. The building will be complete this summer.

W. O. Baker Named Consultant

President Dwight D. Eisenhower has appointed W. O. Baker, Vice President — Research, to membership on the President's board of consultants on foreign intelligence activities. Dr. Baker succeeds Dr. James R. Killian, Jr., who is returning to the Massachusetts Institute of Technology.

Varactor Diode Used in UHF Radio Receiver

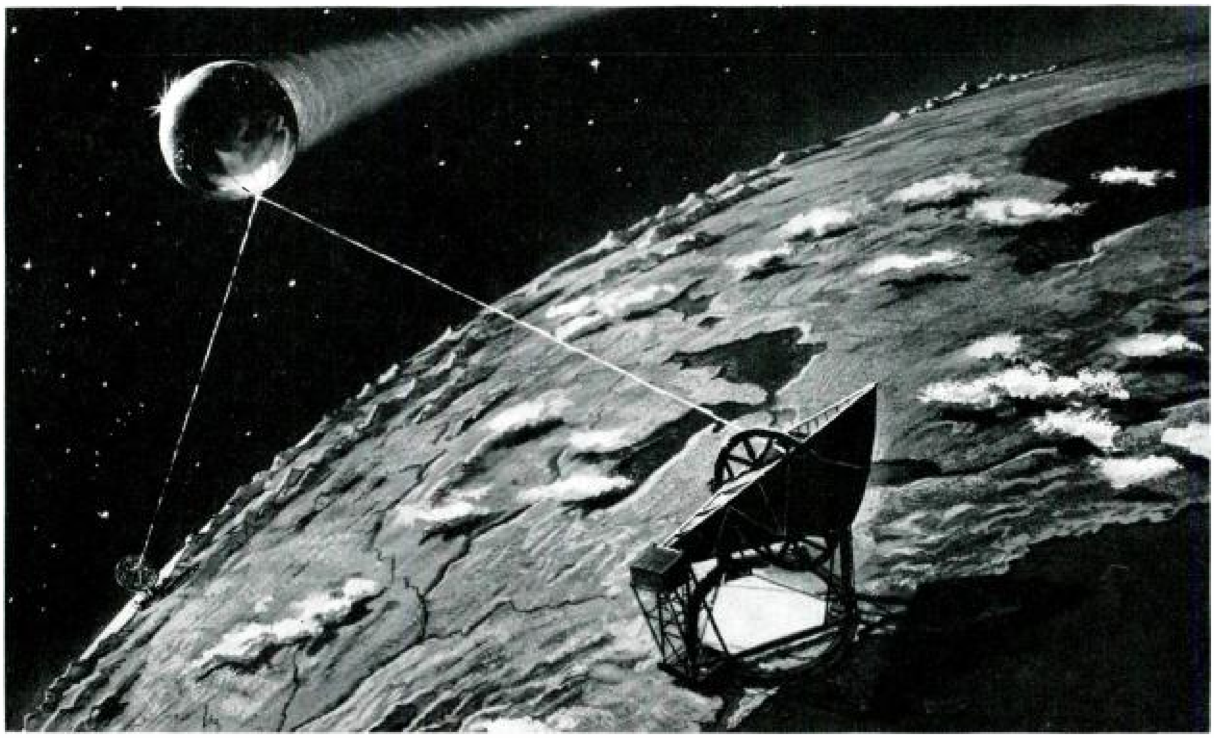
Using solid-state devices, the Laboratories has developed a radiotelephone receiver operating in the UHF band. The receiver was described recently by L. G. Schimpf of the Systems Research Department. Speaking at the annual meeting of the Professional Group on Vehicular Communications of the I.R.E. in St. Petersburg, Florida, Mr. Schimpf told how new devices such as the "varactor" diode can be used in a solid-state radio receiver that operates at around 900 mc.

In the receiver, all operations involving amplification, conversion, and frequency generation are fulfilled with solid-state devices. A typical operation is multiplying a low-frequency signal to obtain power at a higher frequency for use in the receiver. This is done in three steps. A signal is generated in a crystal-controlled transistor oscillator. Its frequency is then doubled in a transistor doubler and tripled in a frequency tripler. It is in this frequency-tripler stage that the special characteristics of the varactor diode are employed to advantage.

The "varactor," or variable-capacitance diode, was developed at Bell Laboratories by A. H. Uhlir, Jr. and A. E. Bakanowski. It consists of a p-n junction whose capacitance varies as a "reverse" voltage across its junction is varied. Thus, if a sine wave is impressed on the diode, the output signal will be very rich in harmonics. For this reason, the varactor diode is a very efficient harmonic generator and can function as a frequency tripler.

The varactor is a versatile device. It has been used extensively as the variable reactance element in parametric amplifiers to provide extremely low-noise amplification at radio frequencies.

Satellite Communication Research



Artist's conception of telephone transmission via space satellite. Bell Laboratories will take part in National Aeronautics and Space Administration's "Project Echo" to test whether satellite transmission is feasible for transoceanic communication. "Horn antenna" in foreground is highly directional receiver designed at the Laboratories. A different antenna, left background, will be located at Jet Propulsion Laboratory at Goldstone, California, with a similar one to be located at Holmdel.

