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Miracle Men of the Telephone

BY F. BARROWS COLTON

In observance of the centennial of the birth of Alexander Graham Bell, inventor of the telephone, on March 3, 1947, the NATIONAL GEOGRAPHIC MAGAZINE presents this story of the Bell Telephone Laboratories, which carry on the work that Dr. Bell began. Dr. Bell was one of the original members of the National Geographic Society when it was founded in 1888. While President of The Society, 1898 to 1903, he initiated the extension of its membership and the popularization of its Magazine. He contributed to the NATIONAL GEOGRAPHIC MAGAZINE and served as a trustee of The Society until his death in 1922. Mrs. Bell and her family gave The Society its first building, Hubbard Memorial Hall, in memory of Gardiner Greene Hubbard, first President of the Bell Telephone Company and first President of the National Geographic Society.

IN a quiet room in downtown New York I sat one day with a scientist and a man who had been totally deaf from birth. He never had heard a human voice.

Before us were a small luminescent screen, a microphone, and some complicated electrical apparatus. Turning so that the deaf man could not read his lips, the scientist spoke into the microphone. As he talked, a series of patterns of dull greenish-yellow lines and shadows moved slowly across the screen, rising and falling, now blurred, now sharp.

Watching the screen, the deaf man smiled and repeated aloud the words the scientist had spoke words he could not hear. "All of it was perfectly clear," he said. "I can read those patterns now about as easily as print."

What he was reading was "visible speech," a by-product of the never-ending study of transmission of the human voice carried on at Bell Telephone Laboratories. With it, spoken words are turned into visible patterns on a screen that it is possible to learn to read. Like shorthand, they are patterns not of words but of sounds. They provide a new way of studying speech and, better still, a new way for the deaf to "hear by seeing" (pages 300, 301).

"Visible speech" is only one of the countless achievements of the more than 2,000 scientists and engineers of the Bell Telephone Laboratories. They, with as many more associates, carry on today in this great research institution the work begun more than 70 years ago in a Boston attic by Alexander Graham Bell, inventor of the telephone (page 281).* These men today are "inventing" the telephone of tomorrow.

Amazing things they do make them seem indeed like "miracle men." Yet, like all scientists, they actually get results only by long, hard work, over months and years.

"Our job, essentially, is to devise and develop facilities which will enable two human beings anywhere in the world to talk to each other as clearly as if they were face to face and to do this economically as well as efficiently," Dr. O. E. Buckley, President of Bell Laboratories, told me.

"To this end we study everything from the most fundamental matters, such as the mechanism of speech and hearing and the molecular structure of copper wire and rubber insulation, to the detailed design of equipment. We're equally interested in an operator's enunciation and in building her switchboard for long life."

Everything that happens to human speech between the brain of a speaker in Los Angeles and the brain of the man he is calling, either

*See, in the NATIONAL GEOGRAPHIC MAGAZINE, "Miracle of Talking by Telephone," by F. Barrows Colton, October, 1937, and "Prehistoric Telephone Days," by Alexander Graham Bell, March, 1922.

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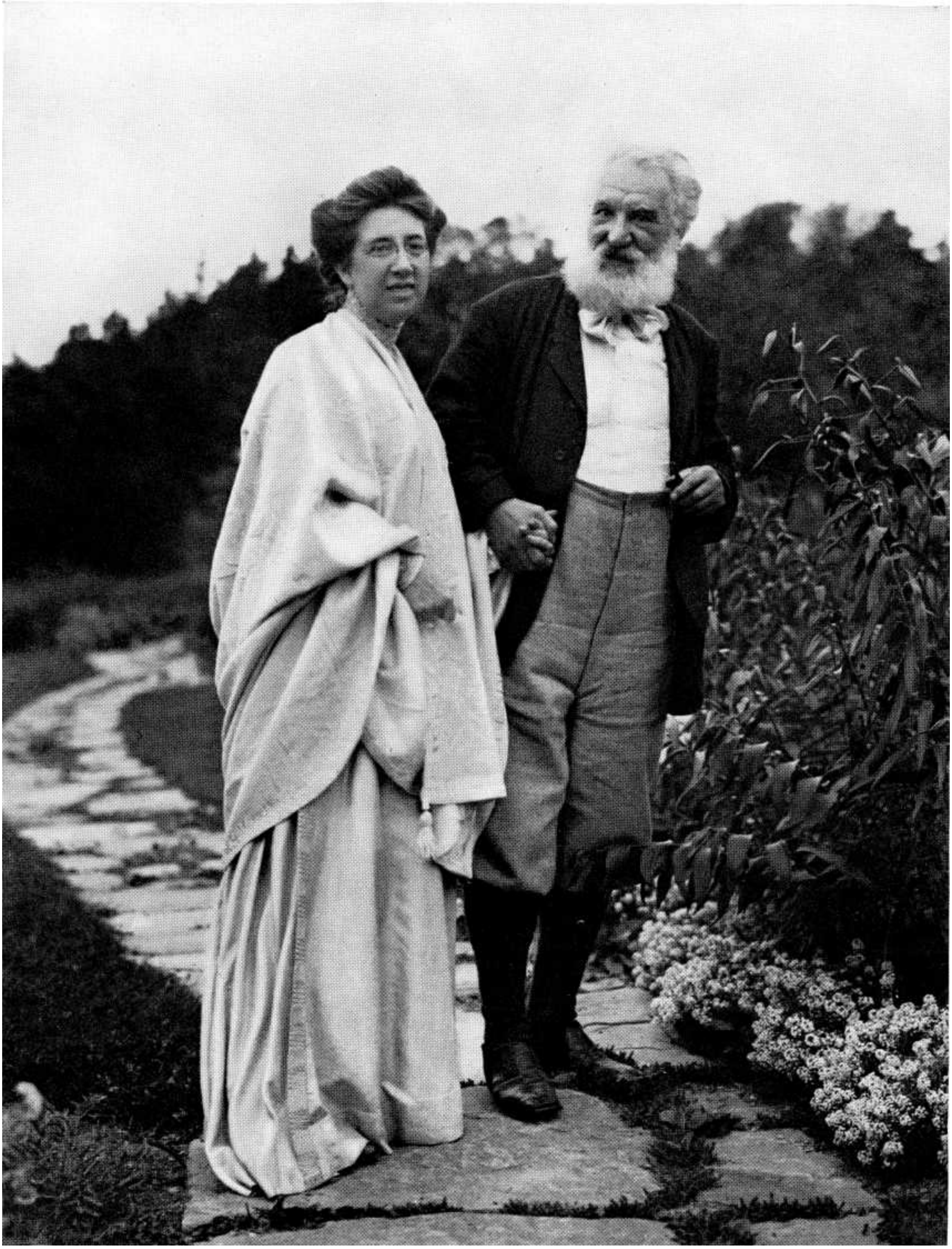

Gilbert Grosvenor

Alexander Graham Bell and Mrs. Bell in Their Garden at Baddeck, Nova Scotia

The inventor of the telephone was born at Edinburgh and became a citizen of the United States and resident of Washington, D. C., in 1882. Until the day of his death, August 2, 1922, his active mind delved into an amazing variety of subjects, including aviation, sheep breeding, distilling fresh water from salt, high-speed motorboats, and many others. Mrs. Bell (Mabel Hubbard) became totally deaf at age four from scarlet fever. She and Jennie Lippitt were the first children in America to learn to read the lips and converse like hearing people.

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in the next block or in far-away Portland, Maine or even Paris or Shanghai is the concern of Bell Laboratories people.

That includes such diverse things as taking movies of human vocal cords in action; choking off mischievous round-the-world radio echoes that occasionally distort transoceanic telephone talk; and harnessing the energies of countless electrons which are so small that no one ever has seen one and which, in fact, may not have any definite form at all !

Out of all their work has come not only the world's finest telephone system but many other useful things not connected directly with the telephone. Among them are many phases of radio broadcasting, talking movies, and public-address systems.

Out of telephone research, too, came the electrical gun director, which gave Allied anti-aircraft batteries in World War II almost miraculous accuracy; the mirrophone, which shows you how your own voice sounds, so that you can improve your speaking or singing; and of course "visible speech."

How Alexander Graham Bell, born in Scotland 100 years ago, March 3, 1847, would have rejoiced at "visible speech"! He was originally a teacher of the deaf, and it was his quest for better means of teaching them to speak that led him to invention of the telephone (page 282). Bell himself once tried with only modest success to work out a similar idea as an aid in teaching his deaf pupils to utter sounds properly.

Though not yet ready for general use, modern "visible speech" has great possibilities. Deaf people can and have learned to read it, and thus use it to "see" what others are saying. Hooked on to a telephone or radio, it would serve the same purpose, though that is still in the future.

Teaching the Deaf to Speak

Better still, deaf people can use it to improve their speech, a difficult task normally for those who are deaf from birth or early childhood, for they are unable to hear the proper pronunciation of words and their speech is likely to be harsh and unnatural.

With "visible speech" they can practice by watching the patterns of their voices on the screen and comparing them with patterns of normal speech, until they learn to speak correctly. Its use in teaching deaf children to speak is now being carefully studied by specialists at the University of Michigan.

All the "miracles" of telephone engineers have come from the study of electric waves, which are among the most sensitive and temperamental things in the Universe.

Electric waves used in the telephone have only about one-millionth of the power that lights the electric lamp beside your chair. Nursing these nebulous waves along, delivering them strong and clear over thousands of miles of wire or through the air as radio waves, passing them safely through millions of connections and relays, and doing it always better and faster, is the main task of Bell Laboratories men.

In doing that job, they have reached out through 93 million miles of space to study the sunspot cycle and to learn to forecast the showers of electrified particles from the sun that periodically disrupt radiotelephone channels across the oceans. They have probed into the mysteries of how electrons, dancing inside the atoms of a copper wire, transmit the energy of speech from one end of the wire to the other.

Bell men's problems are never-ending and ever new.

Inside the mouthpiece of your telephone, for instance, behind the little holes that you talk into, a thin diaphragm of duralumin is vibrated by the energy of your voice. To protect it from rust-producing moisture, it used to be covered with a membrane of oiled silk. But cigarette and cigar ash, mixed with the moisture of people's breath, got inside and made a caustic deposit that ruined the oiled silk. So Bell men worked up a synthetic rubberized protector that is impervious to that caustic action.

They've developed a paint for telephone operators' chairs that won't snag the girls' stockings or rub off on them.

They've raised termites to find out what those pernicious insects *don't* like to eat, to help find a preservative for telephone poles in termite-infested country. In the process they discovered that termites will pine away, refuse food, and even digest themselves if their colony is disturbed. Maybe that will be some comfort to you if you have termite trouble!

They have a movie camera in which the film runs 70 miles per hour, taking up to 8,000 pictures a second, to slow down the movement of fast-acting automatic switches to see just how they work, or why they don't. Those cameras, incidentally, were used to photograph still-secret details of the atom bomb tests at Bikini Atoll.

You've wished sometimes (except when caught in the bath!) for a television set beside your telephone to let you see the person on the other end. Bell scientists 20 years ago built such a combination and had it working for a while between two buildings in New York. But installing it for general use today would

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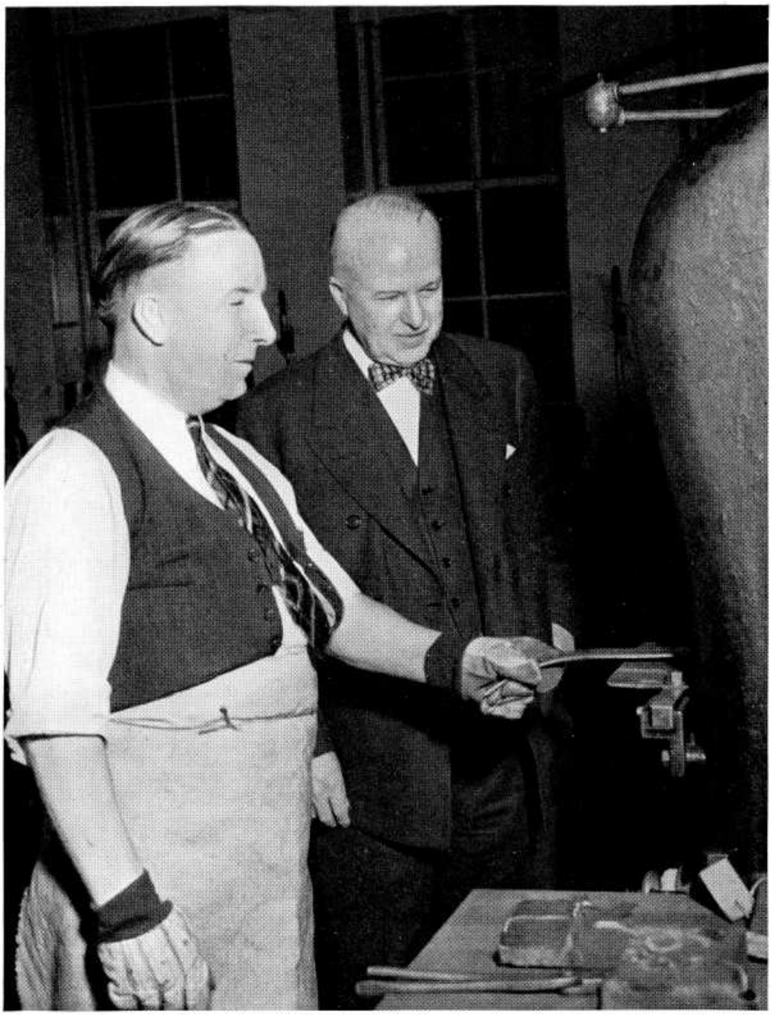

Metal Is Rolled to Calling-card Thinness

Walter S. Gifford (right), President of the American Telephone and Telegraph Company, watches while permalloy is fed into a machine which compresses it into strips 14/1000 of an inch thick. These are used in relays that are the heart of the telephone dial system.

be too costly to be practicable. Bell men, too, put on the first television demonstration between New York and Washington in 1927.

Constantly delving into endless secrets, solving countless problems, searching for knowledge that will be useful in ways as yet unknown, Bell Laboratories is typical of the many great industrial research institutions of the United States which have helped give this country its high standard of living and its leadership in many fields of science and technology.

Coal Grains Make Your Telephone Work

To tell all the things that Bell men do would take up volumes of this MAGAZINE, but a few examples will give you an idea.

Consider the coal in your telephone. Yes, coal about 50,000 finely crushed granules of it, in a pea-sized box just behind the diaphragm inside the mouthpiece (Plate IV). Through these bits of coal flows the current that carries your voice over the wire.

Coal is used because it's carbon, and carbon is not only a good conductor but quite elastic. As your voice vibrates the diaphragm, pressure of the granules against each other changes the area where they touch. That varies its resistance to the current passing through, and translates your voice waves into waves of electric current.

But that coal, though it is specially selected from only a few deep mines in Pennsylvania, has its drawbacks. Probably you're satisfied with the way it works, but the Bell scientists are not. It gradually deteriorates, and replacing it costs around $250,000 a year. More important, the tiny lumps are rough and uneven, providing a rather variable contact. Round grains, like tiny balls, would work better.

You can't make coal that way, though ; so the Bell scientists have found a way to make tiny balls out of silica sand, so small that even under a microscope they look smaller than BB shot. Heated methane gas is passed over the globules. It deposits on them a layer of carbon only one-millionth of an inch thick.

