BELL LABORATORIES RECORD

COAXIAL SYSTEM
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TELEPHOTOGRAPH EQUIPMENT
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RADIO NOISE REDUCER
N. C. NORMAN

MAY 1937 Vol. XV No. 9

Bell Laboratories Record

Published Monthly by Bell Telephone Laboratories, Inc.

Single Copies $0.25; subscriptions are accepted at $2.00 per year; foreign postage $0.60 extra per year. Subscriptions should be addressed to Bell Laboratories Record, 463 West Street, New York City

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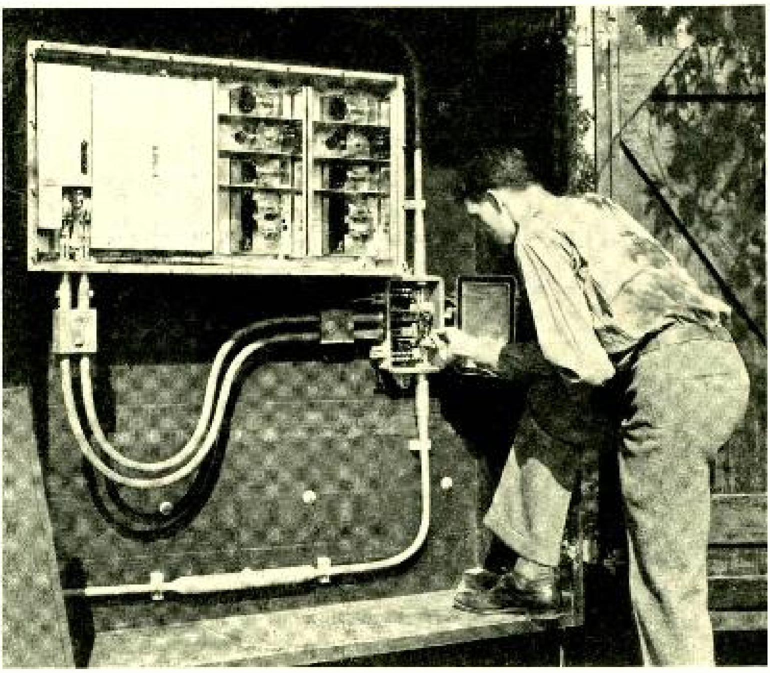
BELL LABORATORIES RECORD

Examining a handset exposed to light from a mercury-vapor lamp

MAY, 1937

VOLUME FIFTEEN—NUMBER NINE



The Coaxial Cable System

By E. I. GREEN
Toll Transmission Development

THE experimental coaxial cable system between New York and Philadelphia was in place and ready for a series of field experiments at the end of last year. Preliminary test conversations have been held over the system, both between New York and Philadelphia and also over a circuit looped back and forth at the terminals to give a total length of 3800 miles. In general, the results thus far obtained have been in accordance with expectations, and no insurmountable barriers have appeared which would prevent the successful application of such systems in the future. Much work remains to be done, however, before coaxial systems suitable for general commercial service can be produced. Although the quality of transmission has been shown to be satisfactory, many other problems require consideration. A more precise system for regulating the transmission to compensate for changes in attenuation will be needed for systems which are to operate over transcontinental distances, particularly where aerial construction is involved. The accumulation of noise and crosstalk over long distances must be kept within satisfactory limits, and the repeaters must be made so stable and reliable that continuity of service will be assured even when hundreds of repeaters are placed in series.

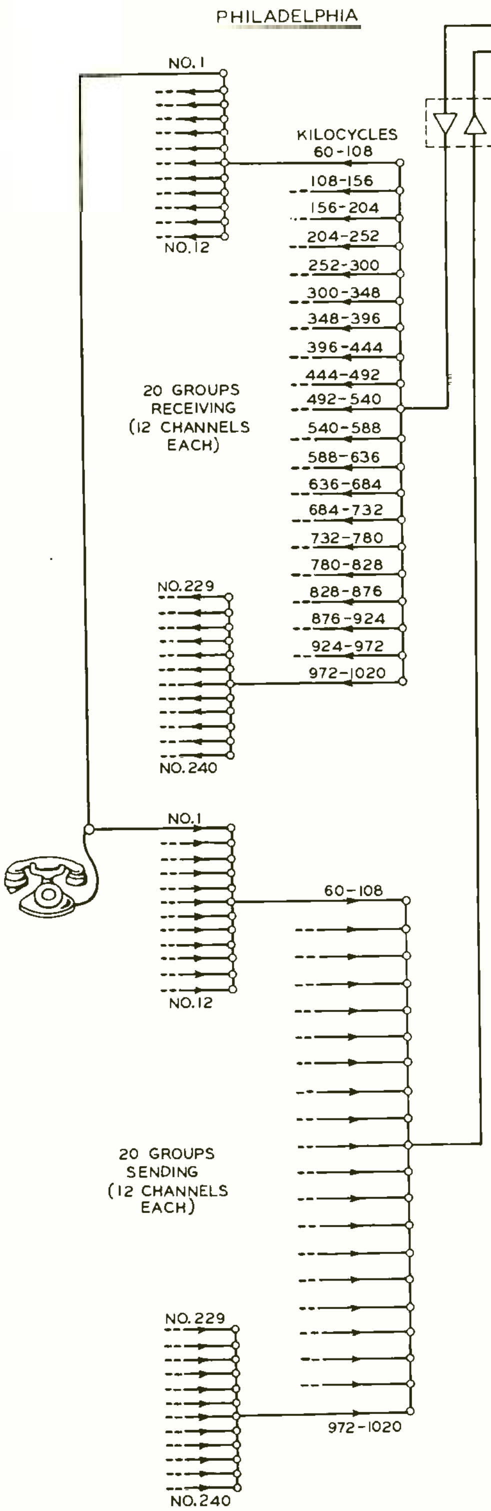
The coaxial system will represent an important step in the development of what have been termed "broad-band" carrier systems for long distance transmission. These broad-band systems permit the use of a much larger number of channels over a single pair of conductors than has heretofore been possible. Broadest of broad-band systems is the coaxial system, which, employing a frequency band at the present time of a million cycles, is capable of providing 240 one-way channels over a single coaxial circuit; and it is expected that the transmitted frequency band may be at least doubled in the future.