PAPERS

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

Allen, F. G., Eisinger, J., Hagstrum, H. D., and Law, J. T., *Cleaning of Silicon Surfaces by Heating in High Vacuum*, J. Appl. Phys., 30, pp. 1563-1571, Oct., 1959.

Augustyniak, W. M., and Brown, W. L., *The Energy, Orientation and Temperature Dependence of Defect Formation in Electron Irradiation of n-Type Germanium*, Proc. Conf. on Radiation Effects in Semiconductors in Gatlinburg, Tenn., 30, pp. 1300-1309, Aug., 1959.

Augustyniak, W. M., Brown, W. L., and Waite, T. R., *Annealing of Radiation Defects in Semiconductors*, Proc. Conf. on Radiation Effects in Semiconductors in Gatlinburg, Tenn., 30, pp. 1258-1268, Aug., 1959.

Bemski, G., *Paramagnetic Resonance in Electron Irradiated Silicon*, J. Appl. Phys., 30, pp. 1195-1198, Aug., 1959.

Bond, W. L., and Kaiser, W., *Nitrogen, A Major Impurity in Common Type-I Diamonds*, Phys. Rev., 115, pp. 857-863, Aug. 15, 1959.

Bozorth, R. M., Corenzwit, E., Davis, D. D., Matthias, B. T., and Suhl, H., *Magnetization of Compounds of Rare Earths with Platinum Metals*, Phys. Rev., 115, pp. 1595-1596, Sept. 15, 1959.

Brossel, J., Geschwind, S., and Schawlow, A. L., *Optical Detection of Paramagnetic Resonance in Crystals at Low Temperatures*, Phys. Rev. Letters, 3, pp. 548-549, Dec. 15, 1959.

Brown, W. L., see Augustyniak, W. M.

Brown, W. L., see Augustyniak, W. M.

Buchanan, D. N. E., and Wertheim, G. K., *Electron Bombardment Damage in Oxygen-Free Silicon*, J. Appl. Phys., 30 pp. 1232-1234, Aug., 1959.

Burrus, C. A., *Stark Effect at 0.93, 1.18 and 1.5 Millimeters Wavelength: DCl, DBr, and DI*, J. Chem. Phys., 31, pp. 1270-1272, Nov., 1959.

Collins, R. J., *The Mechanism and Defect Responsible for Edge Emission in CdS*, J. Appl. Phys., 30, pp. 1135-1140, Aug., 1959.

Collins, R. J., Geschwind, S., and Schawlow, A. L., *Optical Detection of Paramagnetic Resonance in an Excited State of Cr^{3+} in Al_2O_3*, Phys. Rev. Letters, 3, pp. 545-548, 1959.

Compton, K. G., *Instruments for Measurements in Underground Corrosion Work*, Corrosion, 15, pp. 31-35, Nov., 1959.

Compton, V. B., Corenzwit, E., Matthias, B. T., and Suhl, H., *Ferromagnetic Solutes in Superconductors*, Phys. Rev., 115, pp. 1597-1598, Sept. 15, 1959.

Corenzwit, E., see Bozorth, R. M.

Corenzwit, E., see Compton, V. B.

Davis, D. D., see Bozorth, R. M.

D'heedene, A. R., *Wide-Band Lumped-Element Compression Networks*, Report on Symposium on Recent Advances in Matched Filter Theory and Pulse Compression Techniques, RADC-TR-59-161, pp. 276-277, Sept., 1959.

Eisinger, J., see Allen, F. G.

Feher, G., *Electron Spin Resonance Experiments on Donors in Silicon Part I: Electronic Structure of Donors by the ENDOR Technique*, Phys. Rev., 114, pp. 1219-1244, June 1, 1959.

Feher, G., and Gere, E. A., *Electron Spin Resonance Experiments on Donors in Silicon Part II: Electron Spin Relaxation Effects*, Phys. Rev., 114, pp. 1245-1256, June 1, 1959.

Flood, W. F., *Simple Way of Measuring the Power of High-Intensity Light Beams*, Rev. Sci. Instr., 30, pp. 487-488, June, 1959.

Frisch, H. L., Lebowitz, J. L., and Reiss, H., *Statistical Mechanics of Rigid Spheres*, J. Chem. Phys., 31, pp. 369-380, Aug., 1959.

Frisch, H. L., and Lundberg, J. L., *A Viscosimetric Criterion of Polymer Dispersity*, J. Poly. Sci., 37, pp. 123-129, 1959.

Frost, H. B., *New Methods for the Measurement of Cathode Interface Impedance*, Trans. I.R.E. Prof. Gp. on Electron Devices, 6, pp. 315-321, Nov., 1959.

Garrett, C. G. B., and Pfann, W. G., *Semiconductor Varactors Using Surface Space Charge Layers*, Proc. I.R.E., 47, pp. 2011-2012, Nov., 1959.

