With the Compliments of

BELL TELEPHONE LABORATORIES

Note—Technical papers, descriptive of wire and radio systems of television, were presented June 23, 1927, before the American Institute of Electrical Engineers and will receive later publication.

TELEVISION

Reprinted from

Bell Laboratories Record

A Monthly Magazine of Information for Members of

BELL TELEPHONE LABORATORIES

June 1927

TELEVISION

At the first public demonstration of television, April 7, 1927, Walter S. Gifford, President of the American Telephone & Telegraph Company, said:

"Today we are to witness another mile-stone in the conquest of nature by science. We shall see the fruition of years of study on the problem of seeing at a distance as though face to face. The principles underlying television, which are related to the principles involved in electrical transmission of speech, have been known for a long time but today we shall demonstrate its successful achievement. The elaborateness of the equipment required by the very nature of the undertaking precludes any present possibility of television being available in homes and offices generally. What its practical use may be I shall leave to your imagination. I am confident however, that in many ways and in due time it will be found to add substantially to human comfort and happiness.

"It is our constant aim to furnish this country with the most complete telephone service possible. In connection with that aim, we endeavor to develop all forms of communication that might be supplemental to the telephone. With that in view, we shall continue our work on television which, although not directly a part of telephone communication, is closely allied to it."

In the auditorium of Bell Laboratories, President Walter S. Gifford, of the American Telephone and Telegraph Company, views Honorable Herbert Hoover, Secretary of Commerce, in Washington as they converse during the first public demonstration of television, April seventh, 1927. With him as he talks and sees over 300 miles of long distance lines are members of Bell Telephone Laboratories; from left to right: E. P. Clifford, Vice-President, H. D. Arnold, Director of Research, E. B. Craft, Executive Vice-President, F. B. Jewett, President, and also Vice-President of American Telephone and Telegraph Company, Dr. Herbert E. Ives and Dr. Frank Gray, members of the technical staff

Remarks by Dr. Frank B. Jewett at the Television Demonstration:

THE general principles underlying television have been known for a long time. It is one thing to appreciate general principles, however, and frequently quite another to realize them practically. In the case of television many of the elements long recognized as essentials to success were not possible of attainment until general science had been farther advanced. But even when recently fundamental research work developed new knowledge, new materials and new methods, the problem of successful television demanded a vast amount of coordinated research and development work to crystallize scientific possibilities into practical realities.

The research and development functions of the Bell System, of which these Laboratories are a most important part, are organized for the solution of just

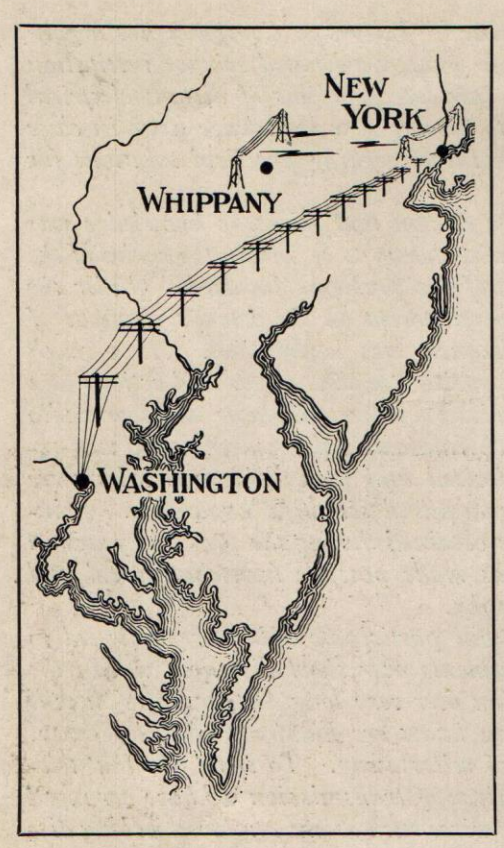
such problems. The American Telephone & Telegraph Company has organized its scientific work to provide in one great coordinated science institution every facility needed for the solving of intricate problems of distant electrical communication. Scientists competent to develop new knowledge work in close association with other scientists and engineers seeking practical solutions for a host of problems.

When some years ago it began to be evident that scientific knowledge was advancing to the point where television was shortly to be within the realm of the possible, we took up seriously a study of the problems involved. Under the supervision of Dr. Ives research and development on the various elements of terminal equipment and connecting channels was undertaken. As a result of this coordinated work we are today in position to view scenes and actions at a distance and to employ in their transmission either telephone wires or radio waves. To accomplish this result much fundamental research work was required, many new things had to be devised and many old principles were applied under the guidance of recently acquired scientific knowledge. Principal in all this has been the knowledge obtained during the past few years in the research and development which has made possible transcontinental and transoceanic telephony and telephotography.

The demonstrations in which you will participate today are designed to show you not merely laboratory achievements over short distances within the walls of a building but also transmission over very long distances. You will see and converse with people whom you know are hundreds of miles away. They might equally well be thousands of miles away. To show you that television is not confined to any single medium of transmission we have arranged that you shall witness television both over wires such as are employed in long distance telephony, and by radio. From Washington, D. C., you will have transmission wholly by wires, while from the Laboratories' great radio experimental station at Whippany, N. J., you will have simultaneous sight and sound by radio. That television from either place is not inferior to that obtained within the laboratory itself you will have opportunity to prove with the apparatus which we have assembled at the two ends of this auditorium.

While research and development work for the perfection of television will go on for years, enough has already been accomplished to indicate that it is likely to have a real place in the world's work of distant communication. Today we are relatively farther along in our work on television than we were on transoceanic telephony in 1915 when the American Telephone & Telegraph Company conducted the first successful test from Washington to Paris and Honolulu. Just what the ultimate field of television is to be can, as Mr. Gifford has said, be left to your imagination. The one thing that seems clear is that it will be a use closely associated with telephony.

In attempting to form a picture as to the future development of television there is one inherent limitation of any television method which we should keep clearly in mind, however. This is the fact that it requires the use of a large group of frequencies and the transmission of these frequencies requires as great capacity as a considerable number of ordinary telephone circuits. It is this fact which puts television economically into a class quite different from that of ordinary telephony or telegraphy.



TELEVISION was presented to the public on April 7 by demonstrations in these Laboratories to representatives of the press and to other guests. The demonstrations were the culmination of work dating back for several years, but carried on more and more intensively as its fruition drew near. Certain laboratory groups had made it their chief concern for several months; it merged into the normal activity of others. It is estimated that two hundred engineers, scientists and technicians contributed to the success of the project.

For some weeks before the demonstration, our Auditorium had been a place set apart for strange activities. Past the uniformed guard at the door, curtained enclosures contained arrays of panels and wiring; "Washington", "Whippany", "the big disc", "synchronize" were words frequently heard. Last-minute requests for apparatus were loyally met by double shifts and long hours of overtime. Finally the day was set. With invitations issued, the final difficulties had to be overcome and the program carried out with the smoothness characteristic of Bell System demonstrations.

As each of the two audiences took their places in the Auditorium, music from the Vitaphone was heard. Then President Gifford rose to welcome the guests in behalf of the American Telephone and Telegraph Company; Dr. Jewett spoke similarly for the Laboratories and introduced Dr. Ives' popular explanation of the technical developments embodied in the television system. Then that system spoke for itself: the guests, gathering around the local transmitter and filing by the "big disc" had an opportunity to see and talk with each other.