Although other forms of line structure could be used to transmit this wide frequency band, the line structure employed—which gives its name to the system—consists of a copper conductor supported within a flexible copper tube by thin discs of hard rubber spaced a few centimeters apart along the entire length of the structure. Two of such coaxial units, one for each direction of transmission, are enclosed with two quads of nineteen-gauge paper-insulated wires in a lead sheath only seven-eighths of an inch in outside diameter. A cross-section of this coaxial cable is shown in Figure 1 above a voice-frequency toll cable of the more usual construction.

The experimental coaxial installation runs some ninety-five miles from the Long Lines Building at thirty-two Sixth Avenue, New York, to the Bourse Building in Philadelphia. The entire run is underground, and repeaters are provided about every ten miles. The simplified diagram of Figure 2 indicates the main features of this new system.

The outer tubular conductor of the coaxial unit serves as one side of the circuit, the central conductor being the other. Of no little importance is the shielding effect of this outer tube. Because of the "skin effect" at the high frequencies employed, the signal currents in the tube crowd toward its inner surface, and the undesired interfering currents crowd toward the outer surface. Effective shielding of the circuit is thus secured, which makes it possible to allow the transmitted signals to drop to very low levels without danger of introducing noise. Another advantage of the construction employed is that the small amount of solid dielectric—only that of the thin hard-rubber discs—avoids the large dielectric losses that would

Fig. 1—The coaxial cable occupies but one-ninth of the space required for a full size toll cable



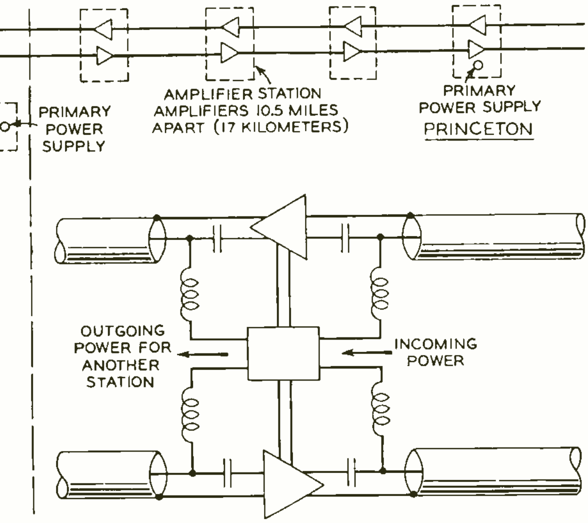
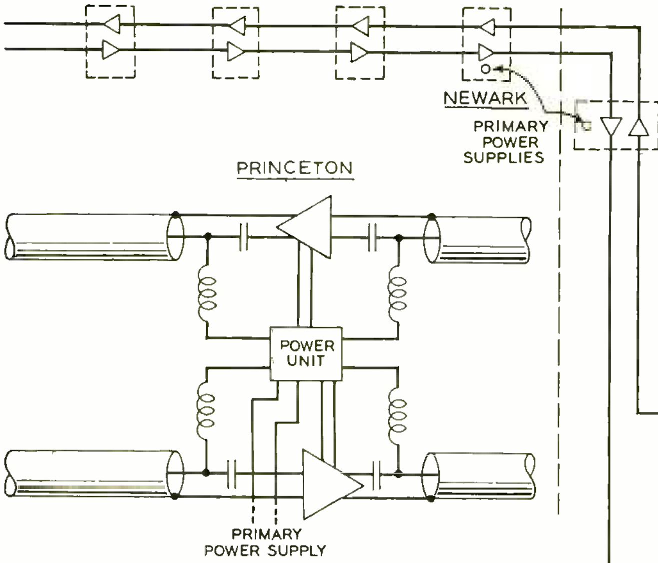