Gere, E. A., see Feher, G.

Geschwind, S., see Brossel, J.

Geschwind, S., see Collins, R. J.

Hagstrum, H. D., see Allen, F. G.

Hensel, J. C., and Peter, M., *The Stark Effect for Cyclotron Resonance in Degenerate Bands*, Phys., Rev., 114, pp. 411-417, Apr. 15, 1959.

Hogg, D. C., *Effective Antenna Temperatures Due to Oxygen and Water Vapor in the Atmosphere*, J. Appl. Phys., 30, pp. 1417-1419, Sept., 1959.

Hrostoski, H. J., and Kaiser, R. H., *The Solubility of Oxygen in Silicon*, J. Phys. & Chem. of Solids, 9, pp. 214-216, Mar., 1959.

Kaiser, W., and Wheatley, G. H., *Hot Electrons and Carrier Multiplication in Si at Low Temperatures*, Phys. Rev. Letters, 3, pp. 334-337, Oct. 1, 1959.

Kaiser, W., see Bond, W. L.

Kaiser, R. H., see Hrostoski, H. J.

Kiernan, W. J., *A.S.T.M. Method for Specifying Color by the Munsell System, D1535-58T*, Inter-Society Color Council News-Letter, 143-144, pp. 17-18, Sept.-Nov., 1959.

Koehler, D. C., *Automatic Processing of Photographic Code Plates for Electronic Telephone Switching Systems*, Photographic Sci. & Eng'g, 3, pp. 292-298, Nov.-Dec., 1959.

Lander, J. J., and Lynch, R. T., *The Growth of Single Crystals* *of BaO*, J. Appl. Phys., 30, pp. 1614-1615, Oct., 1959.

Law, J. T., see Allen, F. G.

Lebowitz, J. L., see Frisch, H. L.

LeCraw, R. C., Martin, R. L., Spencer, E. G., and Van Uitert, L. G., *Proposed Means for Realizing High Power Stability in Magnetic Oxides*, J. Appl. Phys., 30, pp. 1623-1624, Oct., 1959.

Lundberg, J. L., see Frisch, H. L.

Lynch, R. T., see Lander, J. J.

Martin, R. L., see LeCraw, R. C.

Matthias, B. T., Suhl, H., and Walker, L. R., *The Bardeen-Cooper-Schrieffer Theory of Superconductivity in the Case of Overlapping Bands*, Phys. Rev. Letters, 3, pp. 552-554, 1959.

Matthias, B. T., see Bozorth, R. M.

Matthias, B. T., see Compton, V. B.

McGee, J. D., and Mims, W. B., *Spin-Spin Energy Transfer and the Operation of Three-Level Masers*, Proc. I.R.E., 47, p. 2120, Dec., 1959.

McSkimin, H. J., *Performance of High-Frequency Barium Titanate Transducers for Generating Ultrasonic Waves in Liquids*, J. Acous. Soc. Am., 31, pp. 1519-1522, Nov., 1959.

Miller, R. C., and Savage, A., *Further Experiments on the Sidewise Motion of 108° Domain Walls in $BaTiO_3$*, Phys. Rev., 115, pp. 1176-1180, Sept. 1, 1959.

Mims, W. B., see McGee, J. D.

Moore, E. F., *The Shortest Path Through a Maze*, Annals of the Computation Laboratory of Harvard University, 30, pp. 285-292, 1959.

Morgan, S. P., *Generalizations of Spherically Symmetric Lenses*, Trans. I.R.E. Prof. Gp. on Antennas & Propagation, 7, pp. 342-345, Oct., 1959.

Morin, F. J., *Oxides Which Show a Metal-To-Insulator Transition*, Phys. Rev. Letters, 3, pp. 34-36, July 1, 1959.

Paull, M. C., and Unger, S. H., *Minimizing the Number of States in Incompletely Specified Sequential Switching Functions*, Trans. I.R.E. Prof. Gp. on Electronic Computers, 8, pp. 346-367, Sept., 1959.

Peter, M., see Hensel, J. C.

Pfann, W. G., see Garrett, C. G. B.

Pierce, J. R., *Relativity and Space Travel*, Proc. I.R.E., 47, pp. 1053-1061, June, 1959.

Pierce, J. R., *Use of the Principles of Conservation of Energy and Momentum in Connection with the Operation of Wave-Type Parametric Amplifiers*, J. Appl. Phys., 30, pp. 1341-1346, Sept., 1959.

Preziosi, S., Swanekamp, F. W., Van Uitert, L. G., *Ferromagnetic Resonance Line Widths and Phase Distributions in Sintered Yttrium Iron Garnets*, J. Am. Ceramic Soc., 42, pp. 471-473, Oct., 1959.

Reiss, H., *Influence of Solutes on Self-Diffusion in the Face-Centered Cubic Lattice*, Phys. Rev., 113, pp. 1445-1461, Mar., 15, 1959.