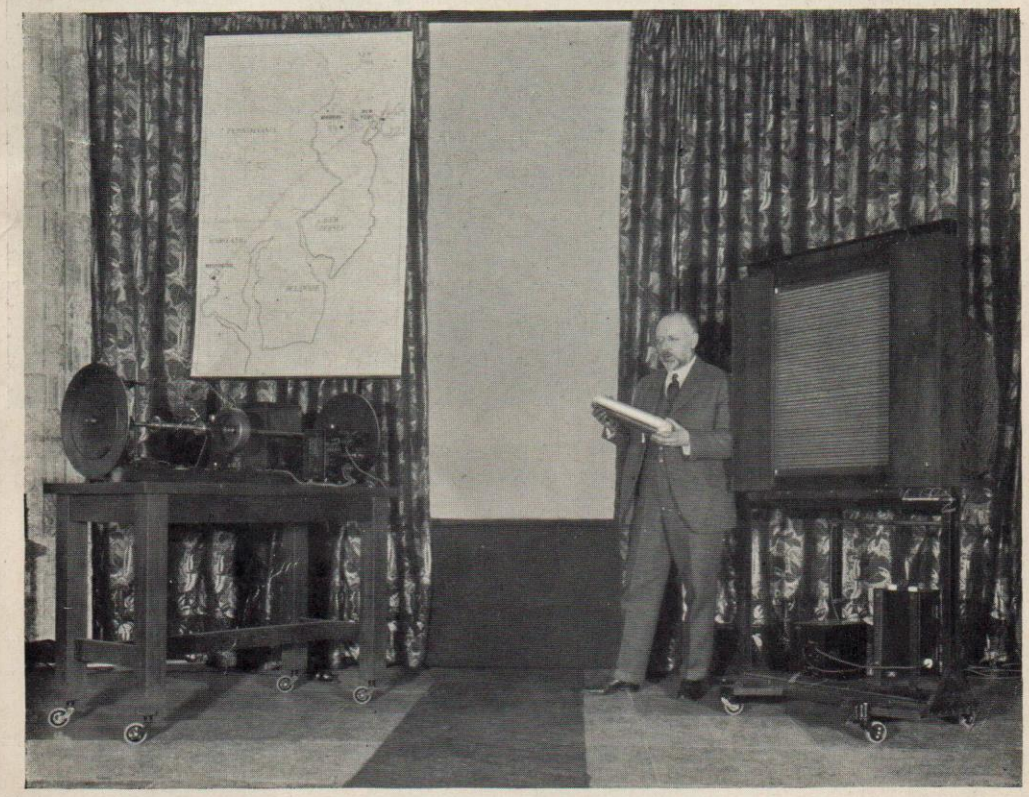
Meanwhile the Washington transmitting disc had been synchronized with the receiving apparatus in New York, and Mr. Gifford took his place at the larger disc reproducer. Over a telephone he exchanged a few words with Mr. Hoover in Washington. Then Mr. Gifford moved to a seat in the audience, where he could see the grid, on which Mr. Hoover's face then appeared. As Mr. Hoover spoke from Washington, the audience could hear him over the loud speaker and see such gestures as he made.

This conversation finished, E. F. Kingsbury of the Laboratories staff, in charge of technical operations at the Washington terminal, read a list of those present in Washington, in order that their acquaintances at New York might see and speak with them.

A number of the New York guests availed themselves of this privilege, recognizing instantly the images which appeared in the two-inch square aperture of the "large disc". During this part of the second show, Mr. Gifford learned that Mrs. Hoover was in the Washington group. When she came to the viewing point, they recalled their wartime associations in Washington, the obviously unpremeditated conversation making the demonstration seem more real.

a practical achievement of the television dream: sight and sound transmitted simultaneously by radio for the enjoyment of a distant audience.

With this demonstration the formal part of each program was concluded: newspaper men, after some additional inspection of the apparatus and asking of questions, departed to file their stories. After the later show, the guests remained for some time, seeing and talking with friends in Washington. Finally the last ques-



Experimental apparatus on the stage of the Auditorium, and Dr. Ives as he explained the fundamental workings of the system

A touch of comedy was inserted at this point by the all-radio transmission from Whippany of a broadcast entertainment program, the faces of the performers being simultaneously visible on the "grid". Here then was

tion had been answered, the last photograph had been made, the last visitor had departed, and the technical staff adjourned to the restaurant for dinner—tired, but jubilant over the success of this epoch-making day.

At the transmitter in Washington as Secretary Hoover talked to New York. Standing are General Carty, Mr. Berry and Judge Davis

Address of Secretary Hoover at the Television Demonstration

IT is a matter of just pride to have a part in this historic occasion. We have long been familiar with the electrical transmission of sound. Today we have in a sense the transmission of sight, for the first time in the world's history.

Human genius has now destroyed the impediment of distance in a new respect, and in a manner hitherto unknown. What its uses may finally be, no one can tell, any more than man could foresee in past years the modern development of the telegraph or the telephone. All we can say today is that there has been created a marvelous agency for whatever use the future may find, with the full realization that every great and fundamental discovery of the past has been followed by use far beyond the vision of its creator. Every school child is aware of the dramatic beginnings of the telegraph, the telephone and the radio, and this evolution in electrical communications has perhaps an importance as vital as any of these.

This invention again emphasizes a new era in approach to important

scientific discovery, of which we have already within the last two months seen another great exhibit—the Transatlantic telephone. It is the result of organized, planned and definitely directed scientific research, magnificently coordinated in a cumulative group of highly skilled scientists, loyally supported by a great corporation devoted to the advancement of the art. The intricate processes of this invention could never have been developed under any conditions of isolated individual effort.

The world is under obligation to the American Telephone and Telegraph Company for its vision in the establishment and support of these laboratories, and owes tribute to all those who have played their part in this development.

These laboratories have produced a long list of additions to the telephonic art and a constant contribution to other arts, but no one of them more dramatic or more impressive than this.

I always find in these occasions a great stimulation to confidence in the future. If we can be assured a flow of new and revolutionary inventions to maintain thought, stimulate spirit, and provide a thousand new opportunities for effort and service, we will have preserved a vital and moving community.

I am glad to welcome television as the latest product of scientific discovery. It promises that where the voice has led the way over the telephone wires, the eye will ultimately follow. Washington and New York are today not only within earshot of each other, but within sight as well.

Scientists for many years, in many countries, have struggled to solve the problems of television. We may all take pride in the fact that its actual accomplishment is brought about by American genius and its first demonstration is staged in our own country. I congratulate you, Mr. Gifford, and through you all of your staff who have contributed to it.

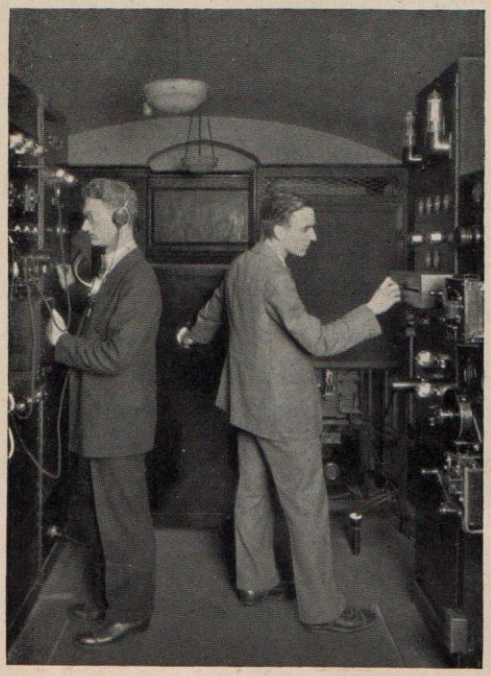
The Demonstration at Washington

WITH Herbert Hoover, Secretary of Commerce, as guest of honor, a gathering of prominent people in Washington saw faces and voices transmitted simultaneously over telephone wires to New York. As one by one they took their places in front of the flickering white light and heard exclamations of wonder from their friends two hundred miles away, they too shared in the awe of the occasion.