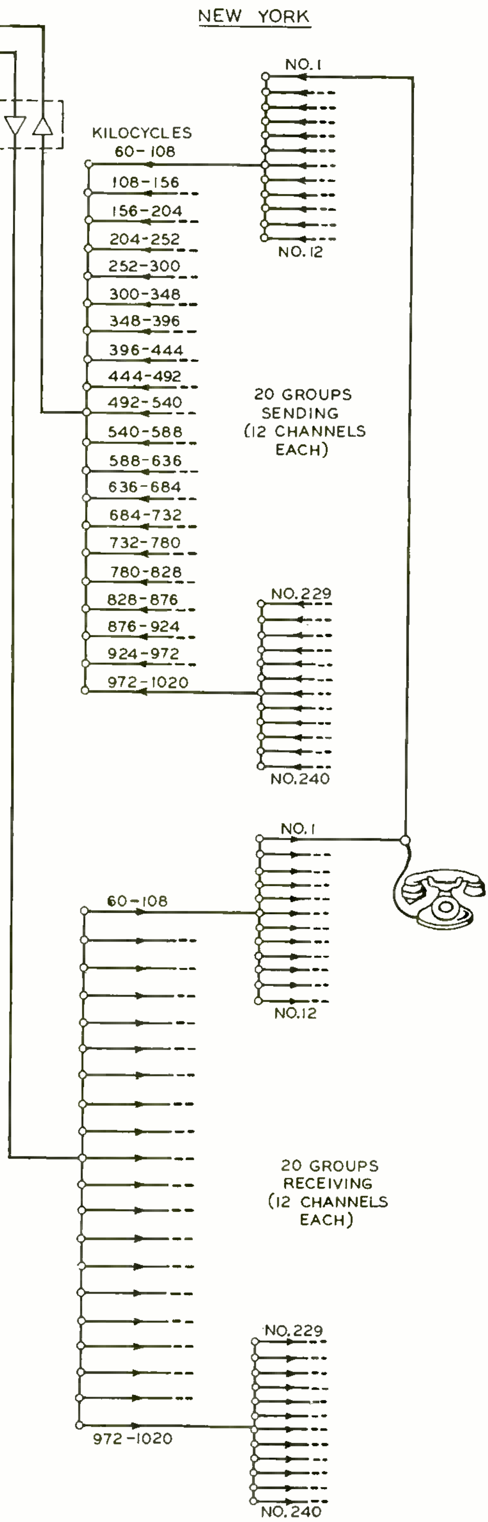
Fig. 2—Major features of the coaxial system

otherwise exist at the high frequencies.

Although the coaxial system gets its name from the line structure, greater novelty resides in the repeaters and terminals employed in the system. To overcome the attenuation of the ninety-five-mile length of circuit, ten repeaters are required, and each is designed to handle the entire frequency band from sixty to 1024 kilocycles. Each repeater consists of two amplifiers, each of three stages with negative feedback around the last two. The use of feedback makes the repeater very stable and minimizes distortion effects that would otherwise give rise to interference between different channels. New and improved transformers and higher-gain vacuum tubes make it possible to amplify the entire frequency range without subdivision.

For a given length of circuit, the attenuation of the coaxial circuit at the top of its band is many times as high as that for older types of circuits at the maximum frequencies they transmit. The total amplification introduced by the repeaters on a given length of coaxial circuit must, therefore, be correspondingly greater, and the problem of securing and maintaining the precision of adjustment which is necessary between the huge line attenuations on the one hand and the huge gains on the other hand, is correspondingly





more severe. Moreover, the sloping characteristic of the line attenuation over the frequency range requires that a very accurately designed transmission equalizer be associated with each repeater.

Merely to compensate for the line attenuation at one particular moment is not sufficient, however. Compensation must be provided also for the changes in line attenuation that result from changes in the temperature of the cable. These changes in attenuation are different for different frequencies, and like the attenuation itself are, for a given geographical length, many times greater than the variations experienced with present types of line circuits. In the experimental installation about one out of every three repeaters is arranged to check its own performance by use of a pilot frequency of 1024 kilocycles, and to adjust its amplification continuously and automatically to compensate for variations in line attenuation. The remaining repeaters are of the non-regulating or constant gain type. With these a pilot frequency of sixty kilocycles is transmitted over the line and used at each attended station to control the "flat gain" regulators.

Instead of being placed in buildings, as has been the practice up to now, most of the repeaters of the coaxial system are mounted in sealed iron boxes placed in or near the cable manholes, where they are expected to function for considerable periods of time without attention. In all there are seven auxiliary repeaters in addition to the main repeaters located in the attended offices at New York, Princeton, and Philadelphia. One of the auxiliary repeaters is housed in the Newark office, four are placed in manholes, and the other two are mounted above ground adjacent to the manholes. A photograph of a repeater above ground is shown in the headpiece.

Another unusual feature of this installation is that current to operate the auxiliary repeaters, other than the one at Newark, is fed at sixty cycles over the coaxial line. The auxiliary repeaters receive their current from Newark, Princeton, or Philadelphia as indicated in Figure 2. The sixty-cycle voltage is applied between the two central wires, the outer coaxial conductors being grounded. The circuit arrangement is indicated in the inset diagram. The central wires are, of course, very effectively protected by the outer conductors from accidental contact, but protective apparatus is provided so that in the unlikely event of a contact between the inner and outer coaxial conductors or an open circuit of the inner wire, the voltage is immediately and permanently removed from the units.