Reiss, H., see Frisch, H. L.

Savage, A., see Miller, R. C.

Schawlow, A. L., Varsanyi, F., and Wood, D. L., *Self-Adsorption and Trapping of Sharp-Line Resonance Radiation in Ruby*, Phys. Rev. Letters, 3, pp. 544-545, Dec. 15, 1959.

Schawlow, A. L., see Brossel, J.

Schawlow, A. L., see Collins, R. J.

Schlabach, T. D., *Applying the Appliqué Technique to Printed Wiring*, Society of Plastics Engineers, Encapsulation, Printed Circuits, Fluidized Bed, II, May 22, 1959.

Scheinman, A. H., *Numerical-Graphical Method in Design of Multiterminal Switching Circuits*, 45, pp. 515-519, Nov., 1959.

Shulman, R. G., *Observation of the Co^{59} NMR in Paramagnetic Salts*, Phys. Rev. Letters, 2, pp. 459-460, June 1, 1959.

Slichter, W. P., *Nuclear Resonance Studies of Motion in Polymers*, Die Makromolekulare Chemie, 34, pp. 67-88, Oct., 1959.

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

Suhl, H., see Bozorth, R. M.

Suhl, H., see Compton, V. B.

Suhl, H., see Matthias, B. T.

Swanekamp, F. W., see Preziosi, S.

Thomas, D. G., *Infrared Absorption in ZnO Crystals*, J. Phys. & Chem. of Solids, 10, pp. 47-51, Apr., 1959.

Unger, S. H., *Pattern Detection and Recognition*, Proc. I.R.E., 47, pp. 1737-1752, Oct., 1959.

Unger, S. H., see Paull, M. C.

Van Uitert, L. G., see LeCraw, R. C.

Van Uitert, L. G., see Preziosi, S.

Varsanyi, F., see Schawlow, A. L.

Waite, T. R., see Augustyniak, W. M.

Walker, L. R., see Matthias, B. T.

Wertheim, G. K., *Temperature-Dependent Defect Production in Bombardment of Semiconductors*, Phys. Rev., 115, pp. 568-569, Aug. 1, 1959.

Wertheim, G. K., *Recombination Properties of Bombardment Defects in Semiconductors*, J. Appl. Phys., 30, pp. 1166-1174, Aug., 1959.

Wertheim, G. K., *Recombination Properties of Nickel in Germanium*, Phys. Rev., 115, pp. 37-47, July 1, 1959.

Wertheim, G. K., see Buchanan, D. N. E.

Wheatley, G. H., see Kaiser, W.

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

PATENTS

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

Bachelet, A. E., Haas, H. H. and Newell, N. A. — *Order Wire Alarm and Control Circuit* — 2,919,307.

Brady, G. W. and Flaschen, S. S. — *Surface Treatment of Ferroelectric Materials* — 2,916,681.

Buck, T. M. and McKim, F. S. —

PATENTS (CONTINUED)

Surface Treatment of Silicon — 2,916,407.

Burton, E. T., Robinson, A. L. and Younker, E. L. — *Time Separation Communication System* — 2,917,583.

Cagle, W. B. — *Electrical Pulse Circuit* — 2,915,649.

Carbrey, R. L. — *Code Translator* — 2,917,734.

Cesareo, O. and Shafer, W. L., Jr. — *Electrical Code Translator* — 2,919,439.

Chase, F. H. — *Current Supply Apparatus* — 2,917,700.

Crowley, T. H. — *High Speed Delta Modulation Encoder* — 2,916,553.

Dimond, T. L. — *Selective Signaling Receiver* — 2,919,428.

Ebers, J. J. and Miller, S. L. — *Semiconductive Switch and Negative Resistance* — 2,915,647.

Flaschen, S. S., see Brady, G. W.

Fleckenstein, W. O. — *Universal Line Concentrator* — 2,916,557.

Fredericks, G. W. — *Alarm Apparatus for Announcement Systems* — 2,917,730.

Haas, H. H., see Bachelet, A. E.

Houghton, E. W. — *Microwave Detector* — 2,919,345.

Ketchledge, R. W. — *Electron Beam Positioning System* — 2,916,660.

Klie, R. H. — *Overload Protection Circuit* — 2,916,708.

Kompfner, R. and Williams, N. T. — *Backward Wave Amplifier* — 2,916,657.

Locke, G. A. — *Semiautomatic Teletypewriter Switching System* — 2,916,542.

Marrison, W. A. — *Apparatus for Converting Radiant Energy to Electromechanical Energy* — 2,919,358.

McGuigan, J. H. — *Toggle Circuit* — 2,917,625.

McKim, F. S., see Buck, T. M.

Miller, S. L., see Ebers, J. J.

Neitzer, C. — *Magnetic Pulse Modulator* — 2,919,414.

Newell, N. A., see Bachelet, A. E.

Pudvin, J. F. — *Plating Method* — 2,916,806.

Robinson, A. L., see Burton, E. T.

Shafer, W. L., Jr., see Cesareo, O.