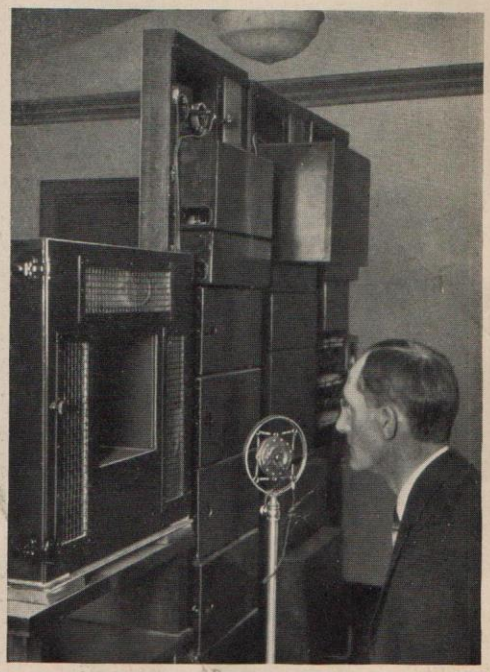
As in New York, two shows were held, for newspaper men and for other guests respectively. To each gathering General Carty extended welcome on behalf of the American Telephone and Telegraph Company, and explained briefly what they were about to witness. After establishing communication with Mr. Gifford in New York, General Carty invited Mr. Hoover to take his place at the viewing point. Through telephone receivers the Washington audience heard an exchange of greetings between Mr. Gifford and Mr. Hoover, after which Mr. Hoover delivered to

both audiences the address which is reproduced in italics above. E. F. Kingsbury of the Laboratories, in charge of the Washington technical staff, then read to the New York audience a list of the guests in Washington, after which a number of them were called to be heard and seen by their friends in New York. These "calls" were handled by Miss Edna Horner, an operator of the Chesapeake and Potomac Telephone Company, who was clearly seen by those in New York. Later, all present had an opportunity to inspect the apparatus and to see in the monitoring aperture each others' faces as they would have been received in New York had the lines been connected.

Quarters for the Washington demonstration could not be obtained in the C. & P. building in which were terminated open wire circuits to New York, so a small building in the same block was rented. Cables were strung from the Telephone Building to the roof of the new quarters. House service was supplied by C. & P. and their staff was of great assistance in arranging for services of contractors and suppliers during the installing and testing of the apparatus.



The nerve center of the photoelectric eyes of the television equipment installed at Washington. C. R. Keith and J. G. Knapp of the Laboratories manipulate the controls at the amplifiers which transmit the scene to New York

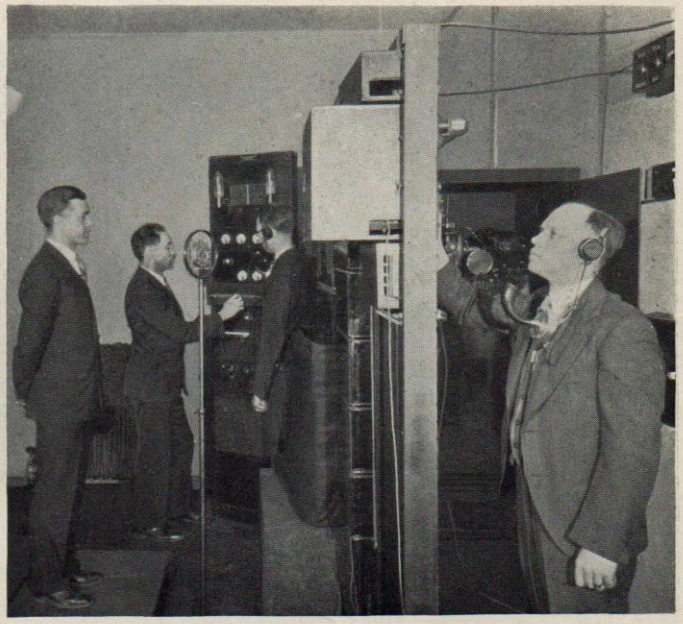


A close-up of the transmitting apparatus for television at Washington. E. F. Kingsbury as he talks to the microphone is viewed by three photoelectric eyes located behind the three screens of the box immediately in front of him

Television by Radio

THE part played by radio in the recent demonstrations of television is of especial interest as an illustration of the essential unity of wire and radio systems of communication. To and from our experimental station at Whippany the same kinds of signals were transmitted by radio as were interchanged with Washington by wire lines. For this purpose it was necessary to provide from Whippany to West Street one radio channel for the picture and another for speech; and in the other direction a radio channel for synchronizing currents. The new high-power transmitter at Whippany, which had been developed by groups under the leadership of A. W. Kishpaugh and A. Haddock, was used without modification for the speech channel. The picture channel employed a standard Western Electric five-kilowatt broadcasting transmitter, which had been modified by F. M. Ryan and his associates for the transmission of side-bands extending 20,000 cycles on each side of the 1575 kilocycle carrier wave.

To receive so wide a band of frequencies imposed on the radio set installed at West Street, requirements so severe that only the Laboratories' advanced technique in measurement enabled them to be met. Filters of wide range and sharp cut-off were designed by the group directed by T. E. Shea; this group with their associates was also responsible for equalizing the radio system for voice transmission. Another problem was to find, in an already congested ether, chan-



In the studio of 3XN, our experimental radio station at Whippany, New Jersey, as a final test was given to transmitting apparatus for simultaneous television and radio telephony. In the position of a performer stands A. R. Olpin, while beside him, O. L. Dupy and A. C. Norwine manipulate the controls. On the extreme right G. R. Stilwell monitors television transmission

nels for the three transmissions. This was further complicated by five-kilowatt stations, one directly across the river from the Laboratories and another in the Laboratories itself with its antenna only a few feet away from the receiving systems.

A standard Western Electric one-kilowatt radio transmitter modified to work at 180 kilocycles was used for the synchronizing channel from West Street to Whippany.

On the afternoon of the demonstrations the guests at Whippany were greeted by E. L. Nelson, who was responsible for the provision of radio facilities. An explanation of the local apparatus was made by A. R. Olpin. Two identical demonstrations were made for the West Street audiences, the performers being A. F. Dolan and Mrs. H. A. Frederick, with Mrs. Homer H. Lowry as accompanist. On subsequent days Miss Sara Davison of the Laboratories, Mrs. Eleanor Janssen of Mountain Lakes and R. E. Coram contributed to the program.

In the power room of 3XN, the Laboratories' experimental radio station at Whippany, New Jersey. On the left, a fifty kilowatt set with its power panel in the rear; on the right the five kilowatt set. At their posts for experimental operation are O. A. Keefe, R. E. Poole, J. W. Smith, W. N. Mellor and J. C. Herber

Physical Principles and Apparatus

TELEVISION, an electrical art growing out of the art of telephony, employs many of the principles and some of the apparatus of telephony, particularly those developed for the electrical transmission of pictures.