That thin layer of carbon works just as well as the solid carbon of the little lumps of coal, and, unlike real coal, its quality can be controlled and never varies. Eventually that "synthetic coal" may be in your telephone, making it work even better than now, and lasting longer, too.

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When you talk today by telephone between some large cities, your conversation may travel with several hundred others, all moving together inside the new "coaxial" cable (page 300). They all travel on currents of high frequency, each conversation using a different band of frequencies, or wave lengths, just as each station you get on your radio has its own band of wave lengths.

That combination of wave lengths, or frequencies, traveling over the cable is like the white light in a theater spotlight, containing within itself all the different colors - red, blue, green, etc. To throw a red light on the stage, you use a red filter which lets only the red rays pass through ; a blue one for a blue light; etc.

Staff Photographer Willard R. Culver

Styles Have Changed in Operators' Headsets Since 1880!

Girl at the right, in a costume of 65 years ago, wears the "Gilliland harness," which weighed six and one-half pounds. The box contains the transmitter. Operator at the left wears the latest headset, weighing only five and six-tenths ounces. Transmitter remains before the mouth when the head is turned.

Man-made Crystals Improve on Nature

You separate out single telephone conversations in the same way with electrical filters. Heart of each filter is one or more quartz crystals, each of which vibrates an unvarying number of times per second. The crystal filter lets through only the one conversation to which it is tuned. Those crystals are made from a special grade of quartz found almost exclusively in Brazil.

That brings up the story of how Bell scientists actually "improved on Nature" and made artificial crystals better for some purposes than the natural Brazilian kind. Those artificial crystals played a big part in helping to win World War II.

When German submarines began sinking Allied vessels wholesale, the Navy issued an urgent call for a device better than those then in use for locating submarines under water. Best way to locate a submerged submarine is to send out sound waves through the water which strike its hull and bounce back to their source. When converted into electrical waves, they reveal the distance and location of the submarine.

To convert the sound waves into electrical waves precisely enough to locate a submarine accurately, the best method is to use crystals which vibrate at a very precise frequency. Crystals of natural quartz had some limitations for the purpose and also were scarce, and those two facts made it essential to find a better way to do the job.

Bell men saved the day with artificial crystals. If you put a little water containing salt in a saucer and let it sit in the sun, the water

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Frederick Schutz

At the Telephone's Fortieth Birthday Party, 800 National Geographic Members Took Voice Voyages to the Four Corners of the U. S.

For the first time in history, through headphones each guest heard Pacific rollers breaking on California beaches; Prime Minister Sir Robert Borden in Ottawa sent heartiest greetings from Canada; and Brig. Gen. John J. Pershing, commanding the Mexican Expeditionary Forces, reported from El Paso on the Rio Grande, "All's quiet on the border." The black "box" on the table was an exact duplicate of the first Bell telephone. At the speaker's table on this great occasion March 7 1916, in Washington, D. C., are, left to right: Mrs. Lane; Thomas A. Watson (who built the first telephone and to whom Bell addressed his first words Plate I); Gilbert Grosvenor, Editor and Director National Geographic Society; Maj. Gen. Hugh L. Scott, Chief of Staff and Actg. Sec. of War, John J. Carty Chief of Eng. Staff, Am. Tel. and Tel. Co.; Dr. Alexander Graham Bell; Theodore N. Vail President Am. Tel, and Tel. Co.' Sec. of Interior Franklin ' K. Lane; O. H. Tittman, President National Geographic Society; Sec. of Navy Josephus Daniels; U. N. Bethell; Postmaster General Albert S. Burleson; Rear Adm. Colby M. Chester, USN, N. C. Kingsbury; Mrs. Burleson; and Sen. Joseph E. Ransdell. In the foreground extreme left corner Prof. Edwin A. Grosvenor of Amherst College, and Theodore W. Noyes, 38 years Editor Washington *Evening Stay*. At extreme right, Harvey W. Wiley, father of pure food laws.

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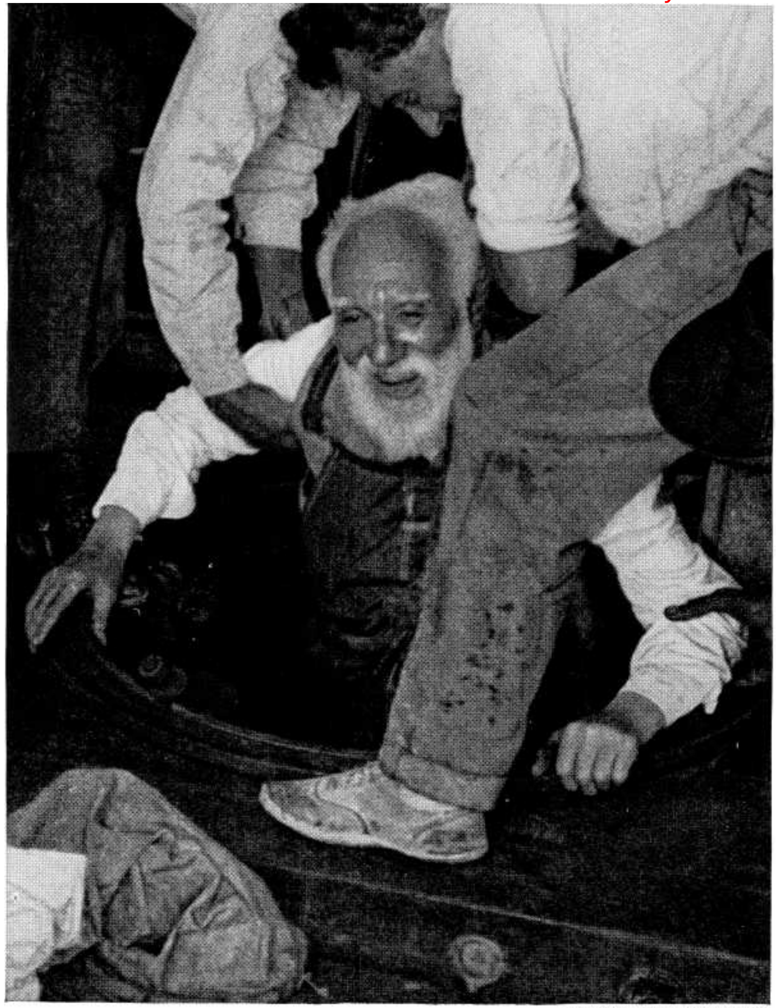
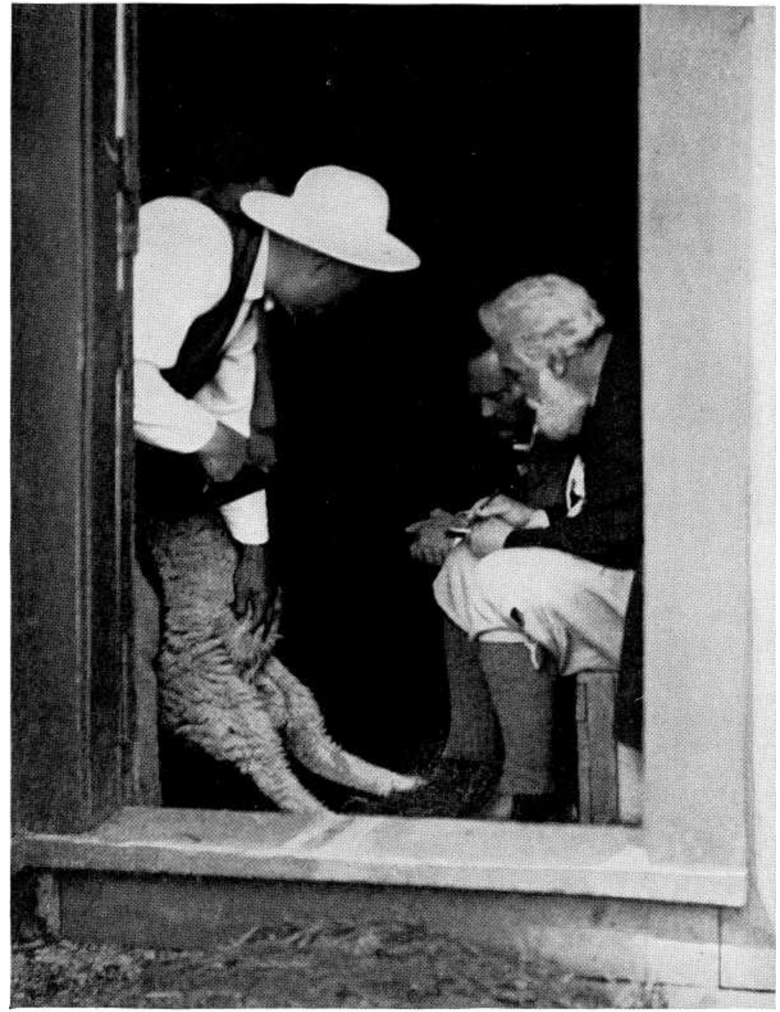


Submarine Film Corporation

UP from Davy Joness Locker Comes a Smiling Dr. Bell

On his visit to Nassau in the Bahamas, the 75-Year-old inventor descended in a submarine tube to study sea life on a coral reef. His friend, Charles Williamson, originated this device, a flexible tube with an observation chamber at the bottom.



Gilbert Grosvenor

The Inventor Examines One of His Twin-bearing Sheep

Since ewes usually bear a single lamb each year, Dr. Bell increased their yield to help farmers of Nova Scotia. Working for 35 Years, he developed a flock in which ewes bore twins and triplets half the time. Dr. Wilfred Gren-. fell, Labrador medical missionary, in center.

Dr. Bell's Prediction Comes True. He Talks to a Man "in a Distant Place"

The inventor of the telephone, in 1892, opens long-distance service between New York and Chicago over 800 miles of open wire line. Only 14 years before, in 1878, he had predicted that some day "a man in one part of the country may communicate by word of mouth with another in a distant place." Today all New York-Chicago connections are in underground cable, also forecast by Bell. The man with full beard is John E. Hudson, then President of the Bell Telephone Company

evaporates and you have some salt crystals left in the dish.

The Bell men began the same way, but instead of ordinary salt they used a chemical solution that contained ammonia, hydrogen, and phosphoric acid. They evaporated a little of it, and what they had left was a small crystal. This was too rough and imperfect to use in submarine detectors, but it served as a "seed" to build larger and better crystals.

If you revolve a crystal seed in a tank full of the chemical solution, more of the chemicals will come out of the solution and deposit on the seed (Plates XII and XIII). Gradually a large, clear synthetic crystal is built up. When it's large enough you take it out, cut off the good part, and use the seed over again to build another crystal.

Those synthetic crystals are not quartz, but they are built in almost the same way that Nature makes quartz crystals. But Nature takes uncounted thousands of years, while the scientists do it in days.

More than a million of those synthetic crystals went to war. Built into the Navy's famous submarine detector known as "sonar"

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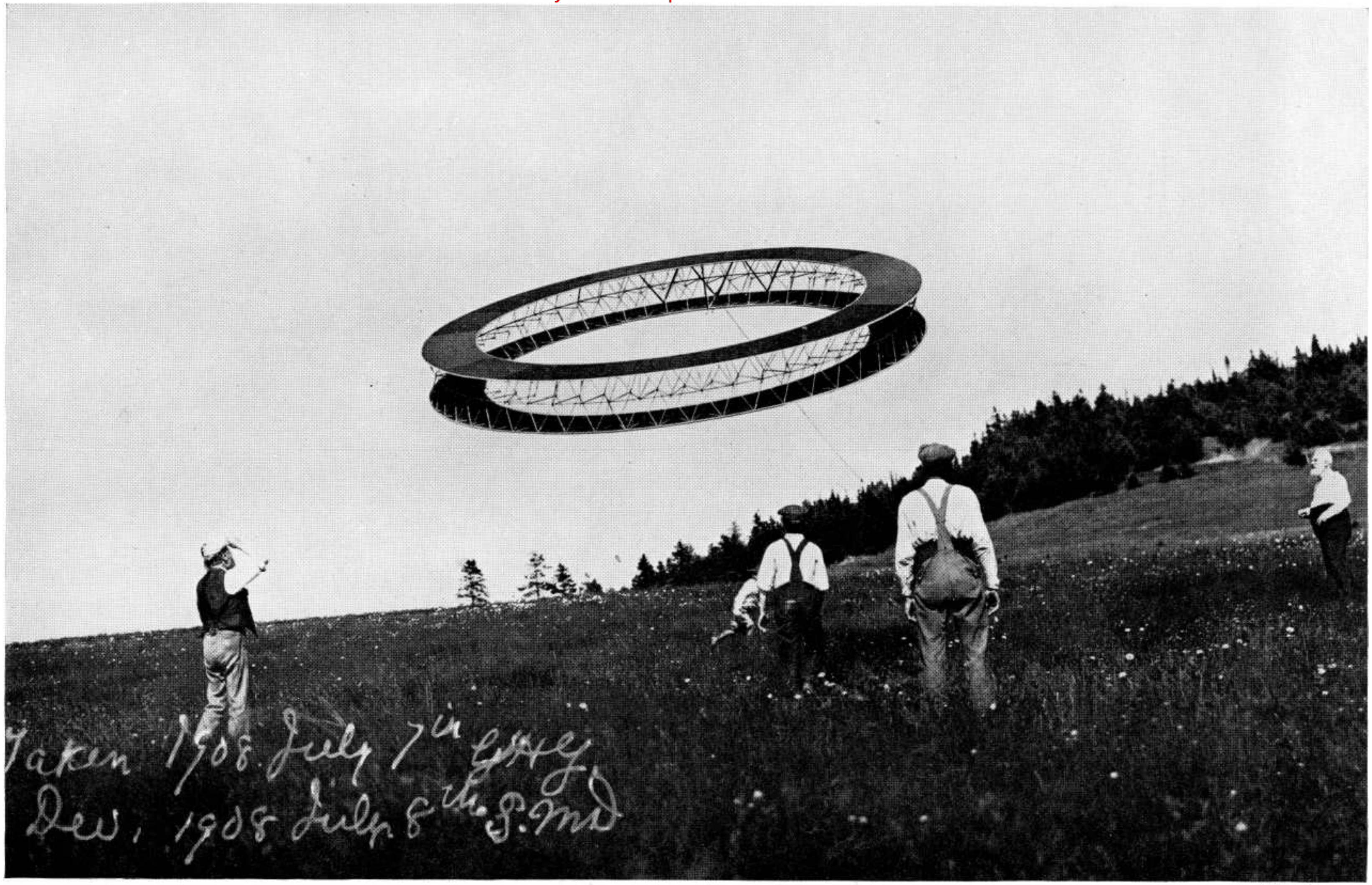

Gilbert Grosvenor

Flight of an Experimental Wheel-shaped, Multicelled Kite Is Watched by Dr. Bell Extreme Right m July, 1908

Dr. Bell was interested in developing an airplane that would take off at slow speed for safety's sake. He reasoned that if a kite could be made to develop a certain lift in a ten-mile wind, it would be possible to build a plane that would take off at ten miles per hour. His laboratory at Baddeck recorded the date on each negative.