Toms, R. S. — *Terminal Insulator* — 2,916,719.

Williams, N. T., see Kompfner, R.

Young, J. A., Jr. — *Helical Wave Guides* — 2,915,715.

Young, W. R., Jr. — *Time Bias Detector* — 2,918,623.

TALKS

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

A.I.E.E. CONFERENCE ON MAGNETISM AND MAGNETIC MATERIALS, Detroit, Mich.

Barrett, W. A., *A Field Calculation for a Partially Saturated Ferromagnetic Rod.*

Gyorgy, E. M., *Flux Reversal in Soft Ferrogmagnetics.*

Gyorgy, E. M., and Hagedorn, F. B., *Switching Behavior of Low Remanence Ferrite.*

Hagedorn, F. B., see Gyorgy, E. M.

LeCraw, R. C., *Electron Spin Relaxation in Ferromagnetic Insulators.*

Nielsen, J. W., *An Improved Method for the Growth of Yttrium-Iron and Yttrium-Gallium Garnets.*

Stadler, H. L., *Localized Field Permanent Magnet Arrays.*

Weiss, J. A., *The Tetrahedral Junction.*

OTHER TALKS

Ahearn, A. J., *Mass Spectrographic Studies of Bulk Impurities and Surface Contaminants of Metals,* Semiconductors and Insulators, Eastern Analytical Symposium, N. Y. C.

Albano, V. J., *Coulometric Reduction—A Tool for Studying Surface Films,* A.I.M.E Powder Metallurgy Symposium, Chicago, Ill.

Bailey, C. M., Jr., *Design of a Saturable Core Power Inverter,* Eastern North Carolina Subsection, I.R.E., Raleigh, N. C.

Becker, F. K., *Stereophonic Radio Systems,* North Carolina Section, I.R.E., Greensboro, N. C.

Biondi, F. J., *Cleaning of Electronic Devices and Materials,* I.R.E., Corning-Elmira, N. Y., Nov. 23; Emporium, Pa., Nov. 24.

Blecher, F. M., *High Frequency Applications of Transistors,* I.R.E. Detroit Mich.

Bollman, J. H., *The Prediction of Reliability,* I.R.E. Lecture Series, Hilldale School, Montclair, N. J.

Bomba, J. S., *Alpha-Numeric Character Recognition Using Local Operations,* 1959 Eastern Joint Computer Conference, Boston, Mass.

Bomba, J. S., *Some Problems in Machine Recognition of Visual Characters,* Electrical Engineering Department Seminar on Switching to Automatic, Princeton University, Princeton, N. J.

Brattain, W. H., Appearance with Film, *Brattain on Semiconductors,* College of Chemistry and Physics, Pennsylvania State University, University Park, Pa.

Buchsbaum, S. J., *Plasma and the Electromagnetic Field,* Electrical Engineering Department Seminar, University of Illinois, Urbana, Ill.

Bullington, K., *System Engineer-*

ing of a Speech Interpolation System, Applied Physics Laboratory of Johns Hopkins University, Baltimore, Md.

Burgiel, J. C., Jaccarino, V., and Schawlow, A. L. *Nuclear Quadrupole Resonance in an Antiferromagnet*, A.P.S. Meeting, Cleveland, Ohio.

Chapin, D. M., *Making Solar Cells in the High School Laboratory*, New York State-New York University In-Service Institute for Secondary School Science Teachers, Yonkers High School, Yonkers, N. Y.

Compton, K. G., *Corrosion of Lead Cable Sheath*, All Florida Corrosion Conference, Miami, Fla., A.I.E.E. Meeting, Atlanta, Ga.

Cowell, W. R., *Measuring and Coding Information*, Mathematics Colloquium, University of Delaware, Newark, Del.

Dahms, K. J., and Shuhart, J. H., *Determination of the Coefficient of Linear Expansion with Temperature of Cable Structures*, Eighth Annual Signal Corps Wire and Cable Symposium, Asbury Park, N. J.

D'Altroy, F. A., *Semiconductor Surface Phenomena and an Application to a Field Effect Device*, Lehigh University, Bethlehem, Pa.

Darlington, S., *Guidance of Lunar Probes*, I.R.E. Student's Night Montclair, N. J.

Deutsch, M., *Some Experiments in Social Perception*, Clark University, Worcester, Mass.

Deverall, G. V., see Purvis, M. B.

D'heedene, A. R., *Wide-Band Lumped-Element Compression Networks*, Symposium on Recent Advances in Matched Filter Theory and Pulse Compression Techniques, Rome, N. Y.

Dienel, H. F., *Process Variables Which Affect Germanium Alloy Transistor Reliability*, I.R.E Prof. Gp. on Electron Devices, Washington, D. C.

Drenick, R. F., *A Theory of Nonlinear Transducers*, Graduate Seminar, Columbia University, N. Y. C.

Dudley, H. W., *Control of Machines by the Spoken Word*, Mid-Hudson Section, I.R.E., Poughkeepsie, N. Y.