The physical principles basic to television are also most easily appreciated when traced by analogy from the earlier art of telephony. Both employ electrical means to overcome the effects of long distances, one to reproduce for the ear, sounds; and the other for the eye, scenes. What spans the distance is neither sound nor light but electrical energy derived by proper terminal equipment from the original sound or light; and again by adequate apparatus this energy must be correctly translated for the listener or observer into sound or light. Terminal apparatus, complementary in function, are therefore required to transmit and to receive; also an intervening channel for the passage of the electrical energy; and the whole constitutes a system for electrical communication. Between telephony and television historically, is the electrical art of transmitting pictures, which is intermediate also in physical operations and apparatus.

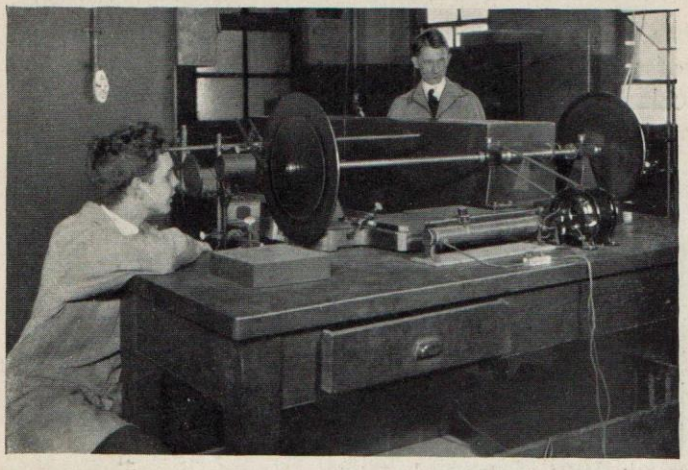
One of the giant photoelectric cells, which serve as eyes in television, is being examined by Herbert E. Ives from whose researches it arose. At the right is G. R. Stilwell who assisted in its production

The specific principles involved in television are conveniently described following a summary of corresponding operations in these earlier arts.

In telephony the transmitter is a device responsive to sound waves,

from which there proceeds to the receiving equipment an electric current. The intensity of this current corresponds in its variations to the varying pressure of the sound waves and thus embodies their speech significance.

In the electrical transmission of pictures the transmitter is responsive to light waves. Its sensitive element is a photo-electric cell; and the current from it varies in intensity according to the light to which it is exposed. When this cell is exposed to light emanating from successive small areas of a picture there results a current with variations in intensity corresponding, and in similar order, to the variations in light and shade of the picture. This is accomplished by using a film-transparency of the picture, passing through it onto the photoelectric cell a narrow beam of light, and moving the film uniformly and continuously so that the cell responds successively to the light from all the elemental areas of the picture.



Research apparatus used in the development of television. Through a peep-hole J. R. Hefele is observing the image recreated through the rotating disc. The scanning disc at the other end of the shaft intervenes between an illuminated transparency and the photoelectric cell. The latter is in the box which is visible just beyond the driving shaft. Behind this box stands Dr. Frank Gray

Reception in telephony is an operation of translating current variations into sound waves. In a telephone receiver a diaphragm is vibrated by the electromagnetic action of the varying current and in its movement of the adjacent air it acts as a source of sound to emit waves similar to those which impinged upon the distant transmitter.

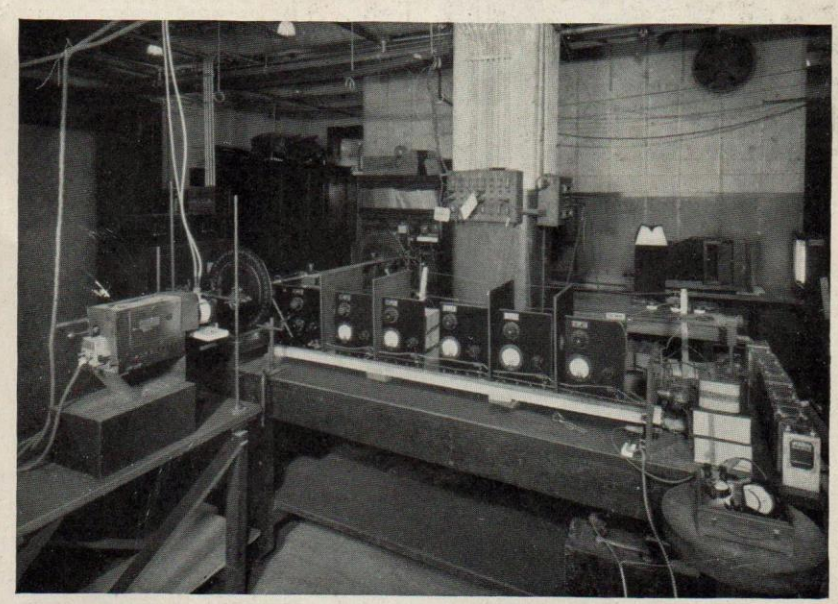
For the reception of pictures, current variations are translated into variations of light intensity. This might be accomplished by an electro-optical action of the current, giving rise to light waves similar in intensity to those which acted on the distant photoelectric cell. In the electrical transmission of pictures, however, translation is obtained most conveniently by varying the portion of light from a constant source which is allowed to fall upon a sensitized film. An electromagnetic action of the varying current, therefore, is employed to operate a "light valve" through which passes a narrow beam of light.

The valve varies the size of the beam in exact accordance with the current variations; and thus the sensitized film is exposed to variations in light intensity similar to those in the picture which is being transmitted. The film is moved across the beam continuously and uniformly so that its successive areas are exposed in the same order, and for the same small intervals of time, as the correspond-

ing elemental areas of the original picture were exposed to the beam which actuates the photoelectric cell of the transmitter. The necessary synchronization of the mechanisms, which drive the negative at the transmitting station and the sensitized film at the receiving station, is accomplished by electrical means. For this purpose there are employed other currents, or other waves in the case of radio, which pass between the two stations and by their electromagnetic actions control the driving mechanisms and maintain them in step with each other.

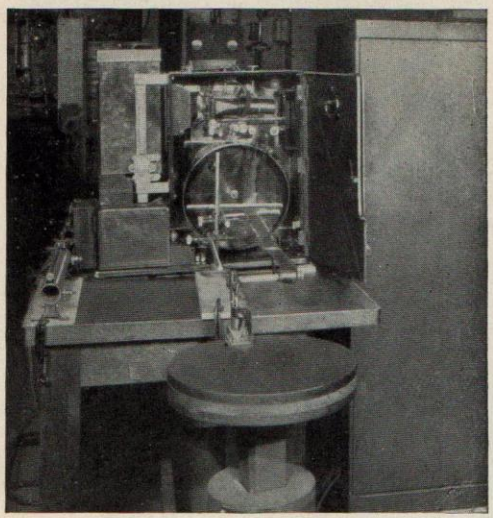
In television a series of essentially instantaneous views of a scene with action must be transmitted and reproduced at a rate, fifteen or more a second, such that an observer will detect no discontinuity of action. In broad principles the method is similar to that of the electrical transmission of pictures. A photoelectric cell, acting as an "eye", rapidly scans the scene, viewing in orderly succession each detail of it, and transmitting to the distant station a varying current, the variations of which correspond to the differences in light and shade of the successive details.