By the use of sharp selecting circuits, a band width of only 4000 cycles is required for each voice channel. A full complement of 240 channels thus requires a total band width of 960 kilocycles. By a combination of single and double modulation these channels are distributed over the frequency range from sixty to 1020 kilocycles as the single side bands of carriers of sixty-four kilocycles and every multiple of four kilocycles up to 1020 kilocycles. The scheme of modulation is illustrated in the frequency allocation diagram of Figure 3. The channels are arranged at the terminals in groups of twelve. The incoming voice channels comprising one group are first modulated by twelve carriers, 4000 cycles apart, from sixty-four to 108 kilocycles. One of these groups is then put on the coaxial line to form the lowest part of the transmitted band. In a complete system the other nineteen groups will be modulated a second time by carriers spaced forty-eight kilocycles apart and will thus be raised to successive forty-eight kilocycle bands above 108 kilocycles. A reverse process is employed at the receiving end.

In the experimental installation, channel terminal equipment is provided for only three groups or a total of thirty-six two-way voice channels, but the group equipment is arranged so that the three groups may be placed in various parts of the frequency range. In the test conversations referred to above, the channel and group equipments were connected together so as to obtain five voice-frequency links in tandem, each link being 760 miles long, and by connecting these links in tandem a total circuit length of 3800 miles was obtained. In each direction the conversation passed through seventy stages of frequency transformation, while the same speech passed twenty times through each one of the line amplifiers.

In a multi-channel system such as this, it is very important that the carriers accurately maintain their frequency. This is accomplished by deriving all the carriers from a single reference frequency of 4000 cycles. From this reference frequency twelve carriers from sixty-four kilocycles to

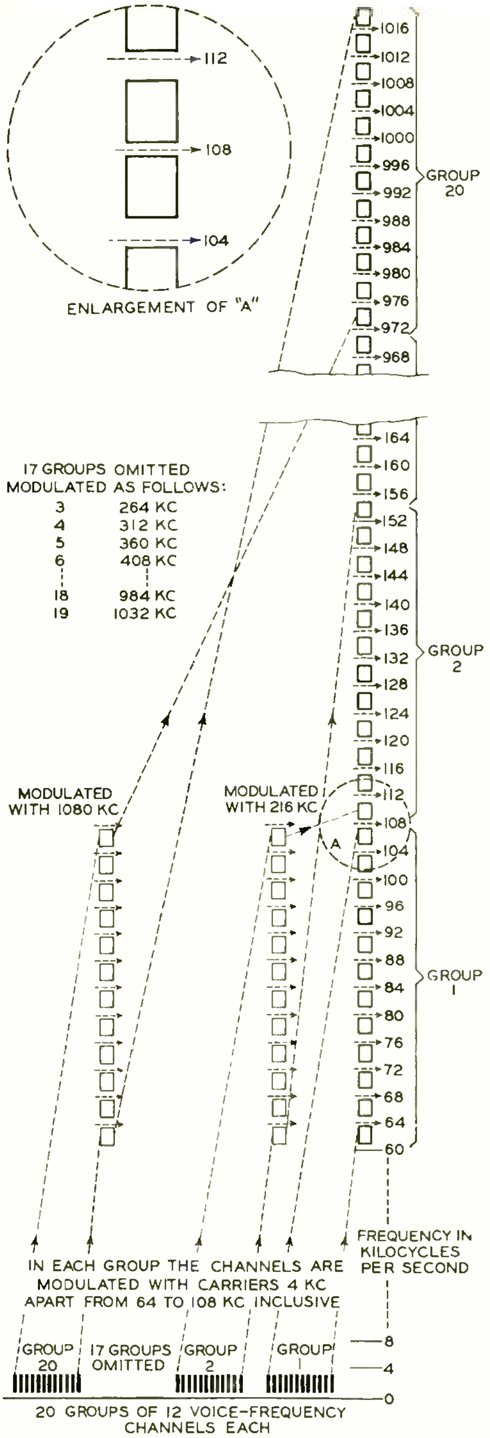
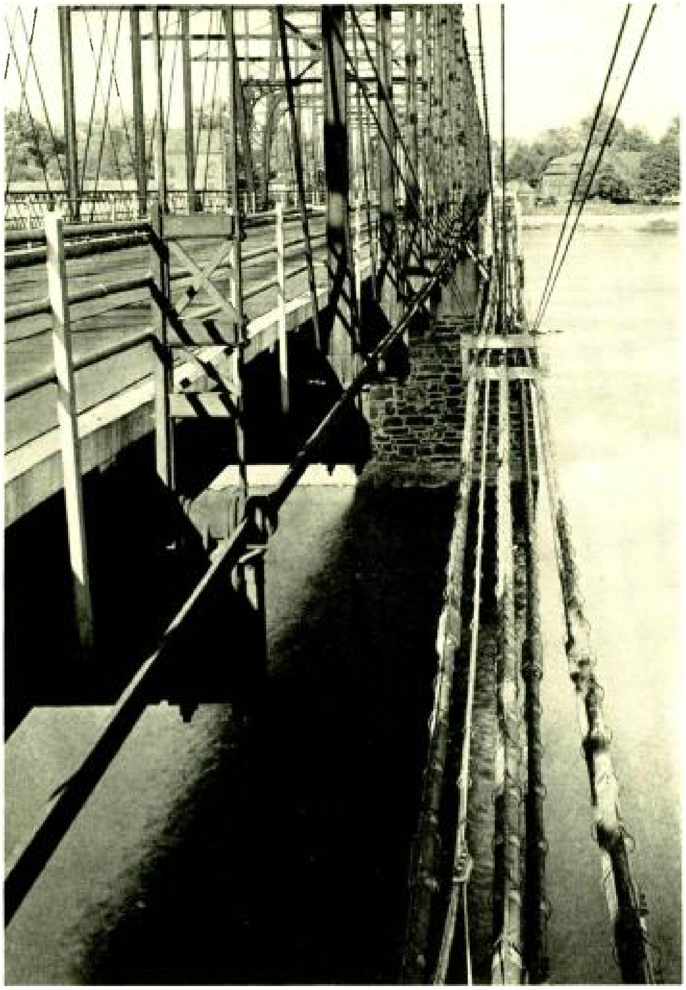