Ferrell, E. B., *Time Sharing and Pulse Coding*, Society of Professional Engineers and Scientists, A.I.E.E., Oklahoma City, Okla.

Ferrell, F. B., *Time Sharing and Pulse Coding*, I.R.E.-A.I.E.E. Student Branch, Oklahoma State University, Stillwater, Okla.

Fraser, J. M., *TASI Operation*, New Hampshire Division, A.I.E.E., Concord, N. H.

Garrett, C. G. B., *A Quantitative Theory of Catalysis at a Semiconductor Surface*, Iowa State College, Ames, Iowa.

Geballe, T. H., *Measurements of Surface Transport Phenomena*, Second Conference on Semiconductor Surfaces, U. S. Naval Ordnance Lab., Silver Spring, Md.

Gentner, K., *Development and Production of Deposited Carbon Resistors*, I.R.E. Prof. Gp., Winston-Salem, N. C.

Gerard, H. B., *Social Influence and Attitude Consistency*, Psychology Colloquium, Duke University, Durham, N. C.

Gibbons, D. F., *The Interaction of Acoustic Waves with the Conductor Electrons*, A.S.M. Seminar on Resonances and Relaxations in Metals, Chicago, Ill.

Gillette, D., *Modern Applications of Mathematics*, Dover High School Mathematics Club, Dover, N. J.

Gordon, E. I., *Charged Particle Orbits in Varying Magnetic Fields*, Princeton University, Princeton, N. J.

Groll, P. A., and Sobel, M., *A Problem in Restrictive Group Testing*, Annual Meeting of the Institute of Mathematical Statistics, Washington, D. C.

Gupta, S. S., and Sobel, M., *On a Problem of Estimation*, Probability and Statistics Seminar of the Institute of Mathematical Sciences, New York University, N. Y. C.

Gupta, S. S., *Order Statistics from Gamma Distribution and Their Applications to Reliability and Life-Tests Problems*, A.S.A./-A.S.Q.C. Meeting, N. Y. C.

Gupta, S. S., *Selection and Ranking Procedures and Order Statistics for Gamma Distribution*, Joint Symposium of McGill University and University of Montreal on Probability of Statistics, Montreal, Canada.

Hamming, R. W., *Present Trends in the Computer Field*, A. C. M. Meeting, Union College, Schenectady, N. Y.

Hamming, R. W., *Using Computing to Get Insight*, Seminar on Automatic Computers and Their Capabilities, University of Pennsylvania, Philadelphia, Pa.

Hannay, N. B., *Low Mobility Semiconductors*, Merck, Sharp and Dohme Research Laboratories, Rahway, N. J.

Hannay, N. B., *Semiconductors, Inorganic and Organic*, Rohm and Haas Company, Phila., Pa.

Hawkins, W. L., Metreyek, W., and Winslow, F. H., *Localized Oxidation in Polymers Effect on Physical Properties*, Regional Tech. Conf., National Academy of Science, Washington, D. C.

Hayward, W. S., Jr., *Queuing Problems—How to Recognize and Solve Them*, Western Regional Conference of A.I.I.E., Denver, Colo.

Heiss, J. H., Lanza, V. L., and Martin, W. M., *Dependence of Photolytic Degradation of Polyethylene on the Degree of Dispersion of Carbon Black*, Eighth Annual Symposium on Tech. Progress in Communication Wires and Cables, U.S. Engineering Signal Laboratory, Asbury Park, N. J.

Herbst, R. T., *Automatic Mechanical Design on Modular Type Apparatus*, A.I.E.E. Student Section, Duke University, Durham, N. C.

Holden, A. N., *Crystals*, Physics Club of Milwaukee, A.I.E.E./-I.R.E., Brookfield High School, Lewaukee High School, Hartland High School, Evening Science Seminar of Milwaukee School System, Manitoba School, Science Section of Wisconsin State Teachers Convention, Milwaukee, Wis.

Hoth, D. F., *New Developments in Communications*, Joint Meeting of Engineering Society of Cincinnati and A.I.E.E., Cincinnati, Ohio.

Jaccarino, V., see Burgiel, J. C.

Jakes, W. C., Jr., *Holmdel and the Space Age*, Holmdel Elementary School, Holmdel, N. J.

Kostkos, H. J., *Bell Telephone Laboratories Blazes the Trail for Tomorrow's Selling*, Central Area, Bell Tel. Co. of Pa. Sales Meeting, Pocono Manor, Mt. Pocono, Pa.

Kruskal, J. B., *The Number of Simplices in a Complex*, Combinatorial Problems Seminar, Princeton University, Princeton, N. J.

Lander, J. J., *Recent Work on Surface Properties of II-IV Semiconductors*, Second Conference on Semiconductor Surfaces, Washington, D. C.

Lanza, V. L., see Heiss, J. H.

Lax, M., *Influence of Trapping, Diffusion and Recombination on Carrier Concentration Fluctuations*, Second Conference on Semiconductor Surfaces, U.S. Naval Ordnance Laboratory, White Oak, Silver Springs, Md.