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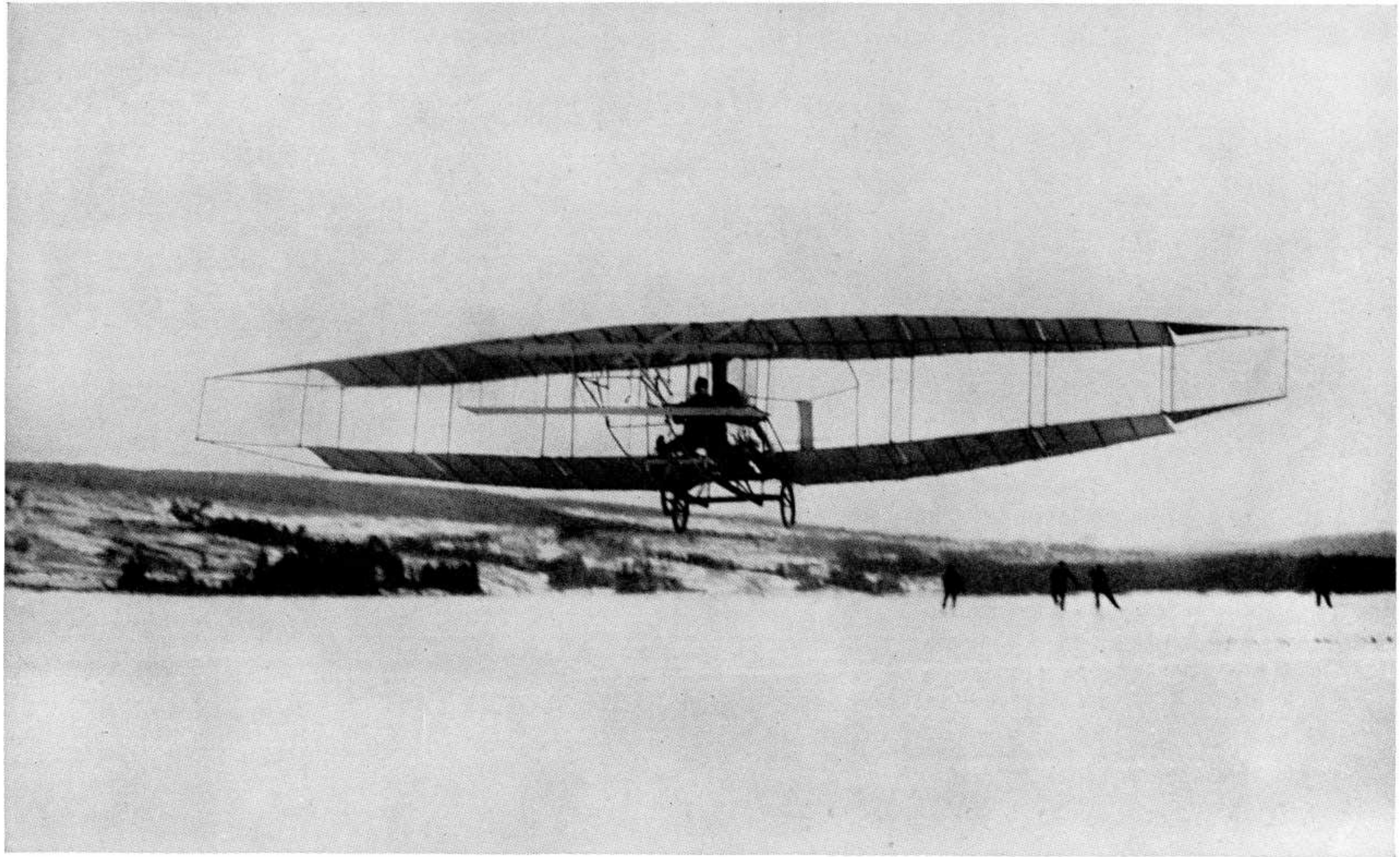

H. M. Benner

"Feb. 23 1909. McCurdy Flew over Baddeck Bay in the *Silver Dart* About Half a Mile-First Flight of a Flying Machine in Canada"

Thus Dr. Bell recorded the historic event in the annals of the Aerial Experiment Association financed by Mrs. Bell and of which he was chairman. The other members included such well-known pioneers in aviation as Glenn H. Curtiss F. W. Baldwin n, J. A. D. McCurdy, and Lt. Thomas E. Selfridge,U. S. Army, the first person killed in an airplane crash. The Silver Dart had a 49-foot wingspread and was powered by a 50-horsepower engine turning a pusher-type propeller.

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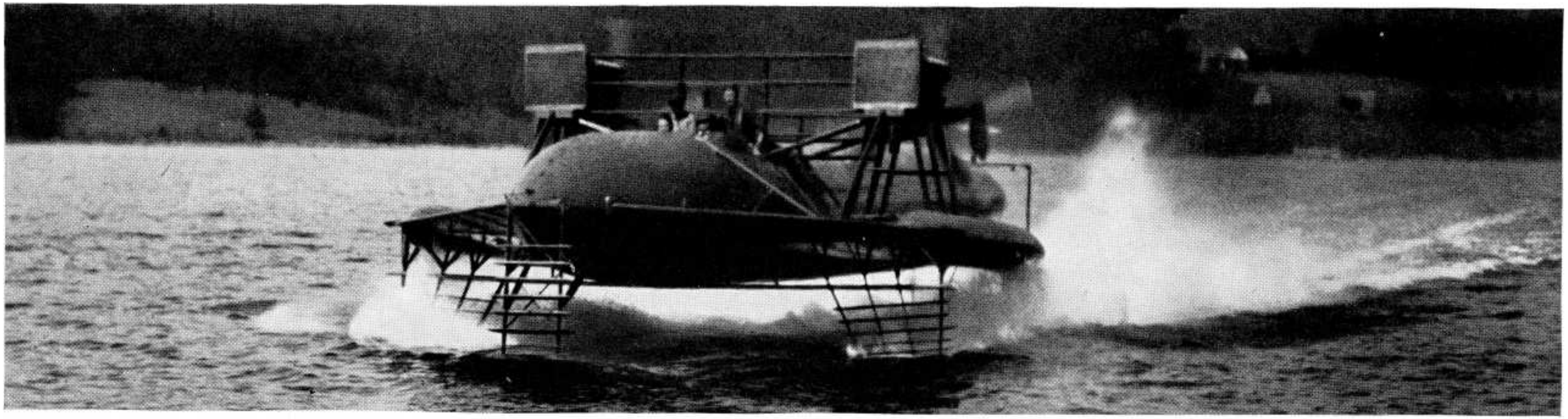
A Picture of Concentration Dr. Bell Studies Performance of the HD-4's Hydrofoils as It Speeds Toward Him-September, 1920

Steel planes, or hydrofoils, were arranged in sets like the rungs of a ladder, graduated from large ones at the top to small ones at the bottom. The faster the boat traveled the higher it rose out of the water until its weight was carried entirely by the lower planes.



Gilbert Grosvenor

Like a Giant Water Bug, the HD-4 Roars Across Baddeck Bay at 1920 World-record. Speed-71 Miles an Hour

As the boat gained velocity from its propellers the hull was lifted clear, as if on stilts, thus cutting down resistance and permitting high speed.

Men Who Developed the Telephone Visit National Geographic Society, March 8, 1916

In front are Alexander Graham Bell (right) and Theodore N. Vail, principal organizer of the Bell System in early days. Others, left to right: H. D. Arnold, director of research, Bell Laboratories; H. E. Shreeve, engineer who took part in first transatlantic radiotelephone conversation ; U. N. Bethell, president New York Tel. Co.; C. A. Robinson, vice president Chesapeake and Potomac Tel. Co.; E. H. Colpitts, executive vice president Bell Telephone Laboratories; O. B. Blackwell, assistant vice president Am. Tel. and Tel. Co.; Thomas A. Watson; A. W. Drake, commercial manager, Long Lines, Am. Tel. and Tel. Co.; G. A. Campbell, research engineer for Bell Laboratories; John J. Carty, vice president Am. Tel. and Tel. Co.

(sound navigation and ranging), they helped to locate a great many of the 996 enemy undersea craft sunk during the war. They helped clear the seas for the troopships and cargo vessels that made possible the successful Allied invasion of the Continent. Later, American submarines used sonar to hunt down Japanese ships.

Now that the war is over, artificial crystals are still being made, because the large sizes needed in filters in the telephone system are rarely found in natural quartz, even if there were enough quartz, which is doubtful.

Another example of how little things helped win the war is the story of the molecules of gold. In all the countless radio sets in airplanes, tanks, command cars, ships, and gun batteries, crystals of natural quartz were used to select out the different wave lengths on which these radios operated.

To make a crystal vibrate at a certain frequency, so that it will receive messages on one certain wave length, you have to cut the crystal to certain exact dimensions. But achieving just the right thickness to pick up the higher radio frequencies is too delicate a job to do accurately with tools.

That's where the molecules of gold came in. Bell scientists cut their crystals an infinitesimal amount off the required thickness. Then, by heating a tiny bit of gold, vapor was boiled off from it and deposited on the crystal in a layer a few molecules thick, until the crystal was altered to produce just the right frequency.

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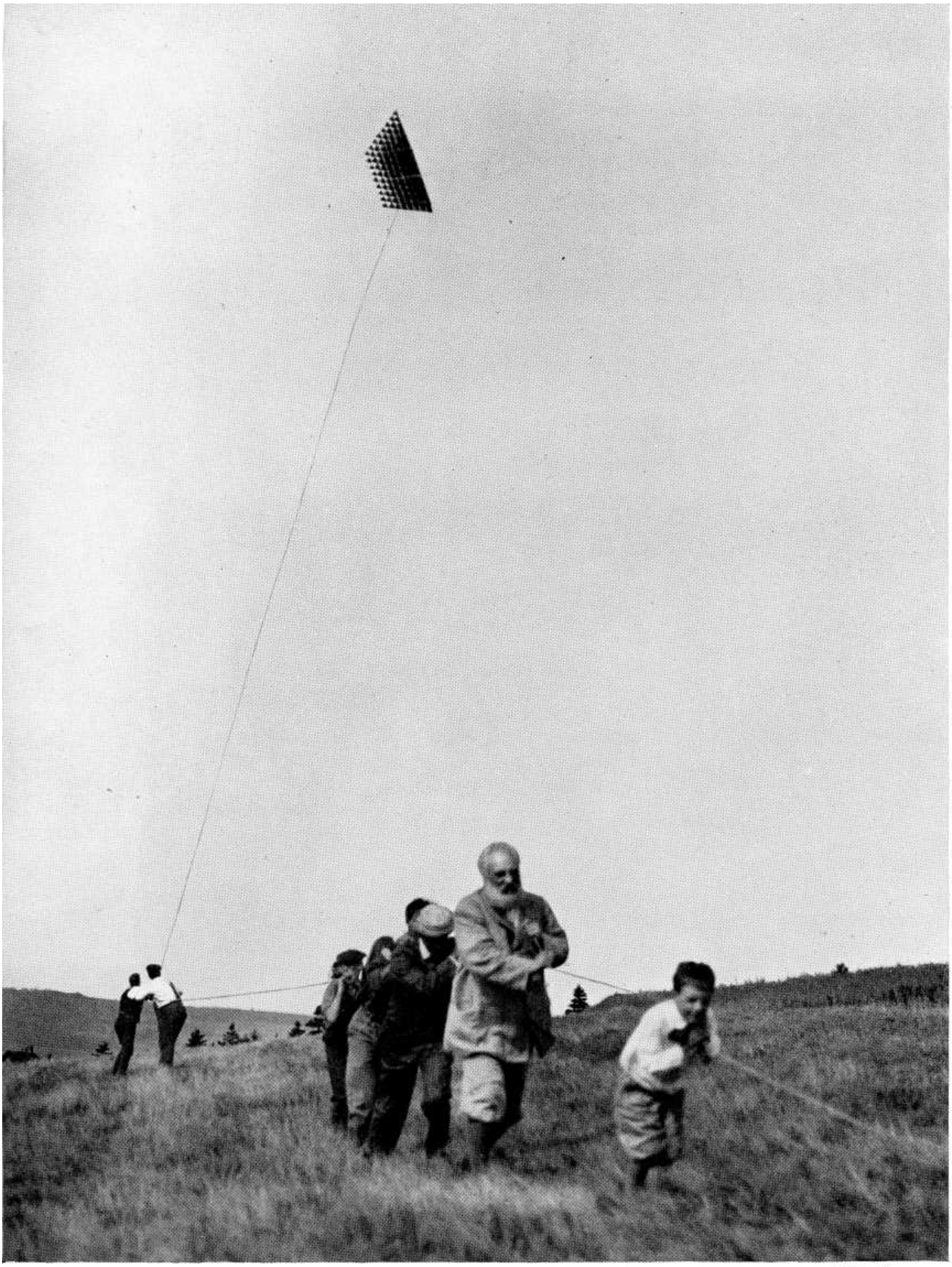

Gilbert Grosvenor

Dr. Bell Lends a Hand in Hauling Down One of His Big Man-lifting Kites

This is the same type of kite that lifted Lt. Thomas E. Selfridge, U. S. Army, to a height of 168 feet in 1907. It is built of tiny tetrahedral, or four-sided, cells, each of the four sides being triangular, a shape which provides great strength. Dr. Bell experimented with various kinds of kites at his summer home at Baddeck, seeking to solve problems of flight. A grandson, Melville Bell Grosvenor, aids in the foreground.

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Not long ago a man riding in an automobile in Washington, D. C., picked up a telephone on the dashboard and talked to his wife in England, learning, incidentally, that their grandson had had his first tooth.

That was a demonstration of the new mobile radiotelephone service which is rapidly being put into use in large cities and on major highway routes in this country (Plate III). With this service you have in your car a telephone with its own number.

If you are a salesman, for instance, out around town in your car, the boss may want to tell you right away about a new good prospect for a sale. He merely calls your car telephone number, the call goes by wire to a radiotelephone station, then through the air to your car. A bell rings and a light flashes on your dashboard. You pick up the phone and carry on a conversation. Later, if you want to call the boss to tell him you put over the deal, you can call him direct from the car.

If you're out on the road between New York and Philadelphia, the boss can get you by calling long distance, giving your car telephone number, and saying he thinks you're about 20 miles south of Newark. The toll operator routes the call through the radiotelephone station that is nearest to that locality. If you don't answer, she tries the next station on down the road.

You can see this system's usefulness for salesmen, police, doctors, buses, newspapers, delivery trucks, and public utility repair crews.

Telephoning to passengers or the engineer on a moving train also will be possible. Eventually, you may be able to talk this way from one train to another in different parts of the country or even of the world, and probably between passenger planes and the ground.

Just delivering your voice anywhere you want it sent, over the existing maze of American telephone wires, is a big enough job. To transmit a human voice over the telephone, you need first to know how the voice works and what it can do, and to make it heard at the other end you need to know how the ear works and what it can and cannot hear.

Alexander Graham Bell, in one of his early experiments, sang songs into a human ear obtained from a medical school. He attached a thin straw to the inner part of the ear, fixed so one end rested against a plate of smoked glass.

When he sang into the ear, the sound waves set up by his voice vibrated the eardrum, and the straw made wavy lines on the smoked glass. In this way he obtained a picture of sound waves that helped in his invention of the telephone. You can still see those old glass plates with the wavy lines on them, preserved at the Bell Laboratories (page 281).

Today Bell scientists are still experimenting with the human ear. Between 20 and 40 thousand nerve fibers connect the ear to the brain. These nerves, telling the brain what the ear hears, form the last link in the process of transmitting the voice over the telephone.