Fig. 3—Frequency allocation diagram of coaxial system

108 kilocycles inclusive are obtained for the channel terminals, and also a 24-kilocycle frequency, which is used as a base frequency for deriving the carriers for the nineteen groups that undergo a second modulation.

A separate set of terminal apparatus is necessary for utilizing the coaxial band for the transmission of television. As is now generally recognized, television requires an extremely wide band of frequencies extending upward from zero or a very low frequency. The coaxial circuit is well adapted to the severe requirements of transmitting television at high frequencies, but the transmission of the lower frequencies of the television band over the coaxial line and repeaters would present very difficult problems. These problems are avoided by shifting the television band upward in the frequency range, using a process of double modulation. Modulating and demodulating apparatus for this purpose is to be provided at the terminals of the experimental installation. This initial apparatus will afford a television band of about 800 kilocycles in width. In using the coaxial line for television, it is necessary to obtain a high degree of uniformity in the time of transmission for the different frequencies of the television band so as to avoid distortion of the picture. Special equalizing circuits are being provided for this purpose.

The work of construction and installation of the experimental system was carried forward rapidly. The coaxial cable was manufactured by the Western Electric Company at its factory at Point Breeze, Maryland. Except for a relatively short length installed by the New York Telephone Company, the work of installing the cable was done by the Long Lines Department of the American Telephone and Telegraph Company. Part of the equipment was constructed by the Western Electric Company, and part by the Bell Telephone Laboratories. By October, 1936, the whole system was in place except for the television modulating equipment, which is still in process of construction. As noted above, the extensive program of field experiments on this system is just getting under way. Study of the numerous problems involved in this new system will continue for a considerable time to come, very likely with substantial modifications in the system from time to time.



The coaxial cable (small cable, second from left) crosses the Delaware en route to Philadelphia

A Noise Reducer for Radio-Telephone Circuits

By N. C. NORMAN
Wire Transmission Research

When service trials of the compandor* on the long-wave transatlantic radio-telephone circuit proved the device a success as a means of combating static interference, it was decided to try a similar installation to improve service on the short-wave channels. A few trials were therefore arranged while one of our engineers was in London to assist in the tests. It became apparent at once, however, that compression and subsequent expansion of the signal volume range on the short-wave circuits offered little or no advantage.

Short-wave channels are particularly subject to selective fading, and it was presumably this fact that was largely responsible for the unsuitability of the compandor on these circuits. Compression at the transmitter modifies the shape of the envelope of the transmitted signal, and expansion at the receiver restores it to its original shape. If, however, there is selective fading over the transmission path, the restored signal will no longer be the same as the original, and the result is a distortion. Realizing these facts, the engineers tried using the expandor section of the compandor alone. The result was a distinct improvement in intelligibility where the circuit was noisy. The improvement was confirmed by a number of observers, and studies of the action of an expandor under various transmission conditions furnished the clue that led to the development of the noise reducer. These studies brought out that the ad-

*Record, *December*, 1934, *p.* 98.

vantages of expansion of the received volume range were greatest when the frequency range was limited, and the noise was of the type usually encountered on the short-wave channels.

If the amplifiers of a radio transmitter are manually adjusted to keep the average volume constant, that is, to smooth out the differences caused by low or loud talking, there will still remain an amplitude range of nearly forty db, representing the difference between the strong vowel and the weak consonant sounds. The compandor provided a compressor at the transmitting end that introduced a gain varying inversely with a function of the signal amplitude from twenty db for the weak signals to zero db for the strong signals. With the compressor in the circuit, therefore, the amplitude of the output signals of the transmitter varied only over a twenty db range instead of over the forty db range. The expandor at the receiving end performed the inverse function; it introduced a loss varying inversely with a function of the signal strength, and thus expanded the instantaneous voltage range from twenty db back to the original forty db.