At the receiving station this current produces at each instant a spot of light of a brightness corresponding to that of the detail of the scene which the photoelectric eye was observing at the moment it originated that particular amount of current. At each instant the position of this spot of light is also caused to correspond to that of the detail of the scene. The entire scene, in successive details, is thus reproduced for an observer. The



Another view of the apparatus shown on the opposite page. At the left is a source which sends light through a transparent picture and the scanning disc onto the photoelectric cell. The control panels of the various stages of the special amplifier, which intervenes between the photoelectric cell of the transmitting and the neon tube of the receiving equipment, extend in a row to the right of the scanning disc

complete process of reproducing in proper order the light details of the scene occupies less than a fifteenth of a second. It is then automatically repeated and thus each detail is instantaneously viewed by the observer fifteen times a second. Because of physiological and psychological phenomena, however, the observer is unconscious of the series of details and apprehends the scene as a whole with continuous action.



The motion-picture projector, shown with its door open, projected the frames of the motion picture at normal speed into the cabinet containing the photoelectric cell. This equipment, developed during the series of researches in television, is of interest historically as that used in the first instance of the electrical transmission of motion pictures

Like the familiar transmitter-microphone and receiver of telephony, the apparatus of television is terminal equipment, and any suitably high-grade medium, whether wire or radio, may be used for the intervening transmission. In its present form the sending apparatus is adapted to obtaining for one participant in a telephone conversation a continuous view of the face of the other participant. Such a view the receiving apparatus re-creates on a picture plane about two by two and one-half inches; or, with an alternative form of equipment, on a plane about two feet square, large enough for observation by more than a single person.

At the sending station there is, in addition to the usual telephone desk-stand, the special equipment for transmission in television. There is, first of all, a gigantic photoelectric eye, which placidly views the scene before it but receives no appreciable stimulus unless the scene is strongly illuminated. The second portion of the equipment includes a high-powered light. The beams from this are not allowed to flood the scene and dazzle the actor. They are reduced to a narrow beam illuminating on the face of the actor a spot not more than a quarter of an inch square. This beam, guided by the so-called "scanning disc", never pauses, and sweeps the entire scene in less than a fifteenth of a second.

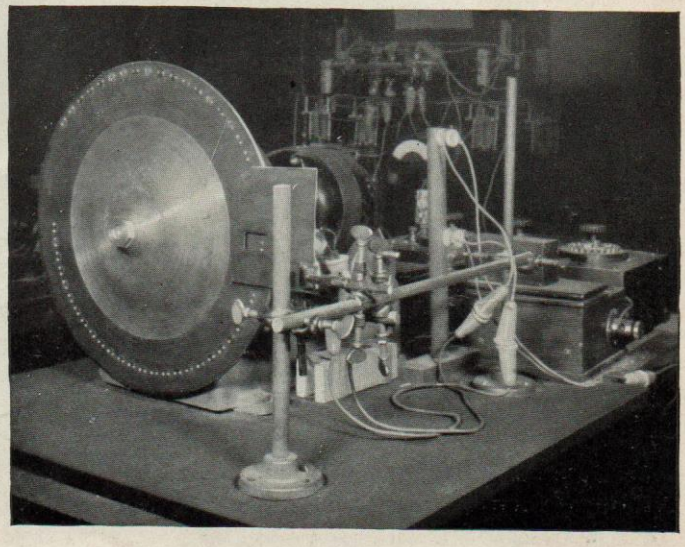
As each detail is illuminated the photoelectric cell instantly responds, initiating a current proportional to the light reflected to it, and hence proportional to the light and shade of the particular detail. As the beam of light swings across the scene, working its way from top to bottom, the current from the cell varies correspondingly. So swiftly does the beam sweep the scene that the current variations are wide and rapid—sometimes corresponding to a change from a maximum current to a minimum and back to a maximum in a twenty-thousandth of a second. These variations, the so-called alternating current components, are transmitted to the receiving equipment, where they are effective in reproducing the scene.

The beam, which assists the photoelectric eye to scan the scene before it, is actually a succession of beams. In front of the source of light revolves a disc, the "scanning disc", in which is a series of holes through which darts of light escape to illuminate, successively, narrow, horizontal strips of the scene. This scanning disc is driven by a combination of two electric motors.

Identical motors operate at the receiving station to insure to the flashes of light the orderly succession necessary to re-create the image. Exact synchronism at the two ends of the system is accomplished by using at each two "synchronous" alternating-current motors. At each end one motor, the main one, operates at a frequency with which complete images of the scene can be formed. To prevent this motor from "hunting", that is, from small variations in speed alternately above and then below that corresponding to eighteen cycles per second, a second and smaller motor assists the drive. This synchronous motor, operating at 2000 cycles in the range of telephonic rather than power frequencies, insures that the rotating mechanisms at the two ends of the system shall not be out of step with each other by more than the amount represented by half of one of the small holes in the disc.

At the receiving station there is, first of all, a source of light which responds with a brilliancy corresponding to the current which is received from the transmitting station. The source is a "neon tube", a glass tube filled with rarified neon gas and provided with electrodes; when a high potential is applied to the electrodes there takes place a glow discharge, the brilliancy of which is exactly proportional to the potential. To obtain sufficiently high potential from the distant photoelectric cell there are inserted in the circuit vacuum-tube amplifiers essentially similar to those used in other operations of telephony.

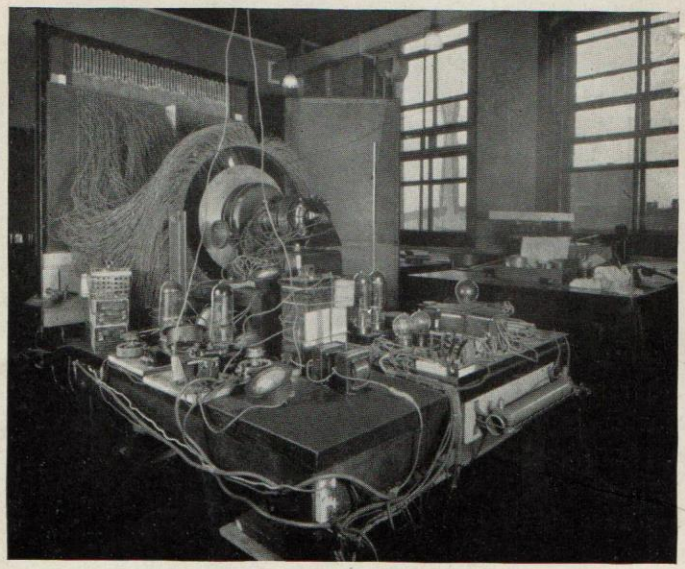
The remainder of the equipment, that for synchronization, provides that the light shall appear to an observer at each instant in the same position on a picture plane as that occupied by the beam-illuminated spot of



The synchronized disc for viewing the motion picture which is transmitted electrically. At the right a shield partially covers the disc, leaving a rectangular space in which the observer sees re-created the motion-picture frames. These frames follow each other at normal motion-picture speed

the distant scene. For an individual observer this is accomplished by using a fairly large neon tube which glows as a whole, according to the current it receives, and revolving before it a disc similar in perforations to the scaning disc of the transmitting apparatus and in synchronism therewith. Although all portions of the tube have the same brilliancy at any instant, the observer sees only that portion which is exposed at the instant by the perforation in the synchronizing disc.