New knowledge of deafness and what to do about it also has come from these studies of the human ear. A device to measure the hearing of a whole roomful of school children at once was developed by Bell scientists.

The children listen to a series of numbers spoken with steadily diminishing loudness, and write them down as long as they can hear them. The last number written indicates the degree of the child's deafness, if any. These tests, now widely used in schools, have shown that one of every 15 American school children is handicapped in his school work by some degree of permanent or temporary deafness.

One Person in 10 Is a Little Deaf

The hearing of more than half a million people was tested in the same way at the New York and San Francisco world's fairs of 1939-40, the first tests ever made of the hearing of a large cross section of the population. Results showed that one in every 10 persons is deaf to some degree, but that some people have supernormal hearing.

Speaking, of course, is just as important as hearing in the telephone system. It begins with the larynx, which contains the vocal cords. They really are not cords but two curtainlike membranes, in your throat behind your Adam's apple, that vibrate when you talk.

Seeking to learn how the vocal cords work, to see if the telephone transmitter was properly designed to handle the sounds that the cords give out, Bell Laboratories scientists took the first high-speed movies ever made of the vocal cords in action (Plate II). People used to think that the cords vibrated like a banjo string, but the movies, run in slow motion, showed that they really have a sort of wavelike action, somewhat like clothes flapping on the line on a windy day.

From the movies they learned, too, that sound comes from the vocal cords in puffs. Since the telephone was already designed to handle this type of energy properly, no changes were needed. The movies revealed that a person with a well-trained voice keeps his vocal cords closed until air pressure is built up in the chest and expelled strongly. In a person with an untrained voice the cords are open most of the time.

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Women's vocal cords are shorter than men's, and this is the reason why their voices are higher-pitched. Opera singers have had their vocal cords photographed by the Bell people in efforts to improve their performance. Doctors are using the high-speed camera to photograph diseased vocal cords.

"First step in making a telephone work right is getting your voice into it," one of the Bell engineers told me. "That's not as simple as it seems. When you talk, the sound waves resonate in the cavities of your mouth and throat and are shaped by your teeth, tongue, palate, and lips.

"About half the sounds you utter are made within the mouth, the other half coming from the vocal cords. When the sounds come out of your mouth, they billow and eddy all around your head, besides traveling straight forward.

"To find out how the voice behaves and how it is transmitted, we use an artificial voice which reproduces all typical voice tones (Plate IX). We found that our efforts to make voices more understandable over the telephone tended to reduce naturalness, and so we try to strike a happy medium. The human voice ranges over about five or six octaves, but not more than about four octaves need to be transmitted over the telephone for good hearing. To transmit the other octaves would be unnecessarily expensive and complicated.

Artificial Voices at Work

"Incidentally, we have artificial voices working regularly as part of the telephone system. Sometimes from a dial telephone you may call a number which is in an exchange where operators handle the calls ; so, when you turn the dial, it starts an artificial voice speaking, and this repeats aloud in the operator's headset the number you have dialed. This is done with numbers recorded on sound movie film, and the dial system selects the numbers to be `played.'

"To do its job well, the telephone mouthpiece should be right in front of the mouth, and the receiver end of the handset should be right by your ear. That means the handset has to be just about the proper length to reach from the average ear to the average mouth. The connecting piece has to fit around the face. We measured hundreds of human heads, big and little, fat and thin, male and female, to design a handset that fits them all.

"How many times have you dropped your telephone on the floor? How many times in a year do you bang it down on the hook when you finish talking or get a busy signal? Not long ago a woman in Washington, D. C., hit a holdup man on the head with her telephone when he tried to stop her from calling the police. It didn't break.

"We make the handset tough by baking the plastic with an electronic process that generates heat inside the material, heating it equally all the way through. On a testing machine we can bang down a handset on the hook enough times in 24 hours to duplicate the wear it gets in 40 years of use" (page 314).

Why is it hard to understand women? That, too, is a problem for Bell Laboratories men. It's not a matter of "advice to the lovelorn" or trying to figure why ladies change their minds. It's why women are somewhat harder to understand over the telephone than men.

The answer is that higher-pitched female voices disturb the inner membrane of the ear in only half as many places as the lower voices of risen. The higher frequencies of their voice tones are not heard because the ear is less sensitive to them. Yet the telephone must overcome this handicap as well as possible.

When you telephone today in any good-sized city, your voice is directed to its destination by a mechanical brain that works faster and in many ways better than any human brain ever could (Plate X). This "brain" is part of the "dial system," developed in its present form by Bell Laboratories engineers.

When you pick up the telephone and start to turn the dial wheel, the "brain" goes into action. First it notes the number you're calling, which is, say, Elmhurst *6-6352.* Then it hunts through the maze of telephone channels for a clear route from your own exchange to Elmhurst. It sets controls to keep that route clear, connects you to Elmhurst, finds the terminal of the *6352* line, connects you to it, and then drops out to handle another call, all in a matter of seconds.

If in setting up a call the "brain" runs into trouble in getting through, it turns on a set of lights to show where the trouble is and rings a bell in the wire chief's office.

Relays Run the Dial "Brain"

Electrical relays play a large part in making the dial "brain" work. A relay may have as many as 60 electrical contacts which can open and close much as you open and close your thumb and forefinger. Part of each relay is an electromagnet made of a coil of wire wound on an iron core. When current flows through the coil of wire, the iron becomes a magnet and pulls the "thumbs and fingers" of the relay together. Current then can flow through and on to another relay, where it activates another magnet, thus closing another contact; and so on.

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Gilbert Grosvenor

No Man Left the Ground to Build Dr. Bell's Tetrahedral Tower at Baddeck

Wanting a lookout on his mountaintop, he invented this type of construction using tetrahedral cells. Two legs of the tower were constructed on the ground from /-inch pipe and joined together. As the third leg was built and jacked up, the tower was hoisted until erect. The 84-foot structure was exceedingly strong and weighed only five tons. The inventor is buried here overlooking the Bras d'Or Lakes.

When all the relays between you and the number you're calling are closed, the current carrying your voice can travel all the way through. When you hang up, the current stops flowing, the relays spring open and are ready to handle another call.

On an average call in the latest type of dial system about 5,000 such contacts operate to make the connection. Each contact is really a pair of bars only 1/16 of an inch long. When the thumb and finger of the relay close, those two bars must meet firmly.

If a single relay fails to close, or to spring open again when the call is ended, or if the two contacts do not touch properly, or are worn, or dirty or tarnished, trouble will result.

Relay contacts used to be made of platinum, because, like all precious metals, it does not tarnish and will not melt under the heat generated by current passing through it. But platinum is costly, and hard to get in time of war when foreign supplies may be cut off. So Bell engineers developed a contact of palladium, another precious metal, also tarnish-proof and much less costly than platinum.

But dirt may collect even on palladium. Dirt on a contact interferes with smooth passage of current and may stop its flow entirely. This puts unwanted noise in the telephone and may even make it go dead. In their intensive war on dirt, Bell scientists have taken dust off contacts and analyzed particles of it weighing as little as 24 millionths of an ounce.

They've had to deal with cotton lint blown on contacts from a near-by laundry ventilator, and with gases and smoke particles present in the air in some industrial cities. To cut down this kind of trouble, air is filtered before it enters the rooms where dial "brains" are working.

As a further safeguard, contacts now are built in twin arrangements so that, if dirt

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Dr. Bell Devised a Concrete "Mulberry" Like Those Used in the Normandy Invasion

He and F. W. Baldwin (left) designed it in 1916 to use as a dock on steeply sloping rocky bottom where piles could not be driven. After being launched like a ship, the concrete caisson was towed into position and sunk, as were the larger "Mulberrys" that formed artificial harbors for the Allied landings of 1944.

Gilbert Grosvenor

In Position, the Caisson Is Sunk by Pulling a Plug in Its Wooden Bottom

Its underside was shaped to fit the contours of the lake floor as determined by soundings. Filled with rocks and topped with concrete, the dock served for many years at the inventor's summer home.

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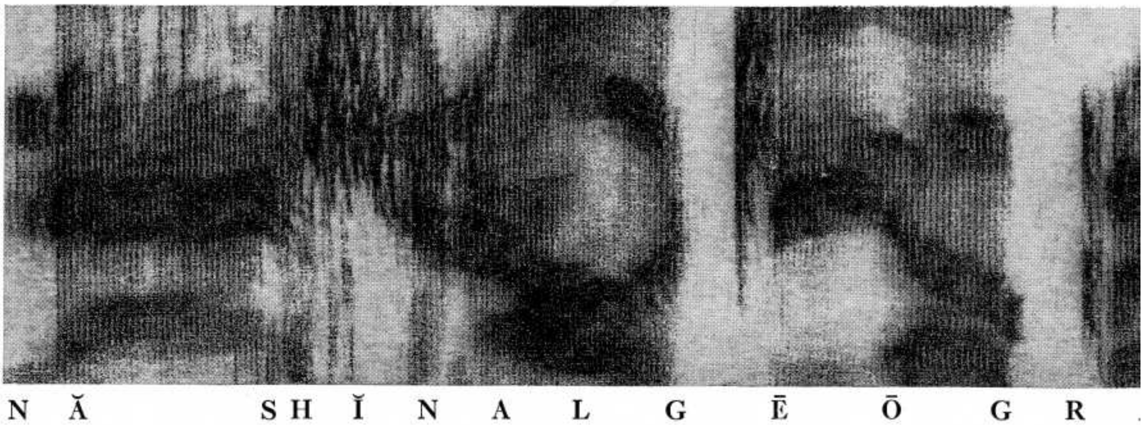

In "Visible Speech," the Words "National Geographic Society" Take This Form

With an apparatus developed by Bell Telephone Laboratories, spoken words are transformed into visible patterns which can be read. They form lines and shadows of varying shape and intensity which represent not letters but sounds. Note the similarity of the patterns made by the short "A" sounds in "National" and "Geographic." Music, bird songs, and noises also can be made into visible patterns.

spoils the working of one pair, the other can handle the entire load of current. By cutting down the size of contacts, the cost of the twin arrangement has been made less than that of the former single contacts.

Today the dial brain is even handling many long-distance calls. A man in Philadelphia, calling a Richmond, Virginia, number, gives the number to the Philadelphia toll operator. She dials a code number that connects her with Richmond and then dials the Richmond number direct from Philadelphia. This method is already in use in several large cities and eventually will be extended over the whole United States.

Giving Your Voice a Boost

Electrical energy rapidly dies away as it travels along a wire, and the smaller the wire or the higher the frequency of the current, the faster it dies. In some cases it may die away to one millionth of its starting energy in only seven or eight miles! In Alexander Graham Bell's day people used to speak loudly to overcome this loss on local calls, but on a transcontinental call that wouldn't help.

In old times they used wire as thick as a pencil to cut down the loss, but with the number of telephone lines in use today such wire would be outrageously costly. Bell Laboratories men overcame that hurdle with the vacuum tube amplifier, or repeater, which in effect takes the faint dying whisper of your speech and turns it into a mighty shout that carries as far as the next amplifier.

On a typical New York to San Francisco call it takes about 180 repeaters, spaced every 16 miles, to boost your voice along, like a series of men on mountaintops, each one hearing the faint callof the man to the east and bellowing it on to the next man to the west.

You must not let the voice's energy die away too much before amplifying it, however, for then it gets fainter than the noise o f the electrons eternally dancing inside the circuits which carry your voice. Then, when you amplify, you amplify the noise, and the voice is lost in the vastly magnified roar of those dancing electrons, which otherwise no human ear ever hears.

Amazing as it may seem, on a cross-country call voice tones echo back along the wire from the other end of the line, a real transcontinental echo. Even though your voice travels thousands of miles a second along a wire, there is sufficient time lag so that the man on the other end hears both you and your echo, a kind of confusing double talk. Bell men finally licked the echo with a device that stops it from returning while you're talking.

Ever since Alexander Graham Bell telephoned his first sentence over a wire between two rooms in 1876, telephone talk has traveled over ordinary parallel wires. But today such wires cannot do the whole job.

Bell scientists are developing brand-new ways of transmitting your voice. One of them is the new coaxial cable, consisting of several hollow tubes with a single thick wire inside each tube. This cable is already in service between a number of large cities and is being extended to cross the continent.

Still other ways to transmit your voice, without using wires at all, also are being

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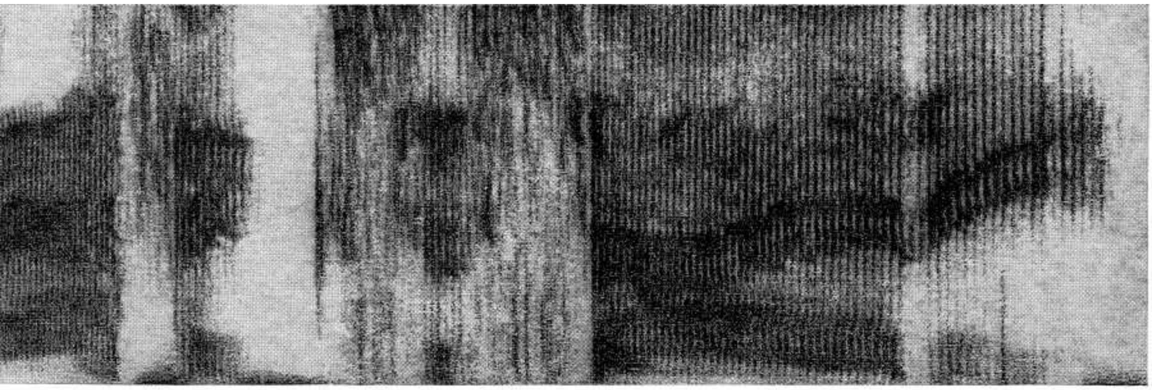

This Invention May Help the Totally Deaf to Speak More Clearly

Many people who have been deaf from birth or early childhood do not speak well because they cannot hear the correct pronunciation of words. With "visible speech" they can compare patterns made by their voices with those of correctly pronounced words until the two match. In a similar way the device can be used for teaching pronunciation of foreign languages (page 273).

studied by Bell men. They are experimenting with very short electric waves vibrating billions of times per second. Such waves won't stay on wires. They must either be shot off into space as radio waves or captured and guided along the inside of a hollow conductor or pipe.

Some day these extremely short waves may be carrying hundreds or even thousands of telephone conversations at the same time, each on its own wave length, without interfering with each other, over a single electrical pathway.

Television, too, is coming more and more to the fore. Television can be broadcast through the air only a few miles around each broadcasting station. To travel any distance it must be carried over some kind of channel or pathway, and the telephone system provides a network to do this (Plate XV).

But, to transmit a television picture, you must transmit almost instantaneously all the degrees of light, shadow, and perhaps color in each of several hundred thousand different parts of the picture, and do it all over again 30 times each second. It takes a broad band of frequencies to do this job, and such a broad band cannot travel more than a short distance over ordinary telephone wires.

Telephoning Without Wires

So new kinds of telephone pathways, which can carry many telephone conversations at once, and television programs as well, are coming into use. One is the coaxial cable, already mentioned, with its hollow tubes or pipes with a thick wire inside each. Through such a cable, using six different tubes at once, you can send 1,000 telephone conversations and several television programs, all at the same time.

Another new kind of telephone pathway is radio-relay, which uses a tight, straight, pencil-shaped beam of very short radio waves instead of wires or cables. These waves are largely free from static.