The action of the compandor may be followed from the dotted curves of Figure 1, where the zero point of the coördinate axes represents the highest amplitude of the speech sounds, and for convenience of illustration it may be assumed that the lowest audible amplitude under normal listening conditions at the output of the receiver is about −40 db, and that the noise level at the input of the receiver is −30 db. For transmitter inputs shown on scale 1, the gain of the compressor, scale 4, is represented by curve A. Without the compressor, the output of the transmitter, scale 2, would be represented by curve B, but the compressor raises it to curve C, where input signals at a −40 db amplitude become output signals at −20 db, and are thus ten db above the noise. At the receiver, the expandor has loss characteristics, scale 3, as represented by curve D for input amplitudes represented on scale 2. It is actuated by the input amplitude to insert a loss varying from zero db at zero input, to twenty db at −20 db input, and remaining constant for all lower inputs. Its effect, therefore, is to restore the speech signals to the original forty db range,

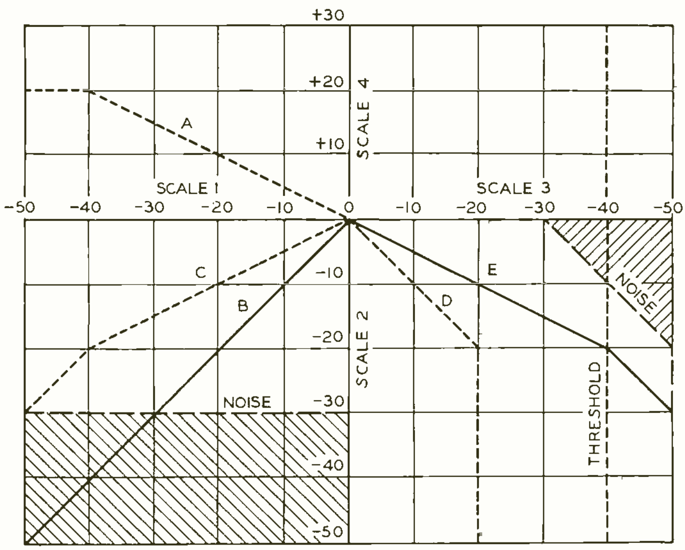


Fig. 1—The action of the compandor, or of its expandor section alone, may be visualized by noting their effects at various amplitudes of speech from scale 1, representing the input to the transmitter, through scale 2, representing the output of the transmitter and the input to the receiver, to scale 3, representing the output of the receiver

as shown by curve E. It keeps the noise at least ten db below the signal, so that at the output of the receiver there is no noise above the threshold when the speech sounds at the input of the transmitter are −20 db or less. While there is noise at higher amplitudes of speech, it is so far below the speech as to be inappreciable. Without the compandor the noise would have been above the speech for all amplitudes below −30 db, and would, as a result, have seriously interfered with intelligibility.

The loss of the speech sounds below −30 db would not in itself have been serious, since experience has shown that satisfactory intelligibility is obtained without the presence of these low-amplitude sounds. The effect seems to be rather that the presence of noise during all the low amplitude parts of speech interferes with the interpretation of the higher-amplitude portions. Thus while speech in which all sounds below −30 db are omitted has ample intelligibility, speech containing all sounds down to −40 db but with noise at a −30 db level becomes appreciably poorer.

When the expandor section of the compandor is used alone, the output of the receiver is also represented by curve E, but the input is represented by curve B rather than by curve C. While the noise is thus limited as effectively as it was with the complete compandor, it will be noticed that all speech sounds below an original amplitude of −20 db are also lost by falling below the threshold at the output of the receiver, so that intelligibility is definitely impaired. Since the expandor introduces an increasing loss beginning at zero db, its effect is to rotate the output curve toward the direction of greater loss, with the center of rotation at zero db. The overall result is that signals at an original amplitude of −10 db come

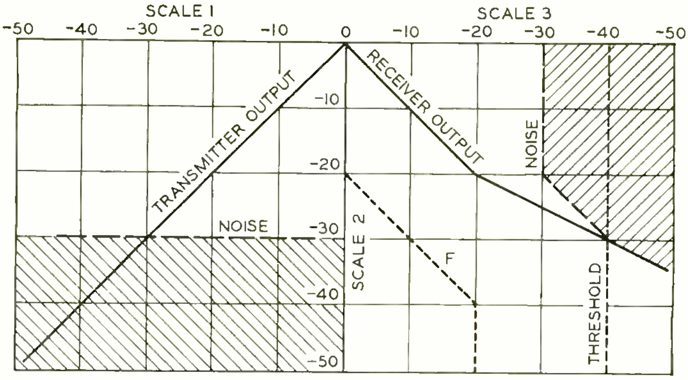


Fig. 2—The action of the noise reducer is similar to that of the expandor section of the compandor, except that the loss begins at −20 db

out at −20 db, signals originally at −20 db come out at −40 db, and signals at all lower original amplitudes come out too low to be audible.