In the production of an image on a larger picture plane, a different method must be employed. Instead of a relatively small tube, successive portions of which are viewed at successive intervals, there is a very long tube folded back and forth to form a grid. Instead of a single pair of electrodes, twenty-five hundred pairs are located along its length. To each electrode corresponds a single elemental area of the picture plane which is scanned by the photoelectric cell of the transmitting equipment. As the current corresponding to each area reaches the receiving station it is distributed through contacts controlled by the synchronized motors to the appropriate electrode and so causes a flash of light similar in location and in intensity. The entire grid-like tube is observed either directly or through a translucent medium. Eighteen times a second each of its twenty-five hundred areas shines forth with a brilliancy similar to that of a portion of the distant scene, but due to the persistence of vision the observers apprehend not a series of discrete light flashes, but a picture as a whole.



Rear view of the large grid showing current distributor, its control equipment and a preliminary form of the high-voltage, high-frequency equipment for exciting the successive areas of the neon tube

Research and Development Leading to Television

TELEVISION constitutes a system of communication supplementary to the telephone; and in that respect is similar to the system recently placed in operation for the electrical transmission of pictures. Its methods and apparatus are developments of Bell Telephone Laboratories, the laboratories through which the American Telephone and Telegraph Company insures the technical progress of the telephonic arts which it undertook as the corporate successor of Alexander Graham Bell.

For decades television has been a dream of inventors, and a general idea as to possible methods has been current. Despite various attempts to apply these commonly recognized ideas no practical system was developed. The methods and means proposed were inadequate to meet the severe requirements of transmitting visual images over long distances.

An elaborate and highly coordinated series of researches was required; new methods and apparatus needed to be devised and refined; and techniques recently developed in other telephonic arts had to be employed before success was obtained.

The achievement of an operative system for television is the result of a series of researches and apparatus developments planned by Dr. Herbert E. Ives, and conducted by him and by others of the technical staff of Bell Telephone Laboratories.

The basic investigation of the physical operations involved in a practicable system for television indicated the separate elements of the general problem and the specific requirements which were to be fulfilled. Each element was then made the subject of a separate research by groups skilled in their respective fields. By such coordination most rapid progress is possible, but nevertheless, due to the nature of the problem, the entire series of researches and of development studies of apparatus required several years.

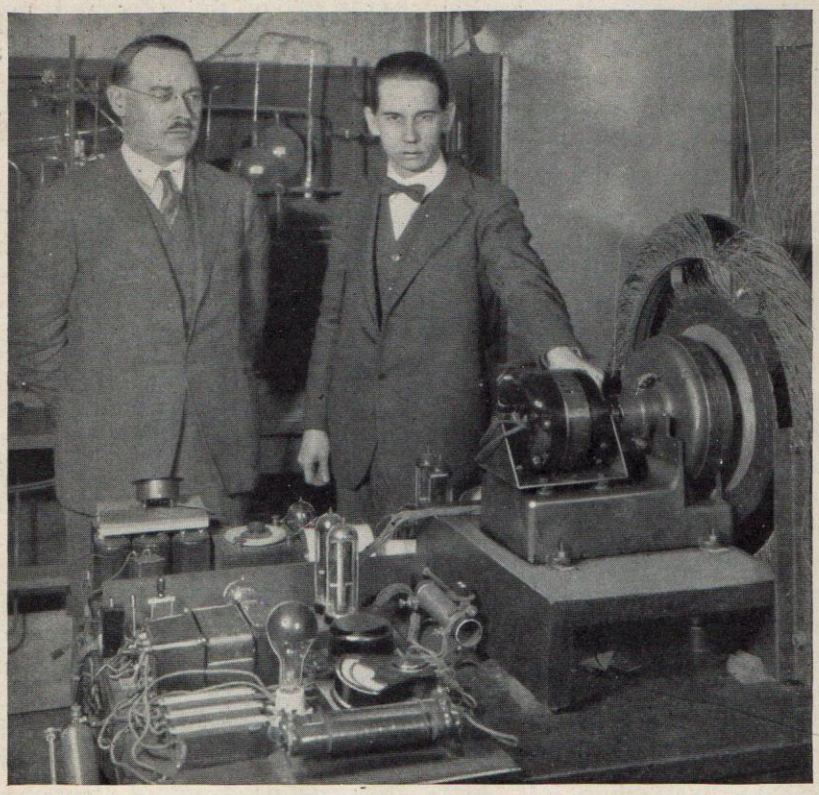
This method of directing the research attack to the elemental phases of the problem is illustrated by the investigation of methods for producing currents in response to light variations and lights in proportional response to currents. This was separated from the other investigations, such as those of methods for synchronization and of characteristics of transmission channels, by driving on the same shaft the scanning disc and the similar disc for reproducing and by operating the transmitting and the receiving equipment in close proximity to one another.

In a later form of experiment a stage of final accomplishment was reached which might seem to have justified publication, but was withheld therefrom as being only a step in the research program. A strip of motion-picture film was projected from a standard machine upon a photoelectric cell. The moving picture of this film was then re-created for an observer by receiving equipment involv-

ing a suitable neon tube and a scanning disc. This apparatus eliminated the problem of the illumination of the scene and thus permitted concentration on its other phases. Its use facilitated the study of synchronous motors, which were developed under direction of H. M. Stoller.

This work with moving-picture films also demonstrated that the varying current from the photoelectric cell could be handled through transformers and other couplings which would carry only alternating current, that is, only the alternating-current components of the current from the photoelectric cell. This made possible the use of alternating-current amplifiers similar in principle to those employed in other fields of telephony.

One of the next developments was that by Dr. F. Gray, a member of the technical staff of the Laboratories, who had previously been responsible for certain early forms of the experimental apparatus. He devised the method of projecting a minute spot of very bright light upon the object which is to be transmitted, and of moving this spot back and forth to illuminate successively the details of the entire area. Previous experimenters had endeavored to secure complete illumination of the object by

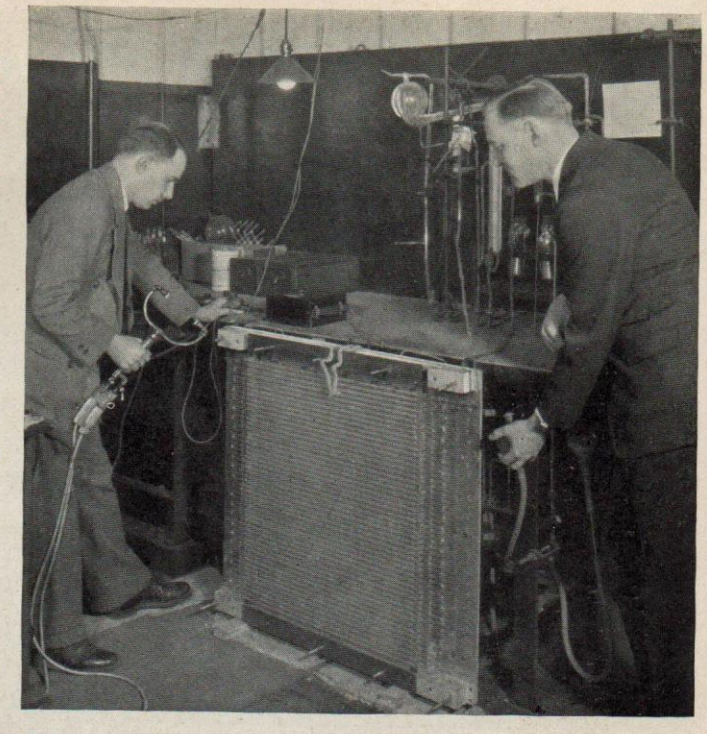


The rotary distributor, with its optic nerve of 2500 conductors leading to the large neon tube, is shown at the right. This picture was taken during the development researches and shows the motor control-equipment at the left of the table and the motor on the shaft of the distributor. Standing are H. M. Stoller and E. R. Morton who were responsible for the development of the system of motor control