Bell engineers see the time when many hundreds of telephone conversations or as many as half a dozen or more television programs may be sent over this beam at the same time.

Radio-relay uses short radio waves that travel in straight lines and, unlike longer waves used in broadcasting, do not follow around the curvature of the earth. Beyond the horizon these short waves go off into space ; so, in order to transmit them any distance along the earth's surface, they must be picked up at a line of sight distance on the horizon and relayed on again to the next horizon. Thus they move in a series of short jumps between towers on mountaintops or other high points.

Radio-relay is now being installed by Bell engineers between New York and Boston. A radio-relay network eventually may spread all over the country, supplementing long-distance telephone cables.

Still another new kind of telephone pathway, a revolutionary new way of transmitting electricity, is the "wave guide," which is really just a hollow pipe. Electric waves travel through it like sound waves through a speaking tube.

It can handle very short waves that would

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Gilbert Grosvenor

Alexander Graham Bell with Three of His Grandchildren on Cape Breton Island

With his white beard and portly figure, the inventor in this pose resembles a jolly Santa Claus. He is clad in one of the homespun working suits that he always wore while at his summer home, Beinn Bhreagh (Gaelic for "Beautiful Mountain"). Here, in a private laboratory staffed with skilled workmen and technicians, he carried on much of his tireless experimenting, keeping detailed notes on everything. With two other noted scientists, S. P. Langley and Simon Newcomb, he once spent hours dropping a cat from his porch trying to discover why a cat always lands on its feet.

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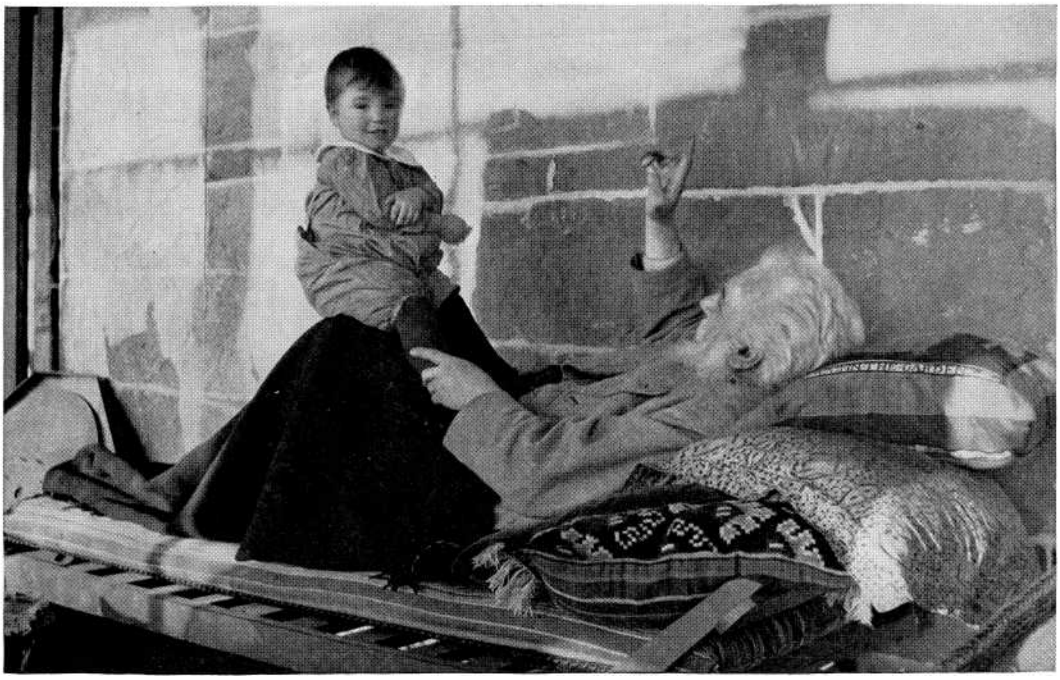

In a Characteristic Pose, Dr. Bell Plays with a Grandson

On the porch of the Bell summer home at Baddeck, Nova Scotia, the inventor entertains the boy by causing "an earthquake," collapsing his knees suddenly. Dr. Bell is survived today by two daughters, Mrs. Gilbert Grosvenor and Mrs. David Fairchild, nine grandchildren, and 19 great-grandchildren.

quickly die away in a wire; so someday, using such waves, it may be possible to send through the wave guide thousands of telephone conversations at one time and many television programs.

Some time, perhaps, wave guides may be used for long-distance telephoning, supplementing present-day cables, so that your voice would be "piped" to its destination instead of "wired."

As electric waves come out of the end of a wave guide, they can be focused by a special metal lens so that they form a narrow, tight jet or beam, just as a glass lens focuses a searchlight beam. You can aim that beam to hit something, or move it around to find something, as you would a searchlight beam.

Talking over a Radio Beam

Such a beam is used in radio-relay telephoning and in radar. In radio-relay you can aim the radio beam to hit squarely a small 10-foot receiving antenna 30 miles away on the next mountain. In radar you can sweep the beam around to find hostile planes or ships, or to locate other planes or ships in fog or darkness.

But wave guides, radio-relays, and coaxial cables are not much good unless you can amplify the waves that they carry. Those waves, just like the waves that travel on wires, need a good strong boost every so often to help them on their way.

Bell scientists are experimenting with a new way to do this by using a sort of "electron wind." This "wind" does its work in a new kind of vacuum tube, the "traveling wave tube." Short waves carrying your voice or television signals are fed in at one end of the tube and travel inside it through a coil of wire.

An electron gun at one end of the tube shoots a stream of powerful electrons down through the inside of the coil. Just as a wind blowing past ripples in a pond makes them into bigger waves, the electron "wind" gives a boost of energy to the electrical waves traveling through the coil, sending them on with new power.

Other Bell Laboratories men, meanwhile, are doing things perhaps easier to understand, such as finding how tree branches rub insulation off wires and how to make insulators for telephone poles that won't break when small boys throw rocks at them. Such things may happen right in your own yard, a little closer to home than the mysteries of the electron.

On a 100-acre "test farm" near Chester,

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New Jersey, is a dense grove of young birch trees among which are strung strands of "drop wire," the kind of wire that connects your telephone to the main line along the street. These little birches quiver and sway in the slightest breeze and their branches rub on the wire, to show whether they will rub through new, tough kinds of insulation.

Even out in the open where no branches rub on it, insulation on a drop wire sometimes breaks down. Bell scientists found it was caused by ultraviolet light from the sun and ozone in the air causing a chemical reaction in the insulation. In the laboratory they made new kinds of insulation, bathed them in artificial ultraviolet light and man-made ozone until they had something that would stand up.

Only "crop" on the Bell test farm comes from a bed where various kinds of fungi grow in a low, moist, shady place. Driven into the ground in the bed are stakes made of samples of all kinds of wood, to test how fungi in the soil may cause the wood in telephone poles to rot and how various kinds of chemicals protect the wood from this attack.

On a near-by hill are set up rows of full-sized poles, some treated and some not, to see how they resist moisture and rot (Plate IV). Poles are impregnated with creosote under pressure to prevent rot, but Bell men found that fir poles are best treated when green, while poles of southern pine need to be seasoned first.

Dancing Wires Make Trouble

Out in the West's "great open spaces," and in other exposed places, strong winds often set wires and overhead cables to swinging. As wires swing, they may make contact with one another, spoiling the transmission of telephone talk. Swinging cables may crack the protecting lead sheath.

This Jersey farm has machines to swing wire and cable artificially, just as the wind does it, over and over, millions of times, at the same time checking the number of hits when the "wind" blows at various speeds. From this Bell scientists figure how far apart to string wires so that they won't hit each other.

They've even taken movies of wires dancing in a high wind and then run them in slow motion. They slip sections of rubber hose over wires, too, to imitate the effect of icing, to see how much more leverage this gives the wind in swinging the wires and how much strain built up in this way is needed to break a wire.

Here, too, they bury samples of cable, conduit, and other things used under ground in the telephone system, to learn how they stand up and whether water will seep in. Once a neighboring farmer, seeing two scientists digging up a piece of cable about dark one evening, thought they were gangsters hiding a victim's body and called the State police!

Meanwhile, other Bell engineers are making plans for a new and better telephone link between America and Europe, a telephone cable under the Atlantic, first transoceanic telephone cable ever laid.

You can telephone across the Atlantic now, of course, by radio. Most of the time it works well enough. Radio waves that carry your voice travel in a series of bounces between the earth and the ionosphere, an electrified region of the upper air between 50 and 250 miles aloft.

But when sunspots are numerous, showers of electrified particles shoot off from the sun and disrupt the ionosphere. Instead of bouncing back down from it, the radiotelephone waves are absorbed in it or go on through and are lost in space. Sometimes, too, different components of the radio waves arrive at slightly different times, causing fading and distortion.

In a cable this wouldn't happen. You may ask, then, why a telephone cable wasn't laid long ago, since transatlantic telegraph cables have been in use since 1866. A telephone cable was designed, about 1930, but it could carry only one conversation at a time. Some radiotelephone circuits now are handling three at once to Europe.

To make an ocean telephone cable that can carry that many or more conversations at once, you need to put repeaters along it, the same as on long-distance cables on land, to pick up the dying power every so often and give it a new boost onward. On land the repeaters are above ground where you can get at them to make repairs and replace the tubes and batteries. You can't do that on the ocean bottom.

But now Bell men are working on a telephone repeater that fits inside a cable and can be wound on a cable drum without being damaged. They've designed a new, tiny, but long-lived vacuum tube for these repeaters which has every prospect of lasting many years inside the cable on the ocean bottom. They plan to send power out to the tubes from land along the cable itself and hope the cable will carry up to 2 0 conversations at once.

Radar, Child of the Telephone

When the Nazi menace began to grow in Europe and while most Americans still were arguing about preparedness, scientists of the Bell Laboratories cooperating with the Army

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and Navy quietly began to get ready for war.

Since 1937 they had been experimenting with radar, but no one had found a way to generate short waves for the radar beam that would reflect back an accurate image of what it found, so that you could tell whether your radar had picked up a battleship or merchantman, a bomber or a fighter plane.

One day in 1940, long before Pearl Harbor, when England stood alone against the Germans, some English scientists brought to America a new kind of vacuum tube, the magnetron, which they had developed. It was a new, powerful generator to produce short waves that would bring back a more accurate image of what the searching radar beam found. Bell men, cooperating with the British, developed and improved the magnetron even further.

Radar was "right down Bell men's alley." Working in peacetime to improve the telephone, they had developed new gadgets and "know-how" that fitted into radar like pieces of a puzzle. Radar sets used many of the same things that Bell men had developed for the telephone system.

Vacuum tubes, used in radar to amplify the faint returning echo, were developed from similar tubes that amplify telephone signals. Saucer-shaped antennas, used to direct radar waves outward and catch them when they echoed back, are near kin to antennas used in telephoning by radio-relay (Plate XVI).

And the wave guide, already mentioned (page 301), which was used to carry the more sensitive types of radar waves from generating tube to antenna, grew out of Bell Laboratories' search for ways to transmit electric waves of very high frequency.

What radar did is well known. One U. S. warship, with radar-aimed guns, sank an enemy vessel eight miles away at night with only two salvos. At Anzio beachhead radar-equipped guns and planes broke up German pattern bombing. Radar-directed guns shot down all but three of 105 buzz bombs launched one day against London.

Radar in America was jointly developed by Bell Laboratories, the Government's Radiation Laboratory at Massachusetts Institute of Technology, the Naval Research Laboratory, the Army Signal Corps Laboratory, and other Government, industrial, and university laboratories.

All cooperated fully, and, together with British scientists, they gave America and her Allies radar sets better than the enemy ever had. Undoubtedly radar greatly shortened the war and saved countless lives.

When the Germans invaded France and the Low Countries, nothing seemed to be able to stop their air force. Antiaircraft fire was not much more accurate than it had been in World War I, when it took an average of 17,000 shots even to hit a hostile aircraft.

One Bell scientist, who like many others had been worrying about the Germans' successes, happened to be working on a potentiometer, or voltage-measuring device, used in connection with sending currents through long-distance telephone cables.

Scientist's Dream Helps Win the War

One night this scientist had a dream. In the dream he saw a potentiometer mounted on the trunnion of an antiaircraft gun, and the gun was automatically "tracking" or following the flight of an airplane.

Unlike most dreams, this one stayed with him. When he woke up he jotted it down, and in this way was born the idea of the amazing electrical gun director, which gave American and British antiaircraft guns almost unbelievable accuracy. It was developed entirely by Bell Laboratories men, based directly on work they did to improve the telephone.

You can appreciate what the gun director had to do if you've ever shot ducks on the wing or tried to swat an elusive fly. You know how hard it is to figure in advance where the ducks or the fly are going to be the next second so that you can put your bird shot or your fly swatter in the right place at the right time.

Think how much bigger a job it is to fire an antiaircraft shell so that it comes near a plane flying 300 miles an hour, and with the fuse set to explode when it is near enough the plane to do some damage.

To score a hit you have to know the height of the plane, its speed and direction of flight, and the distance from the gun to the plane, which is constantly changing. You must know also the velocity of the shell leaving the gun, the speed and direction of the wind blowing against the shell, the temperature of the air, the pull of gravity on the shell, and the effect of air friction.

All this helps determine how far ahead of the plane to aim, so that shell and plane will meet. When you're shooting at a flock of ducks flying past, you may "lead" them with your gun by three or four yards; but you often "lead" a bomber formation with your antiaircraft guns by three or four miles!

When you have all the data, you have to perform an intricate mathematical calculation, and from the result you aim your gun. If you did this by ordinary methods, the planes would be long out of sight by the time you finished.

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Staff Photographer Willard R. Culver

"Drop Test" Helps Make Handsets Hard to Break

Dropping nearly six feet down a slide, this one bounces unharmed off an iron anvil. Others, on the floor, illustrate how some samples fail when carried to destruction in this type of test. Modern handsets are molded from plastic powder electronically preheated to increase strength (page 297).

the fuse setter, which adjusts the fuse on each shell to make it explode at just the right time.

A Hit for Every 90 Shots

When the gun director went into action, American and British gunners shot down enemy planes with an average of only 90 shots instead of thousands. When the Germans started shooting buzz bombs at the great Allied base at Antwerp after the Normandy invasion, the gun director enabled our guns to shoot down all but a few of the 4,856 known to have been launched.

Best of all, the idea behind the gun director has great potential uses in peace as well as war. Out of it has come new knowledge of how to build new high-speed calculators to solve in a few minutes mathematical problems that would take weeks for a man with paper and pencil. The principle of the gun director's electrical brain also may find new uses in blind landing systems for airplanes and in control of the heavy airplane traffic around airports.

But the Bell Laboratories men developed an electrical brain that does all the calculating in a fraction of a second. Its working is not really hard to understand. Into the calculator is fed so much voltage for the plane's speed, so much for its height, so much for the shell's velocity, pull of gravity, force of the wind, etc. You might say that each intake of voltage in effect turns the gun a little to the right or left, or pulls its muzzle a little up or down.

When all the voltages have finished pushing and pulling on it, the gun is pointing so that the shell it fires will hit the target. The electrical brain does all this pushing and pulling in a fraction of a second. It also operates

Another "secret weapon," ready for action when the war ended but never used, is a device that can detect a man just by the heat of his body a quarter of a mile away, and locate ships and the chimneys of factories at night by the heat they radiate.