Levenbach, G. J., *Engineering Reliability*, Annual Princeton Conference, Princeton University, Princeton, N. J.

Lewis, W. D., *Coordinated Broadband Mobile Telephone System*, I.R.E. Prof. Gp. on Vehicular Communications, Tenth National Conference, St. Petersburg, Fla.

Ligenza, J. R., *The Mechanisms for Silicon Oxidation in Steam and Oxygen*, Second Conference on Semiconductor Surfaces, U.S. Naval Ordnance Laboratory, Silver Spring, Md.

Ling, D. P., *Space Communications*, I.R.E., Burlington, N. C.

Lowry, W. K., *A Hard Look at Mechanization*, General Motors Conference on Technical Literature, Detroit, Mich.

Mardis, T. E., *Science or Fiction*, University of Southern Illinois, Carbondale, Ill.

Mason, W. P., *Piezo- and Ferroelectric Crystals*, Sandia Corporation. Albuquerque, N. M.

Mason, W. P., *Research and Development at Bell Telephone Laboratories and Its Relation to Invention*, Honors Society Council, Newark College of Engineering, Newark, N. J.

Martin, W. M., see Heiss, J. H.

Matreyek, W., see Hawkins, W. L.

Nylund, H. W., *Comparison of Wideband and Narrowband Mobile Circuits at 150 Megacycles*, Tenth National Conference, I.R.E. Prof. Gp. on Vehicular Communications, St. Petersburg, Fla.

O'Neill, E. F., *The Oceanic Telephone Cable and TASI*, A.I.E.E./I.R.E., Rochester, N. Y.

Pfann, W. G., *Zone Melting*, Chemists Alumni Association, New York University, N. Y. C.

Prescott, R. E., *Some Design Aspects of Molded Circuits*, Symposium on Printed Circuits, Bell Telephone Laboratories, Murray Hill, N. J.

Priebe, H. F., Jr., *Transistor Applications to Single Sideband Techniques*, I.R.E. Fall Symposium, Greensboro, N. C.

Purvis, M. B., and Deverall, G. V., *Photographic Problems Associated with the Construction of a Large Computer Memory*, Annual Meeting of American Society of Photographic Scientists and Engineers, Chicago, Ill.

Radcliffe, F. E., *A 25-Megacycle Wideband Amplifier Using Printed Circuits*, Arnold Auditorium, Bell Telephone Laboratories, Murray Hill, N. J.

Renne, H. S., *How a Company Technical Journal Serves Management*, Office of Special Services, New York University, N. Y. C.

Renne, H. S., *Expanding Horizons in Communications*, A.I.E.E., Schenectady, N. Y.

Schaefer, J. W., *The Nike-Zeus Guided Missiles System*, Kiwanis Club, Winston-Salem, N. C.

Schawlow, A. L., see Burgiel, J. C.

Schwenzfeger, E. E., *Ferroelectric "and" Gate*, A.I.E.E./I.R.E. Evening Students Section, New York University, N. Y. C.

Shuhart, J. H., see Dahms, K. J.

Slepian, D., *Further Theory of Group Codes*, Meeting International Scientific Radio Union, San Diego, Calif.

Sobel, M., see Groll, P. A.

Sobel, M., see Gupta, S. S.

Stadler, H. L., *Magnet Cards for the Permanent Magnet Memory*, Symposium on Printed Circuits, Bell Telephone Laboratories, Murray Hill, N. J.

Sugano, S., *Line Spectra of Transition Metal Ions in Crystals*, R.C.A. Laboratories, Princeton, N. J.

Terry, M. E., *Design of Experiment*, A.S.Q.C., Pittsfield, Mass.

Tischendorf, J. A., *Sequential Life Testing to Establish Reliability*, A.S.A./A.S.Q.C., N. Y. C.

Vacca, G. N., *Weather and Ozone Resistance of Rubber*, General Motors Technical Center, Detroit, Mich.

Weiss, M. M., *Technical Aspects of Ionizing Radiation and Measurement Techniques*, American Telephone and Telegraph Company Regional Conferences on Radiation Hazards, Denver, Colo., Aug. 11; N. Y. C., Sept. 15; Chicago, Ill., Oct. 6.

White, P. R., *Soldering of Aluminum*, A.S.M., Carolinas Chapter, Asheboro, N. C.

Winslow, F. H., *The Effect of Morphology on the Chemical Reactivity of Polyolefins*, Hercules Powder Company, Wilmington, Del.

Winslow F. H., *The Oxidation of Vinyl Polymers*, Lehigh Valley Section of A.C.S., Lehigh University, Bethlehem, Pa.

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

Wood, D. L., *Infrared Spectrophotometry in Polymer Research*, Analytical Group, A.C.S., Seton Hall College, South Orange, N. J.

Zammataro, S. J., *Test Specification Philosophy*, Fourth Annual Western Electric Company Test Engineering Conference, Winston-Salem, N. C.