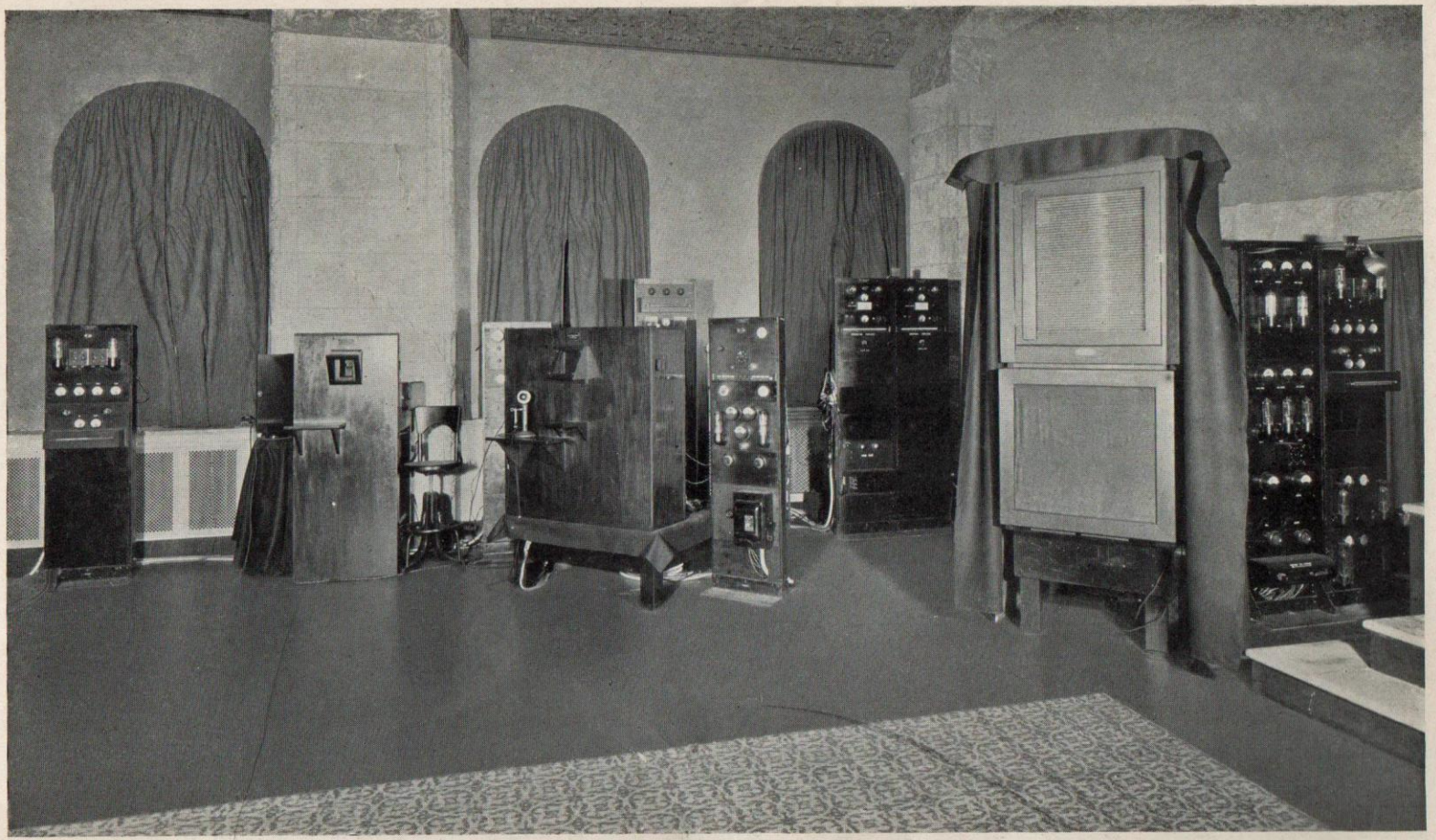
pouring a tremendous flood of light upon it. By the use of this new scanning method, however, it is possible to employ, on the average, a very small amount of light instead of an amount which would be unbearable to the actors who take part in the scene.

Instead of a small photoelectric cell it was therefore desirable to use a very large cell, or a group of cells, to collect most efficiently the light reflected from the successively illuminated spots of the scene. There was then constructed, under the direction of Dr. Ives, what probably is the largest photoelectric cell in the world. In the form of transmitting apparatus next developed, three of these large cells were placed around the object in various positions in order to secure the equivalent of illumination from various directions. The effect thus produced, of illumination by a single narrow beam and its observation by several photoelectric eyes, is equivalent to illumination from various directions and is analogous to the arrangement of lights around the subject in a photographic studio.

Other phases of the research problem were met in the development by Dr. Gray of the large neon tube for the production of an image large enough to be viewed by a considerable audience. The development and use of such a tube, with its present total of 2500 external electrodes, required the development of a current-distributor from which 2500 wires, like a gigantic optic nerve, extended to the tube. When the front of this tube is observed, its whole area appears to glow at once; so rapidly does the instantaneous spot travel from one electrode to another that the eye is altogether unable to appreciate it in its successive positions.



Pumping one of the big neon-tube grids; C. T. Wood manipulates the hand-fire while H. W. Weinhart measures the pressure in the tubes



A general view of the receiving apparatus in the Auditorium. Among the more conspicuous elements are: left to right, the small disc for monitoring, and flanking it, its two control panels; the large disc at which conversations were held with Washington; rising behind it, and at its right, its control panels. The twin panels in the background are incoming-line amplifiers. Next is the grid receiver with its loud speaker immediately below it and its control panels at the right

Television—A Group Achievement

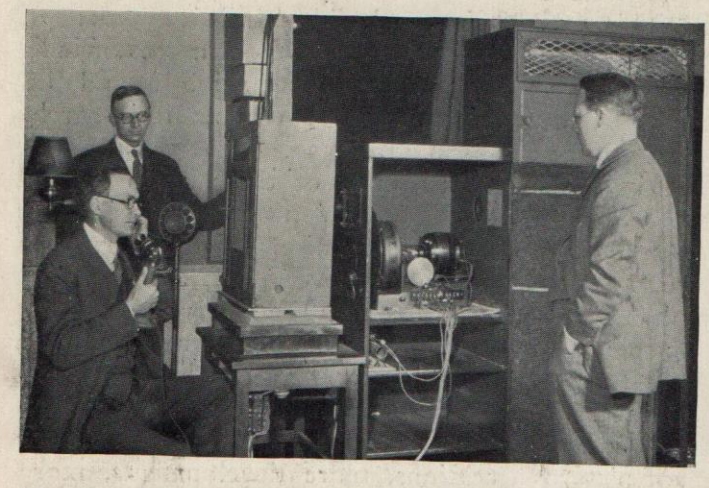
TO the newspaper men who reported the demonstration on April seventh of the practical system for television by wire and by radio there was given at the time a so-called "press release". This was a mimeographed statement covering the main facts as to location of equipment, distances, the program of the demonstration and the text of the remarks by President Gifford and Dr. Jewett. It was supplemented by captioned photographs of the apparatus at Washington, at Whippany, and at New York, and by a pamphlet which described the physical principles and apparatus of television and the underlying research and apparatus developments. The text of this pamphlet and the more important pictures are reprinted in this issue of the RECORD. The press release also contained biographical material as to H. E. Ives, F. Gray, and H. M. Stoller, whose fundamental work in television was briefly described in the pamphlet.