You can sweep this device around a darkened landscape and it will pick up the heat of anything, such as a man hidden in the bushes, that is only slightly warmer than its surroundings. From a high-flying plane it can indicate the pattern of a river by the difference in the heat radiated from land and water.

This device is built around the "thermistor," developed in peacetime by Bell Labora-

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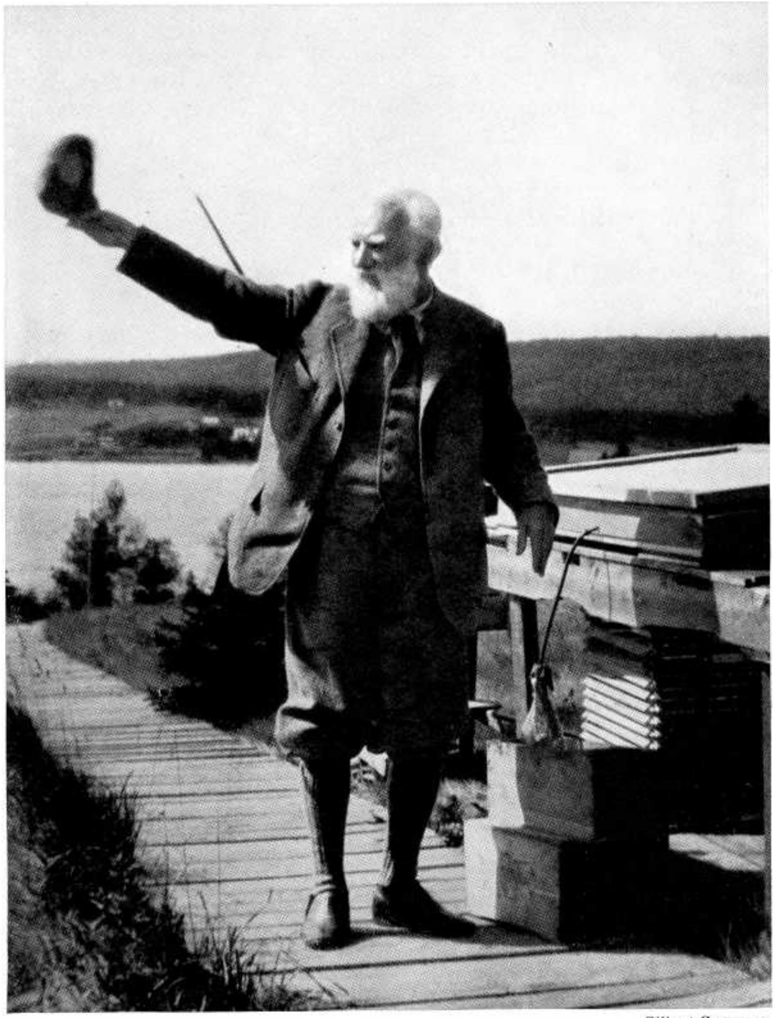
tories engineers to offset changes in temperature that cause variations in the loudness of speech traveling over long-distance telephone lines.

Thermistors are made of peculiar materials that conduct electricity well when warm and poorly when cold just the opposite of most good conductors, such as copper. Tiny specks of thermistor material are imbedded in a glass bead the size of a pinhead and connected to the amplifiers along the telephone line.

They are so sensitive to heat that they can detect variations in temperature as small as 1/1000 of a degree centigrade. As the cable grows warmer or colder, the loss of power in the transmitted waves goes up or down. The thermistor regulates the amplifiers so that they keep the telephone signal always at the proper loudness and conversations are passed on with unvarying clarity.



Gilbert Grosvenor

Dr. Bell with One of His Water-distilling Devices

He was interested in finding a way to provide fresh water for fishermen lost at sea in small boats, long before the problem became urgent in World War I. In this apparatus moisture evaporated from salt water heated by the sun was condensed on a sloping pane of glass. Pure distilled water trickled down the small tube and into the bottle. Six of these stills supplied his house with drinking water when tap water became contaminated. Dr. Bell also condensed fog with a bellows actuated by the rise and fall of the waves.

Mine that "Remembers"

Still another almost-magic weapon, the magnetic mine that "remembers," was made possible by permalloy, an easily magnetized alloy developed originally for telephone use. This mine played a large part in helping defeat Japan by sinking her merchant ships. Since it rested on the bottom of ship channels, it could not be swept up.

When a steel ship passed near, it caused a change in the earth's magnetism that set off the mine. But its best feature was that it could be set to let one, two, three, or any desired number of ships go by unharmed and then explode under the next one. Thus the Japanese never knew when a waterway was clear of mines.

One of Bell Laboratories' biggest contributions to winning the war was the development of special telephones for tanks and giant planes. The frightful noise that accompanies modern war presented a whole new problem to engineers, unlike anything they had to deal with in designing telephones for use in civilian life.

An ordinary telephone that worked well in a quiet home or office was useless against the tremendous roar of hundreds of airplane motors on a great bombing raid or the deafening din of a 400-horsepower engine inside the

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steel walls of a tank. It was often a matter of life and death for a pilot or tank driver to hear correctly a radiotelephone message above the roar of the motors in his ears, and equally vital that his own words spoken into the telephone transmitter should not be drowned out by the noise around him.

Shutting out surrounding noise in order to hear clearly was not so difficult. Bell scientists developed a soft rubber pad for the earpieces of telephone headsets which fitted tightly against the ears and cut down outside noise well enough to permit satisfactory hearing when there was no static on the radio. Such earpieces were used in aviators' helmets and in tank crews' headgear. But keeping unwanted noise out of the telephone transmitter or microphone was a tougher problem.

One solution was the throat microphone. Unlike ordinary telephones, in which a diaphragm picks up vibrations of the air set up by the voice, the throat "mike" had the diaphragm strapped tightly against the user's neck. When he spoke, the diaphragm picked up the vibrations set up by his voice in his throat walls, and other noise was largely shut out. But the throat microphone was not entirely satisfactory, because it did not transmit the speech sounds formed in the nose and mouth which are important for complete clarity (page297).

To overcome this difficulty the Bell engineers built a microphone with a shield which covered the nose and mouth. This excluded outside noise and permitted the user to speak in the normal way with all the speech sounds transmitted. This type of microphone was built right into aviators' oxygen masks, which formed a noise shield in themselves.

Still another antinoise device was the lip microphone. It operated on the principle that if sounds strike both sides of a telephone diaphragm they will cancel out its vibrations and will not be transmitted; but if they strike only one side they will be. The diaphragm of the lip microphone is placed very close to the mouth. Surrounding noise still strikes both sides of it and cancels out, but the voice strikes only one side, and so the diaphragm vibrates and transmits the voice sounds. The lip mike was used in directing landing operations above the noise of battle and in persuading enemy troops to surrender.

Altogether, the Bell Laboratories worked on 1,200 military projects during the war, some of which are still so secret that Bell men don't even mention them to each other. Its staff was expanded from 5,000 to 8,000 men and women during wartime, and $150,000,000 was spent on war developments.

To train Army and Navy officers and men in the operation and maintenance of the new weapons developed there, the Laboratories operated a school in which more than 4,000 students received instruction. So numerous were the instruction books for these scientific weapons that during the war the Laboratories became, next to Uncle Sam, the Nation's largest book publisher in number of titles. What a far cry from the days when all a soldier needed to know was how to load and fire a squirrel rifle

Telephone By-products

From telephone research have come not only these many scientific weapons but also many other by-products for peacetime use which have helped make Bell Laboratories famous.

Bell men developed the orthophonic process of recording sound electrically, and "auditory perspective," a method of picking up the music of a symphony orchestra from several different points, to make it sound more natural when reproduced over loud-speakers. They made the first radiotelephones used on commercial air lines.

Bell men's research made possible new ways to measure accurately the noise in subways, traffic tunnels, airplanes, and factories, and cut it down ; and improvements in acoustics of auditoriums (Plate XIV).

Vitamin B_1, or thiamin, so essential to health and now put into many "vitamin-enriched" foods, was first produced in pure form by a Bell chemist in his spare time. Later he and his colleagues determined its chemical structure so that it could be made in vast quantities synthetically.

Prospects for the future seem endless.

"Most of the fellows on our staff are dreaming about `day after tomorrow' even while they concentrate on telephone problems of today," one Bell engineer told me. "They're free to use their imaginations, to look far ahead, to think up new ideas. In their brains today are being born things that you and I haven't even imagined."

Walter S. Gifford, President of the American Telephone and Telegraph Co., in his 1946 annual report said: "The further we progress in the sciences underlying telephony, the greater becomes the promise of future benefits. The areas which we have under exploration are steadily expanding and the possibilities of electrical communication seem to excel anything achieved in the past."

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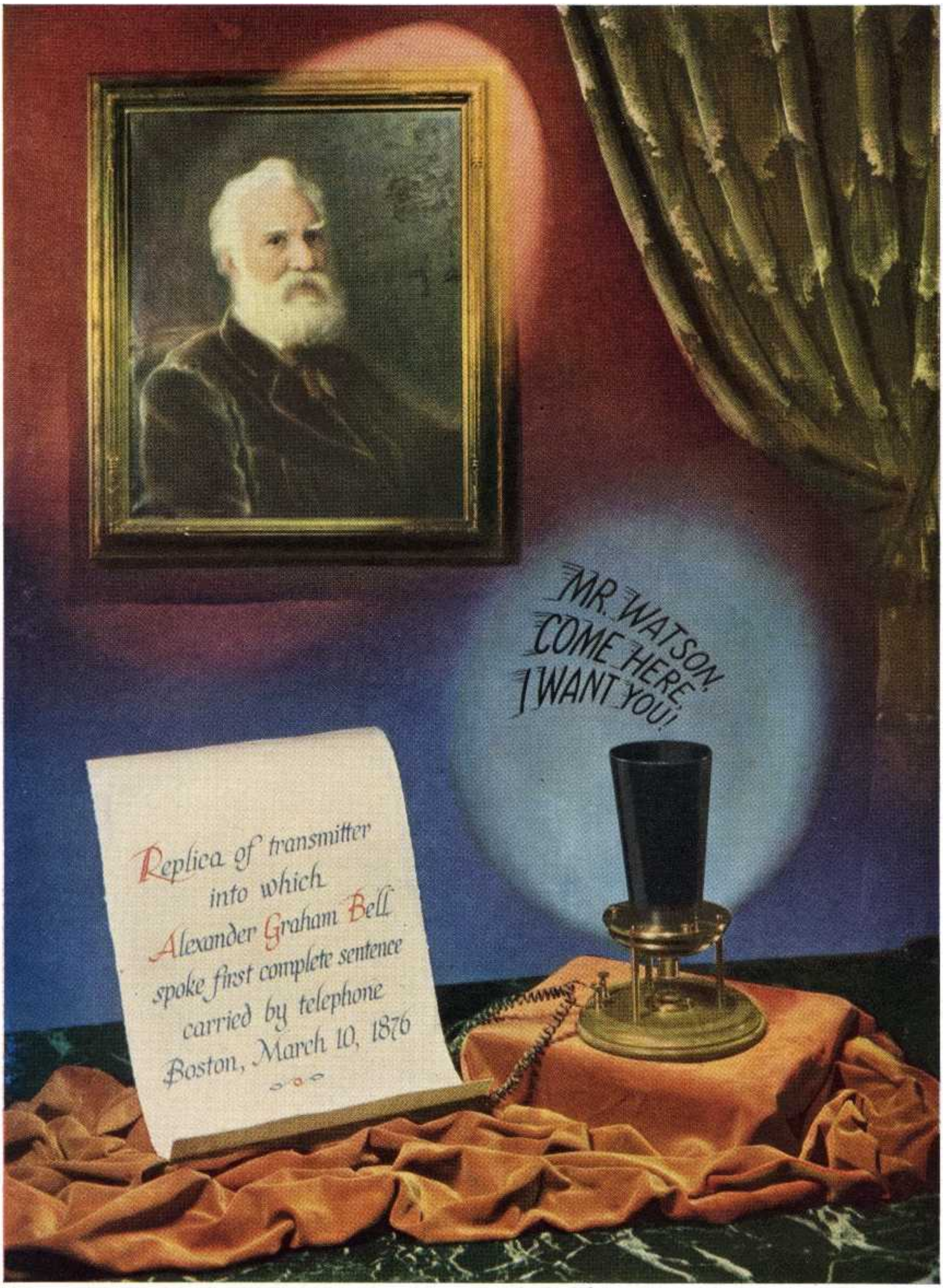
Birthplace of Telephone Magic



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Ektachrome by Willard R. Culver

2,000 Scientists Today Carry on the Work of Alexander Graham Bell, Inventor of the Telephone

In the vast Bell Telephone Laboratories they have produced near-miracles in telephone improvements and scientific weapons of war. Dr. Bell, whose portrait above was painted three years before he died in 1922, invented the telephone at the age of 29. First sentence was transmitted when Bell called to his assistant in the next room.

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While She Says "Ah-h-h " He Shoots Fast Movies of Her Vocal Cords in Action to Learn How the Voice Works

Strong light at the girl's left is reflected from the large square mirror to a dental mirror in her mouth, then down to her vocal cords. High-speed "Fastax" camera shoots through the hole in the large mirror to photograph the reflection of her vibrating vocal cords in the dental mirror.

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III

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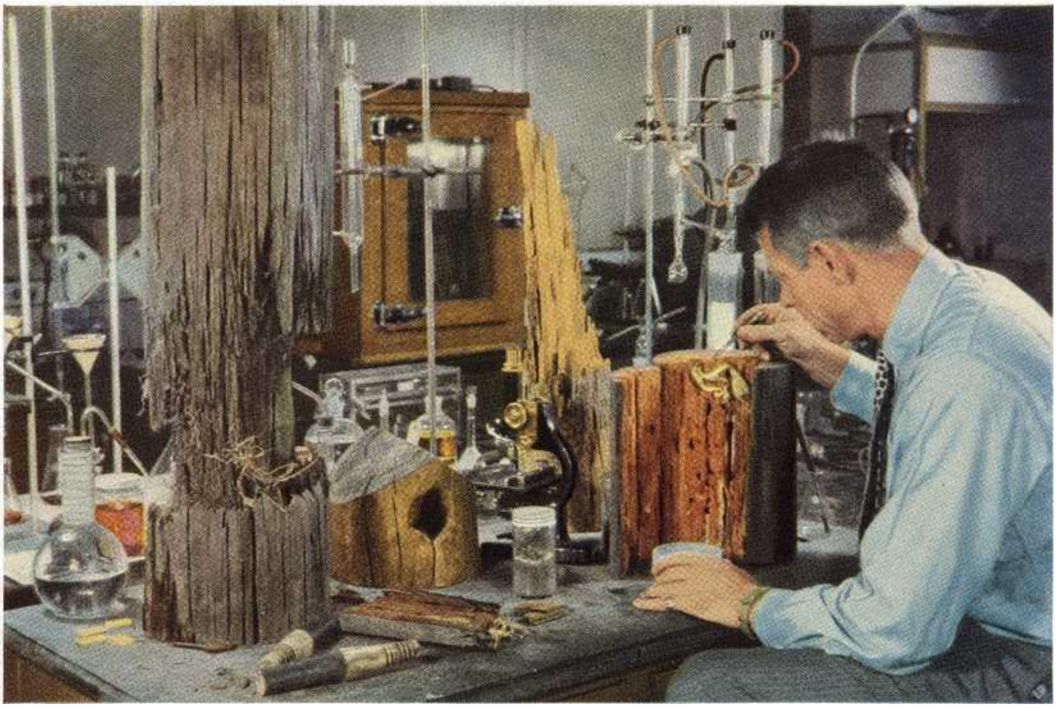
"Having a Lovely Drive, Dear. We'll Be Home by Seven"

New mobile radiotelephone sets installed in passenger cars or trucks make it possible to talk between a moving vehicle and the home or office. Telephone in a vehicle has its own number.