THE AUTHORS

L. G. Abraham "The Complexity of the Transmission Network") was born in Watson, Illinois, and received his B.S. and M.S. degrees from the University of Illinois in 1922 and 1923, respectively. He joined the Development and Research Department of the American Telephone and Telegraph Company in 1923, and transferred to the Laboratories in 1934. He spent two and one-half years at Sandia Corporation, from early 1952 to mid-1954. His work has been largely in transmission engineering and development, from open wire and loaded cable voice-frequency circuits to coaxial and radio-relay systems. It also includes television, mobile radio, submarine cable and TASI. He is a member of A.I.E.E., A.A.A.S. and Sigma Xi, and is a Fellow of the I.R.E.

L. G. Abraham

G. G. Drew, born in La Grange, Illinois, attended Rutgers University from which he received a B.S. degree in electrical engineering in 1936. He worked for the Westinghouse Electric Company and the Naval Ordnance Laboratory before joining the Laboratories in 1946. After training in the Laboratories' Switching School, he joined the group developing accounting-center circuits for the Bell System's Automatic Message Accounting system. He also spent some time redesigning crossbar tandem circuits. In 1952, an exploratory development group was formed in the Switching Systems Development Department to evaluate the application of electronic techniques to telephone switching applications. Mr. Drew was assigned to this work, and has been thus continuously engaged since that time. In this issue, he describes the Electronic Switching System's central control.

G. G. Drew

Karl M. Olsen, author of the article, "High-Purity Nickel," in this issue, is a native of Brooklyn, N. Y. He joined the Laboratories in 1929 and was first engaged in research studies on cable sheathing materials. During World War II he worked on the processing of silicon and germanium and on the preparation of semiconductor rectifiers. He was also active in the Manhattan project. Since 1949 he has been engaged in special metallurgical processing studies, including development of zone-melting techniques and preparation of ferrite cores. More recently he has devoted his time to investigations concerned with high-purity nickel materials for oxide-coated cathode structures. Mr. Olsen received the degree of B.S. in Chemical Engineering from Cooper Union in 1936 and the M.S. degree in Metallurgical Engineering from Columbia University in 1942. He is a member of the American Society for Metals.

K. M. Olsen

J. A. Baird ("Leprechaun Computer"), was born in Omaha, Texas, and received the B.S. degree in E.E. from Texas A&M in 1943. After service in the U.S. Navy, he joined Bell Laboratories in 1946 and spent several years in the development of military radar and communications systems, during this time doing graduate work and receiving the M.S. degree from Stevens Institute of Technology in 1950. He then returned to Texas A&M, from which he received the Ph.D. degree in electrical engineering in 1952. Upon rejoining the Laboratories, Mr. Baird again enter-

J. A. Baird

T. E. Talpey

ed the military development field, with particular emphasis on the applications of transistors and other solid-state devices. He is currently Director of Military Systems Development. Mr. Baird is a member of the I.R.E.

Thomas E. Talpey, co-author of the article, "A High-Performance Tetrode for TH Radio Relay," in this issue, was born in Auburn, New York, and was graduated from Cornell University with the B.E.E. degree in 1946. From 1946 to 1953, he was an instructor in electrical engineering at the University of Michigan, where he received the M.S.E. degree in 1948 and the Ph.D. degree in 1954. He also holds the degree of Doctorat d'Université from the University of Grenoble, France, obtained while studying there on a Fulbright Grant in 1952. Mr. Talpey joined the Laboratories in 1953 as a member of the Electron Tube Development Department, where he worked on the development of high figure-of-merit tubes for wideband amplifiers. He has also been associated with submarine cable tube development and is presently concerned with the development of low-noise traveling-wave tubes.

Norman C. Wittwer, a native of Haddonfield, New Jersey, received his B.E.E. degree from Ohio State University in 1948, and was a member of the first Communications Development Training class at the Laboratories. For several years he was concerned with exploratory studies for achieving high figure-of-merit in space-charge control tubes, and has also worked on the advanced development of tubes for broad-band transmission applications. He is now working on cathode-ray tubes, in particular those for the flying-spot store for the Electronic Switching System. Mr. Wittwer is the co-author of "A High-Performance Tetrode for TH Radio Relay" in this issue.

N. C. Wittwer

L. H. Steiff

Leon H. Steiff, author of "Redesign of Low-Frequency Networks," joined the Laboratories at the Merrimack Valley, Mass., location in 1956 after ten years as an engineer in a family enterprise. His initial Laboratories assignment was equipment design for the fully transistorized P1 carrier system. About six months later he worked on the development of a wideband digital transmission system. He joined the Packaging and Mechanization Group on its inception late in 1957. In addition to specific design responsibilities, Mr. Steiff is engaged in introducing new materials and techniques for Bell System use. A native of Boston, Mass., he received his B.S. degree in Mechanical Engineering from Northeastern University. He is a member of A.S.M.E., and is a registered professional engineer in The Commonwealth of Massachusetts.