It thus appeared that if the characteristics of the expandor were changed so as to begin introducing loss only to signals say below −20 db, its rotating effect on the output curve would be from a center at input signals of −20 db, and a greater part of the original signal would be maintained while the noise would still be reduced. This is illustrated in Figure 2, where it will be noted the loss curve for the limited expandor, or noise reducer as it was named, curve F, begins only at −20 db instead of at zero db. With such an arrangement, the amplitudes of the output signals are exactly the same as the input down to −20 db, and only below this point is the expanding function performed. Thus with the original expandor, signals below −20 db came out below −40 db and were lost, while with the noise suppressor, it is only the signals below −30 db that are lost along with the noise. Since speech has ample intelligibility when only sounds below −30 db are omitted, providing the noise is also decreased, an expandor of this type, while not reducing the noise as much as the original expandor, was more effective when only the expandor was to be used.

From the above explanation it will be evident that a train of speech sounds will be acted upon by the noise reducer as follows: during sound pulses of high energy amplitude, both speech and noise will be unaffected; during intervals in which there is no speech, noise will be reduced in inverse proportion to its amplitude; during intervals in which the sound (speech and noise) is at intermediate amplitudes, there is a progressive reduction, lower amplitudes being reduced more than higher amplitudes. The overall effectiveness of a noise reducer of this type is a combination of these effects.

In view of the wide range of conditions that must be met, the noise reducer was arranged so that the point at which the expansion began could be made either −20, −25, −30, or −35 db. As built and installed in the Transatlantic Control Room in the summer of 1934, the noise reducer consisted of an expandor of the type used with the compandor, to which was added a voltage limiter and an attenuator to adjust the amplitude at which the expandor began to act. It immediately proved of such value on the ship-to-shore facilities that it has been used largely in that service ever since. During the trial period it was used on 68.5 per cent of all calls made, and on twenty-five per cent of the calls on which it was used, the circuit would have been uncommercial without it. On another forty per cent, the circuits were improved from what would have been barely commercial to what would be considered good quality for transatlantic facilities.

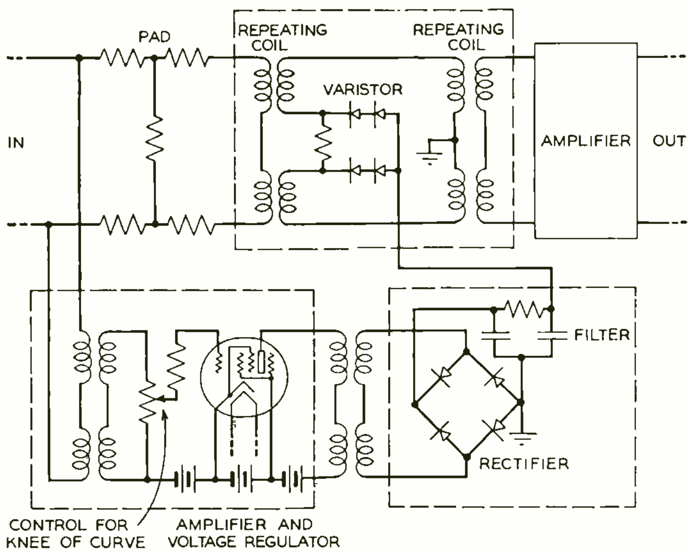
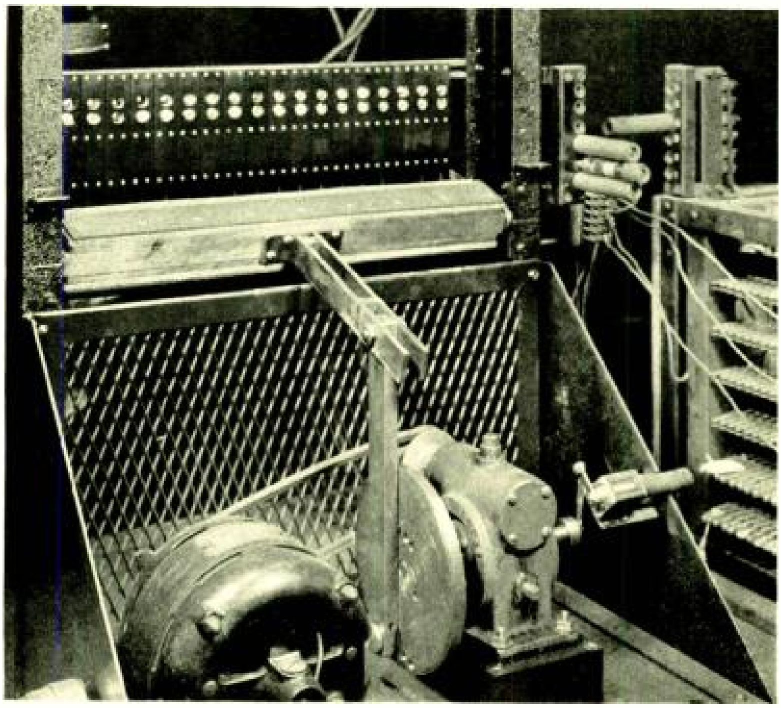


Fig. 3—Simplified schematic of the new noise reducer

As a result of the impressive record made by the noise reducer in ship-to-shore service, it was decided to install a second unit on the short-wave circuits to London. Its operation was observed on 137 calls during December, 1935, and January, 1936. Improvement was reported by the technical operators on every call, and fifty-eight of them would not have been commercial quality without it. Some use of the noise reducer has also been made on the transatlantic short-wave circuits while they were carrying broadcast programs, and the results were very good.