Ektachromes by Willard R. Culver

She Needs a Microscope to Adjust Tiny Vacuum Tube Parts

Magnification shows whether fine wires and other delicate parts are properly placed and tightly welded together. In assembling experimental tubes, gloves are worn because perspiration can corrode metal.



Telephone Pole Diseases Get Expert Study in Bell Laboratories' "Clinic"

Test poles, left to right, have been damaged by fungus, a woodpecker, carpenter ants, and rot caused by fungus. Scientist is removing spore-bearing organs of the fungus for study to find a method of protecting poles.

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50,000 Coal Granules, Used in Every Telephone, Cover Only a Playing Card Spot

Tiny, specially treated particles, crushed from anthracite like the lump at right, conduct electricity and translate voice vibrations into electric waves on wires. Granules are held in transmitter in container in girl's hand.

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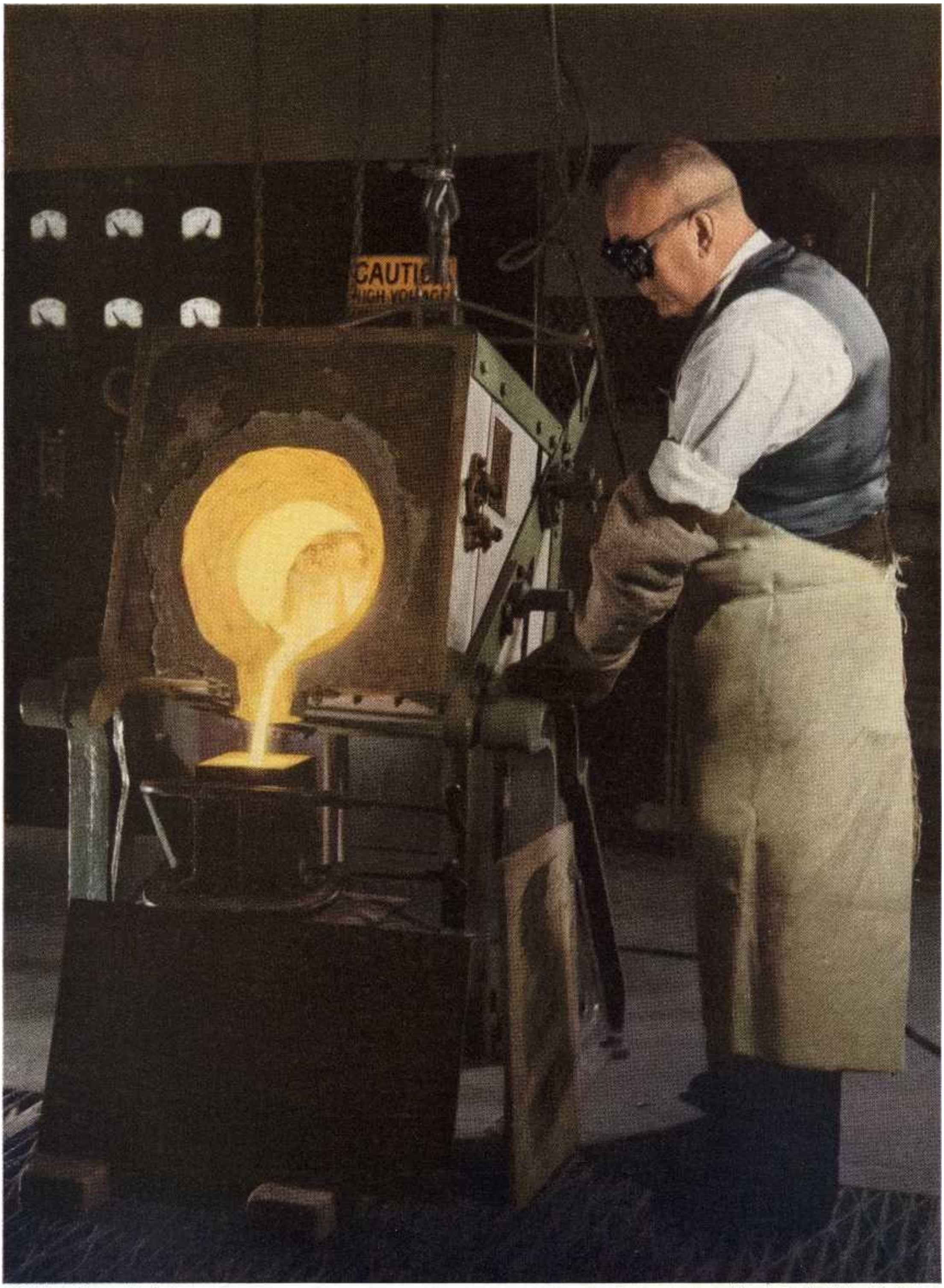

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New Metal for Trial in Telephone Magnets Is Poured from "Self-heating" Furnace

Glowing golden at a temperature of 2,900° F., an experimental alloy of cobalt, nickel, and aluminum is run into a mold. Heating in the furnace is done by the induction process, in which electric current is generated in the metal. Resistance to the current's passage raises the metal's temperature to the melting point.

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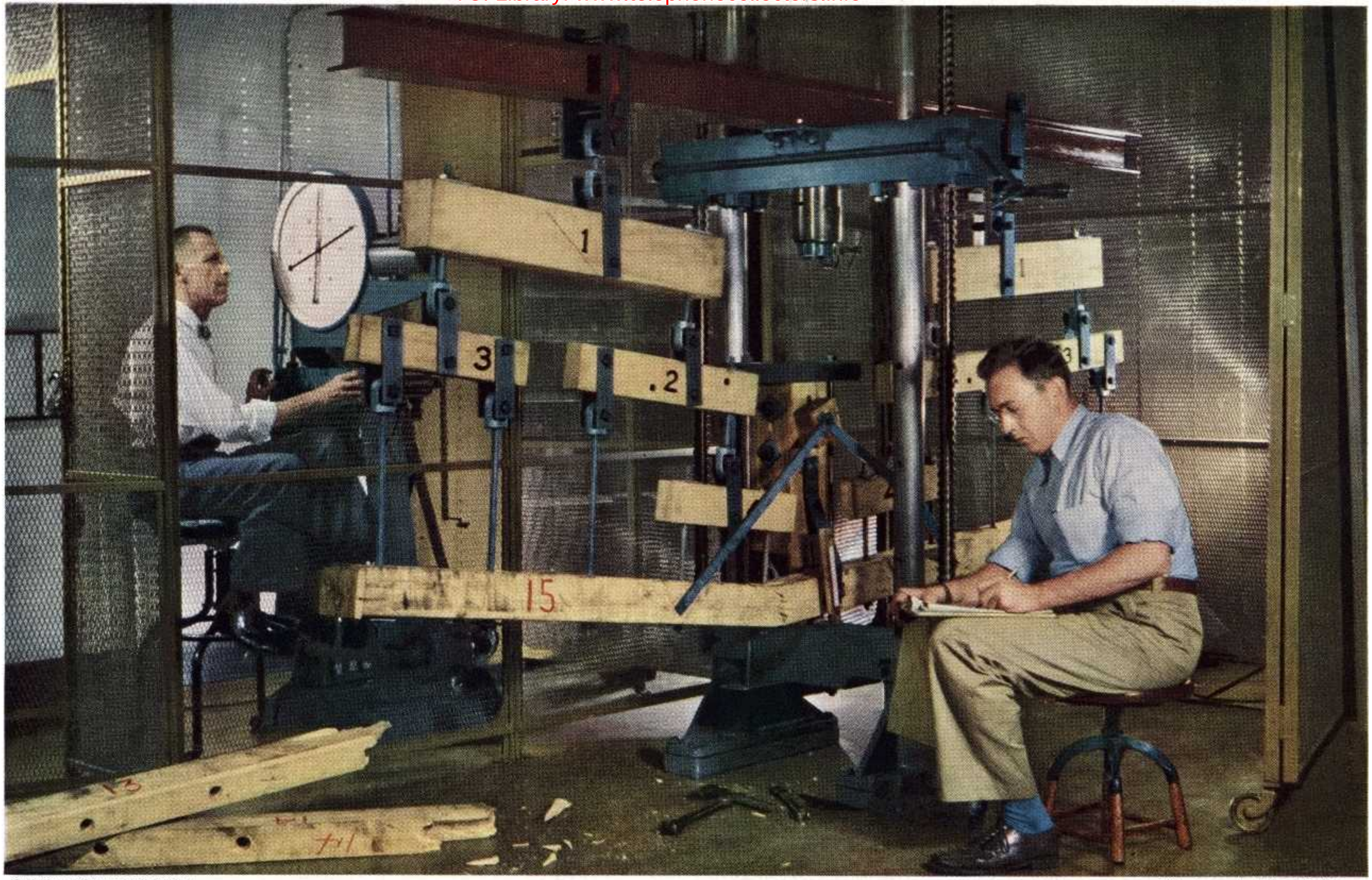
VI



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How Much Weight from Ice-laden Wires Will Break a Crossarm on a Pole? Hydraulic Machine Gives the Answer

Engineers test a crossarm to the breaking point. They use the machine to determine the strength of the various types of wood available for crossarms. Southern pine and Douglas fir crossarms recently tested broke under an average load of about two tons.

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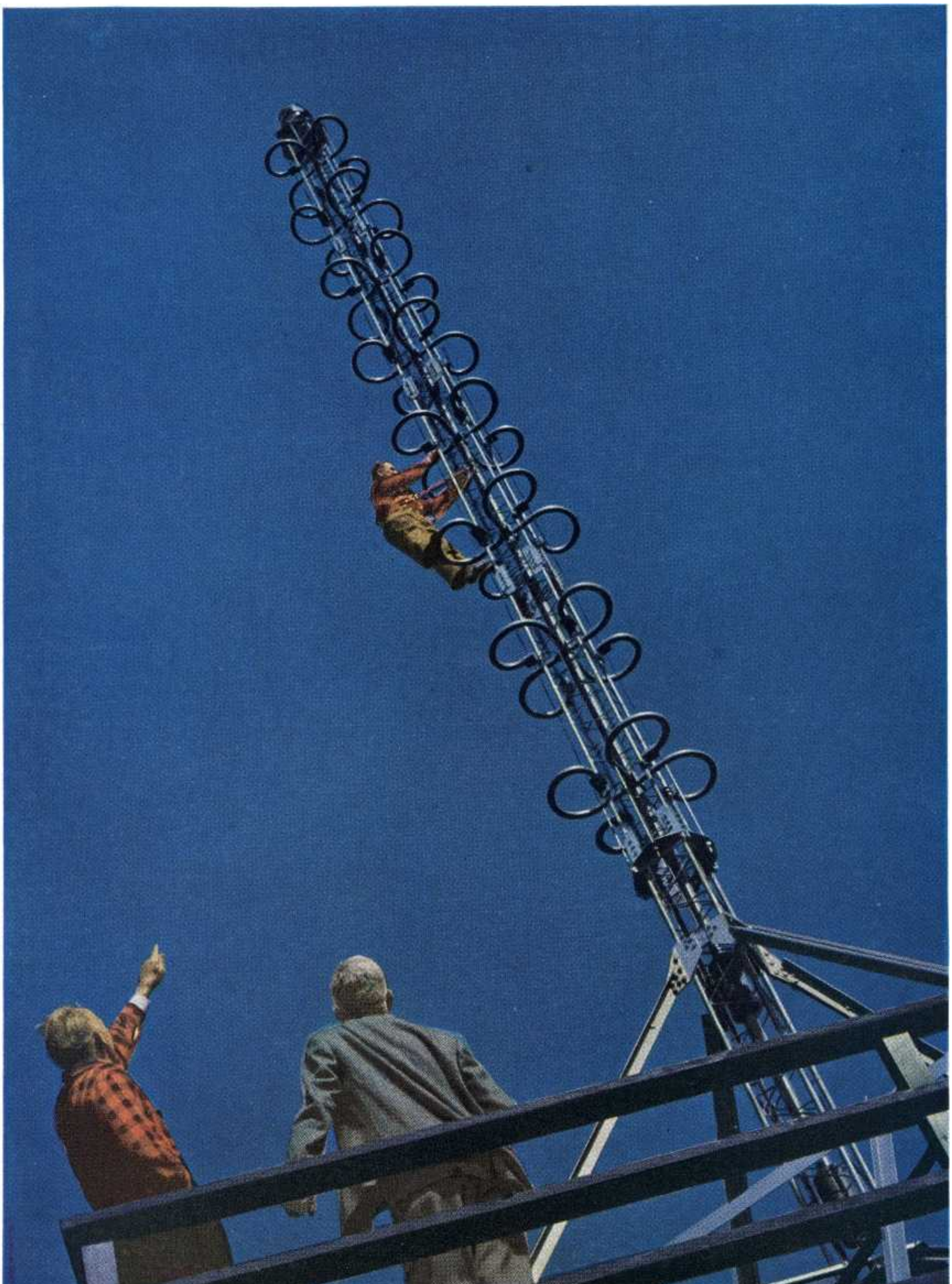
Charting Her Head Shape Makes Her Headset Fit Better

Seeking a more comfortable operator's headset, scientists measured skull contours with this device nicknamed "crown of thorns." It showed human heads vary from almost flat to dome-shaped; so headsets were made adjustable.

Ektachromes by Willard R. Culver

Bells That Ring Your Telephone Are Tuned to Meet Your Needs

A scientist mounts gongs on a turntable on which they revolve. The arm at left swings a microphone in an arc to pick up the sound from all angles for analysis of the bells' quality and power.



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New "Cloverleaf" Antenna for FM Broadcasting Cuts Down Waste of Radio Energy

It was developed by Bell Laboratories for the new frequency modulation broadcasts, which give more lifelike reception and are free of static. From the antenna, radio waves are radiated horizontally, concentrating them toward receiving stations, with fewer sent upward to be lost.