The task of the reporters was relatively easy. They had an executive statement as to the place of television in the program of the American Telephone and Telegraph Company, a spectacular demonstration, and a group of three engineers on whom to center the lime-light of their publicity. The task of the present writer is much more difficult. He proposes to record as completely as practicable the work and contributions of the many individuals and groups who made possible the system of television and its demonstration to the public.

Two incidents illustrate the reason for this record and its necessary incompleteness. One of the reporters after the demonstration turned to the writer and said: "Isn't it unusual for you people to give out names of individuals who did the job"? and the answer was: "No; but it is rarely possible to do so. In the present case the majority of the patents on the strictly television part of the job are for the inventions of the men who were named in the press release. But do you realize the long road between an invention arising from a research and the actual practicable operation of the system based on it? Every step of that road demands more inventions, more developments, more designs, and contributions from the brains of dozens of other men. On my desk is a list of over one hundred men who have definitely contributed to the final achievement. It is never possible in a press release to mention all those who have contributed and it is sometimes almost equally impossible to select two or three men to stand for the group.

"For example, we told you that the transmission of the current for the formation of the image requires a frequency range of about twenty thousand cycles. Now, the provision of a channel of that range, over which all the frequencies in the band will be transmitted with practically similar attenuation and velocity, is a part of the development of television al-

though it is not a matter of scanning, synchronization, or image formation. A group of experts on the characteristics of telephone lines, on the design and construction of networks, and on transmission measurements, were called upon to solve the various problems involved. But that is only an example, although a most important one, in the development of the complete operative system. There were problems of amplification and some growing out of the method of synchronization; and then there was the whole field of adaptations to be made for the development of an operative radio system of television.



Transmitting apparatus for television arranged for demonstration in the Auditorium. Seated before the photoelectric cells which act as eyes is R. C. Mathes; behind him is J. W. Horton. On the right facing a motor of his design is H. M. Stoller, who was responsible for the development of suitable methods of synchronization

"That's on the side of development, but when you come to the preparation of such a demonstration as you have just seen, which required transmission of speech, of image-forming currents, and of synchronizing currents, from one station by wire, from another by radio, and from a third, the local transmitting station in the auditorium, you get into a field where construction and operation, development work and testing, merge indefinably and the final success comes from a cooperative expenditure of brains, nerves, and exhaustive effort on the part of a large number of workers. Well, that's why it is sometimes difficult to describe a large development project as the work of a single man. You will be quite right, however, in the present instance in attributing to Dr. Ives not only his individual invention but also the enormous job of coordinating all the many contributions which produced the result which you have just seen. Some of the men who worked on the job came from other groups than his, and even from other departments and other companies of the System. Relatively few of them reported directly to Dr. Ives, but all cooperated under his leadership."

Another incident which bears on the question of adequately recording large-scale developments was a conversation, at which the writer was present. H. D. Arnold was asked a question as to why certain pieces of apparatus produced in our Laboratories were so reliable in their operation when apparently certain other manufacturers had difficulty with similar productions. Dr. Arnold's reply took the high-power vacuum tubes for an example. He said, "I don't know

any better way to express it than to say that you have just got to love one of those big tubes to make it a good one. You can't just do it as a job. It's really got to have individual care and devotion, and pride and interest in the work. And that's why our tubes stand up as they do."

That's where our Engineering Shops come into the job of television. And that's why, over and over again, from the engineers who were working on the job, the writer has heard praise of the workmanship which went into the apparatus and appreciation of the cooperation of the Shops.

For the purpose of this record the engineers who contributed directly to the demonstration may be separated into functional groups, although, in fact, lines of organization were never a limitation of anyone's activities when need arose for his services.

Dr. Ives' own group might be considered as both the first and last of a logical sequence, since it dealt with the conversion of light-variations into electric currents, and the ultimate conversion of these currents into light-variations. This group, which included Dr. Gray, E. F. Kingsbury and their assistants, developed and made the neon lamps and grid, and the giant photoelectric cells. Next might be considered the amplifiers at both ends of the system; these were designed and constructed by J. W. Horton and members of his group. An oscillator-modulator unit to work at high frequency was designed and built in unusually short time by A. Haddock and some of his associates. The group headed by R. C. Mathes was responsible for transmission and order-wire considerations. This included construction and test of phase-measuring apparatus, operation of order wires and equalizer studies.

One form of receiving apparatus for television; the distant scene is made visible to the audience on the glass screen in the center of the picture. Dr. Frank Gray, who is largely responsible for that method of receiving, stands at the left, his hand resting on a lower screen behind which is the loud-speaking telephone. On the right, W. S. Bishop and E. Peterson manipulate the controls of the amplifier and other associated equipment

The problem of synchronizing the transmitting and receiving discs was submitted to H. M. Stoller, who suggested the use of high-frequency synchronous motors. Under his direction machines of a novel type were designed and built. From the groups headed by E. O. Scriven and J. J. Kuhn, respectively, came the audio amplifiers and equipment for signalling and monitoring.

From the outset, engineers of the American Telephone and Telegraph Company had been in close touch with developments. Based on their experience with wire lines they predicted that television over telephone lines from Washington was possible of achievement. On the strength of this prediction it was decided to proceed with the costly program of preparing a circuit for the experiment. A. B. Clark was in general charge of the engineering carried on by the D. & R. group. To secure lines of the unusual characteristics required for television, an extensive study was made of the facilities available. A circuit was built up from parts of three long-distance lines, for which special transpositions and loading were engineered. H. Nyquist was responsible for methods and apparatus for measuring relations between frequency and phase-shift. Equalizing networks were calculated by O. J. Zobel with K. S. Johnson of the Laboratories.

Eight circuits between New York and Washington were provided by the Long Lines Department. Two heavy-gauge open-wire pairs were used for a regular and an emergency picture-channel. From them all loading coils and other apparatus were removed and a considerable number of special transpositions were cut in. Rearrangements of conductors were made wherever improvements could be foreseen. For the conversations, two-way talking channels were provided in duplicate; these were routed through four-wire cable circuits and specially equalized. Duplicate cable circuits were also provided for the synchronizing channel. Two talking-circuits were provided for the engineers' use, and a telegraph line connected the terminals with all the test boards en route. A tie-line between the Laboratories and the C. & P. private branch exchange was added at the time of the demonstration.

A definite procedure was outlined for reporting trouble involving any of the Long Lines circuits. Ring-down trunks were provided between the demonstration rooms and the test boards at both New York and Washington. These trunks were manned by men who were familiar with the circuit layout in order to make speedy restoration of service in case of trouble. Men were also stationed at various points to handle definite assignments. Before the demonstration, the open-wire line carrying the picture circuits was inspected by linemen to eliminate any possible hazards to service, and during the day of the demonstration linemen were held available at eight strategic points along the open wire route for the quick clearance of trouble.

To connect the Laboratories with the Long Lines office at 24 Walker Street, the New York Telephone Company installed for the picture circuit a special two-pair cable from the Auditorium to Hudson Street, where it was spliced into an existing cable. These pairs were specially loaded at thirteen points. In addition circuits were provided to Whippany, and numerous rearrangements made.