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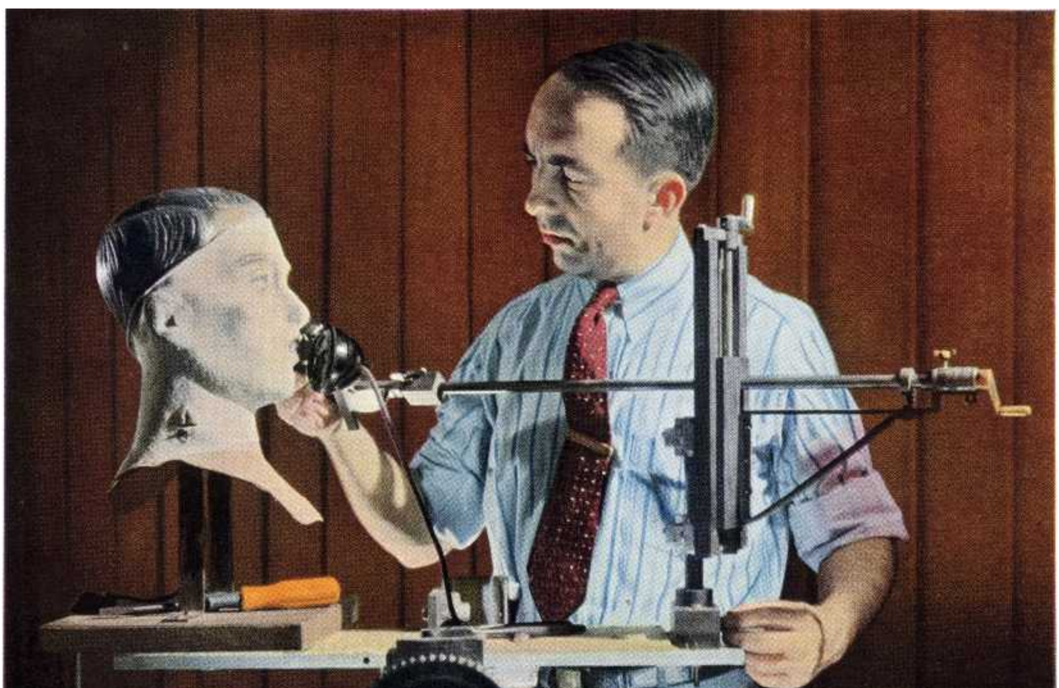
1,500,000 Vacuum Tubes, from Peanut to Coffee-urn Size, Work in the Telephone System

Two largest "overseas" tubes boost the voice across oceans. Overland amplifiers send the voice across country. Power plant tubes charge batteries. Magnetron tube on black base in radar group was a "secret weapon."



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For Best Results, Hold Your Telephone Close to Your Lips

The telephone's ability to pick up speech at various distances from the mouth is tested in a soundproof room. A loud-speaker inside the dummy head emits typical human words and sounds.

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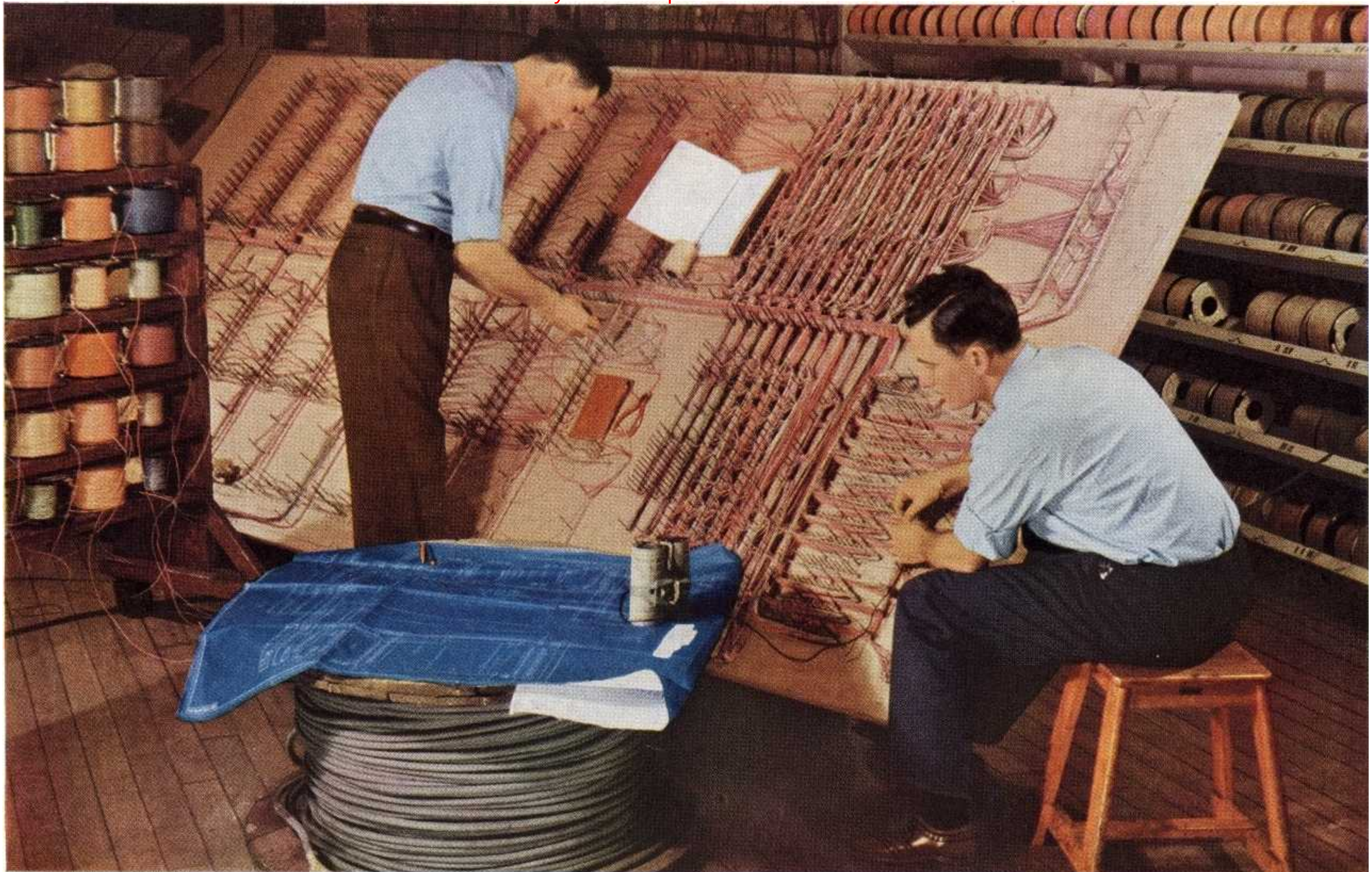

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Ever Try to Design a Nervous System? Theyre Doing It Here with a Wire Pattern for a Dial Telephone Apparatus

Stringing hundreds of wires in a complicated arrangement on nails driven into a large board Bell Laboratories' engineers assemble a working model for an automatic telephone exchange panel that handles calls without operators' aid. Pattern is laid out from the blueprint. Wires are matched by their colors.

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XI

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When She Drops In a Coin He Listens to See if the Signal Tells Clearly Whether It's a Nickel, Dime or Quarter

Because service is speeded up if an operator knows unmistakably what coins are being dropped into a pay-station telephone, Bell Laboratories' scientists make careful tests of the signals' clarity. This experimental setup simulates a telephone office circuit.

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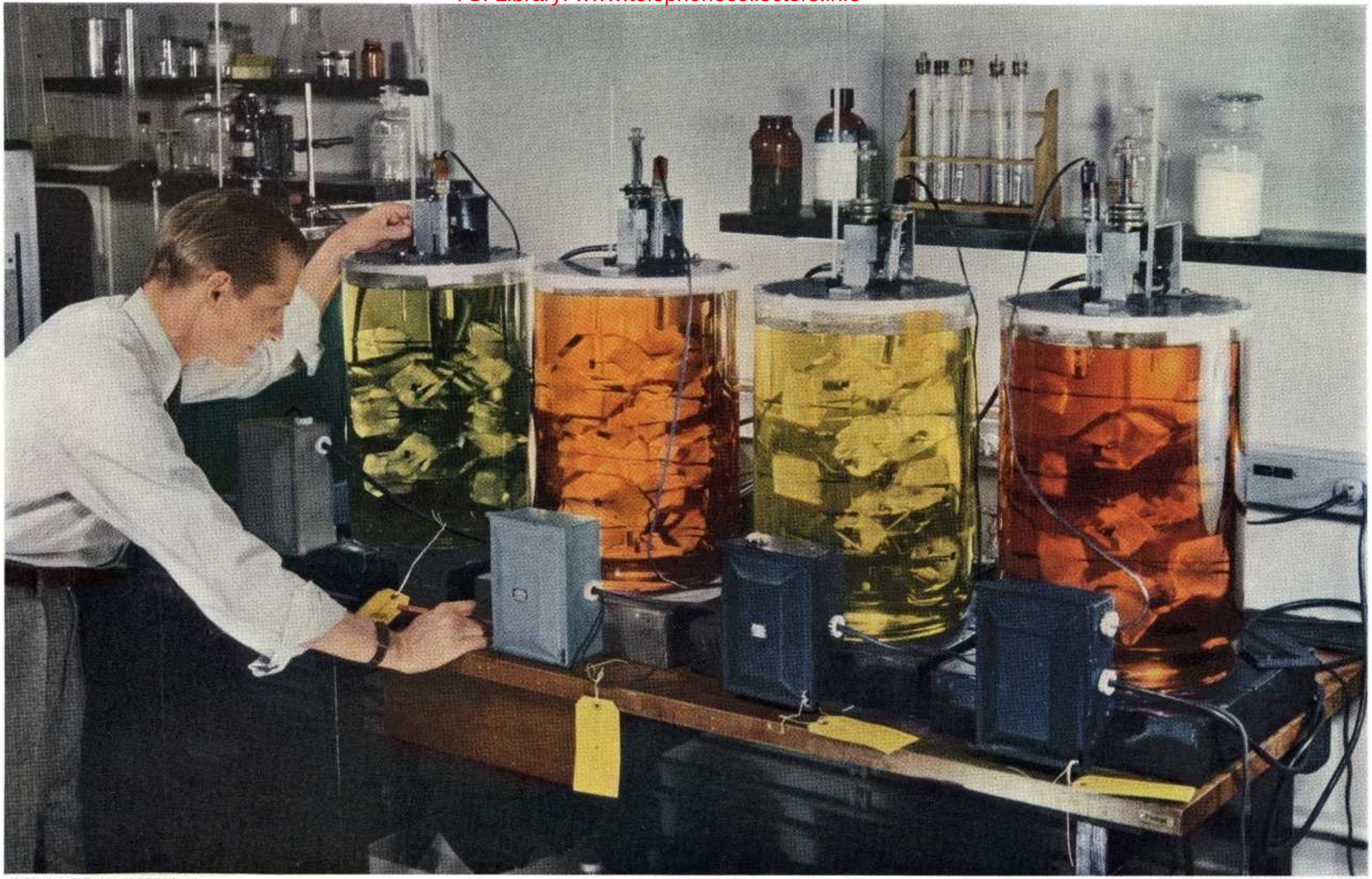
XII



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Ektachrome by Willard R. Culver

Man-made Crystals Better in Some Ways than Natural Quartz, Are "Grown" in Chemical Tanks for Telephone Use

Crystals are grown by rotating "seeds" (Plate XIII) in a chemical solution. Chemicals deposited on the seeds build them up to desired size. Because plates cut from crystals vibrate at precise frequencies, they are used to filter out single conversations from the many that travel together over telephone lines.

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XIII

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Synthetic Crystals Used in Sonar," Submarine-detecting Device, Helped Defeat U-boats in World War II

Thousands of the two-pound production-type crystals (foreground) were grown during the war, and plates cut from them were used as oscillators in sonar. Tiny "seeds," made by evaporating chemical salts, are used to build larger seeds from which crystals are grown (Plate XII). Big 43-pound crystal is experimental.

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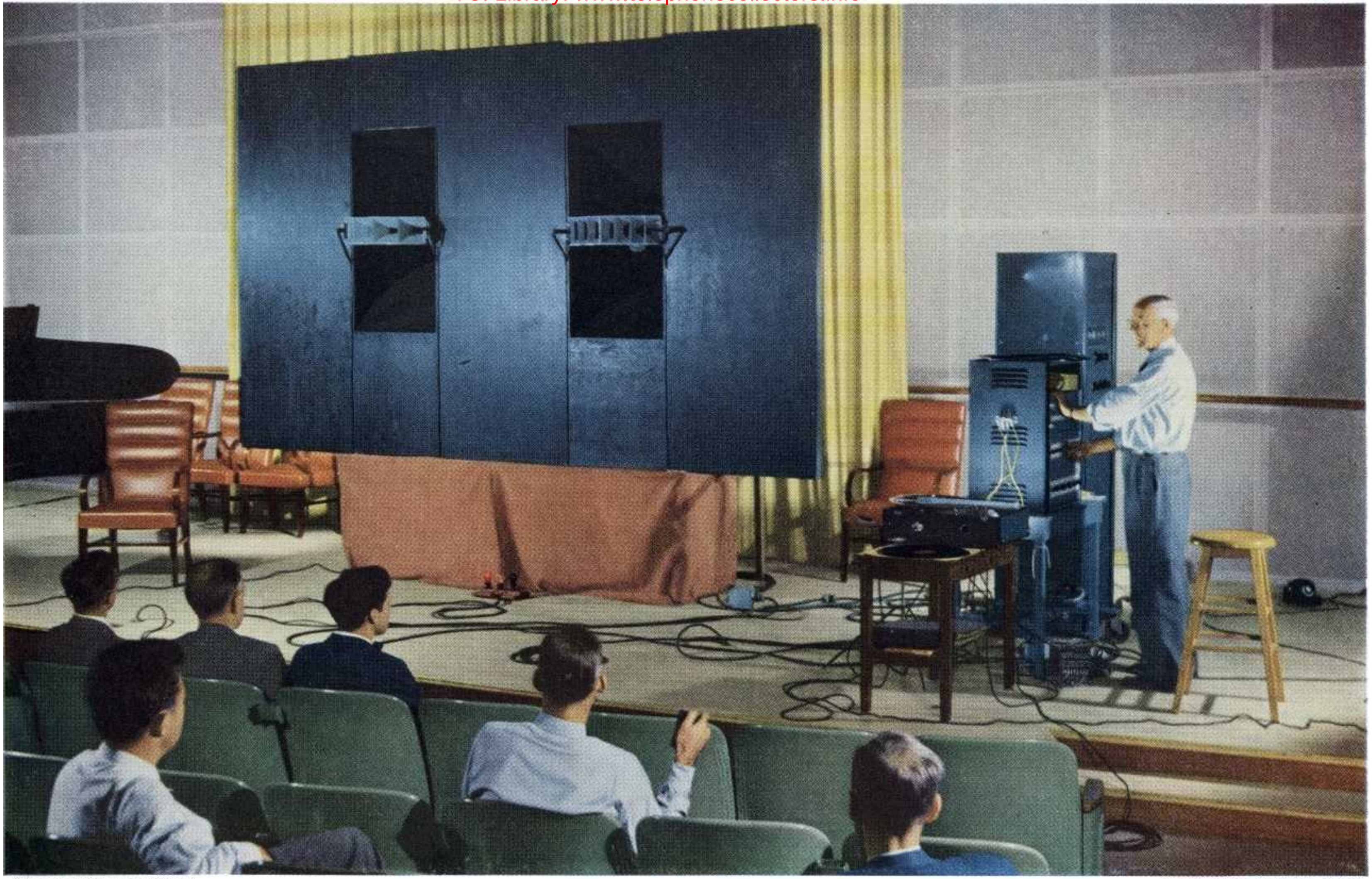

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Critics with "Golden Ears" Hear New Loud-speakers Designed to Reproduce Music and Voice with High Realism

Selected as good judges of musical reproduction these men check performance of two units for use in theaters and halls. High-frequency notes come from the groups of horns in the center, and low frequencies from larger horn openings above and below. Audition is in the Bell Laboratories' auditorium, designed for acoustical research.