In the summer of 1936 it was decided to simplify the noise reducer by taking advantage of the recent development of multi-element vacuum tubes and by substituting copper-oxide rectifier elements for some of the vacuum tubes of the original model. A completely assembled reducer is shown in the photograph at the head of this article, and schematic of the new circuit is shown in Figure 3. The loss introduced by the expandor takes place in the output circuit of the repeating coil, and the amount of loss depends on the voltage applied to the varistor. This voltage, in turn, is determined by the network, amplifier, and rectifier shown in the lower part of the diagram. The potentiometer of the network determines the point at which expansion begins, and at lower inputs the loss will increase inversely with the signal that is being transmitted.



Signal lamps are often mounted in the frames of keys, where they get a certain amount of jarring. This test simulates actual service as the rocker arm flips the key levers back and forth

Conditioning Insulating Materials for Test

By R. BURNS
Materials Engineering

THE electrical and mechanical properties of insulating materials may vary greatly with changes of temperature and humidity, exposure to light or immersion in liquids. An increase of humidity usually degrades the electrical characteristics while moderately high ambient temperatures, which are ordinarily accompanied by a low relative humidity, frequently result in improvement. Mechanical strength is quite likely to be decreased by drying out and the dielectric constant of some insulating materials may be somewhat affected by high temperatures.

In choosing suitable insulating materials for telephone equipment all of these factors have to be taken into consideration and attention must be given not only to the conditions under which tests are made but also to those to which the material has been subjected for some time prior to the tests. Hence the need for conditioning to provide a common background for the material regardless of its history and thus assure reproducible results.

Fig. 1—Air conditioning tests can be made in desiccator jars. The humidity of the air is controlled by the solution in the base of the jar

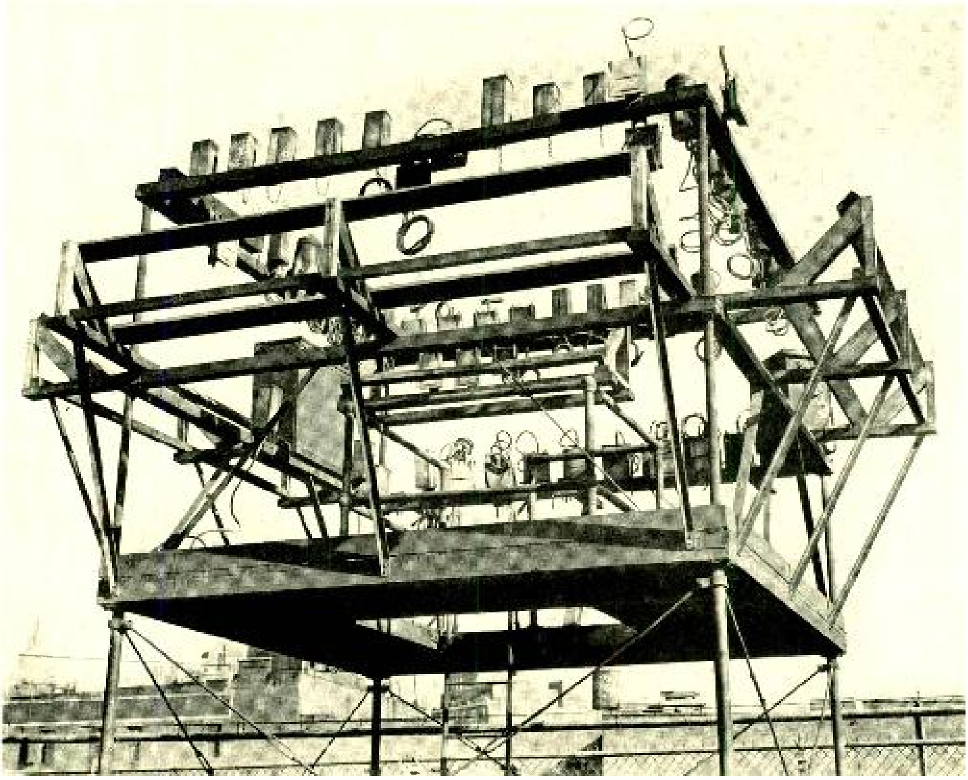


Fig. 2—Roof rack for outdoor exposure of cable terminals and materials used in their construction

Conditioning tests are not ordinarily severe enough or carried far enough to provide complete equilibrium of the material, because this would be uneconomical, in many cases, in view of the time required. All that is necessary is to approach the condition of stability so nearly that variations in the results are small compared with the requirement value. Where exposure tests are made they are usually chosen to approximate as nearly as practicable the conditions likely to be encountered in actual use, but the testing time can sometimes be shortened by using more severe exposures than those expected in service. In determining the extent and type of the conditioning exposure it is necessary to select tests which will not affect the inherent characteristics of the materials significantly. It is also desirable that conditions be chosen which can be easily and economically controlled during such tests.

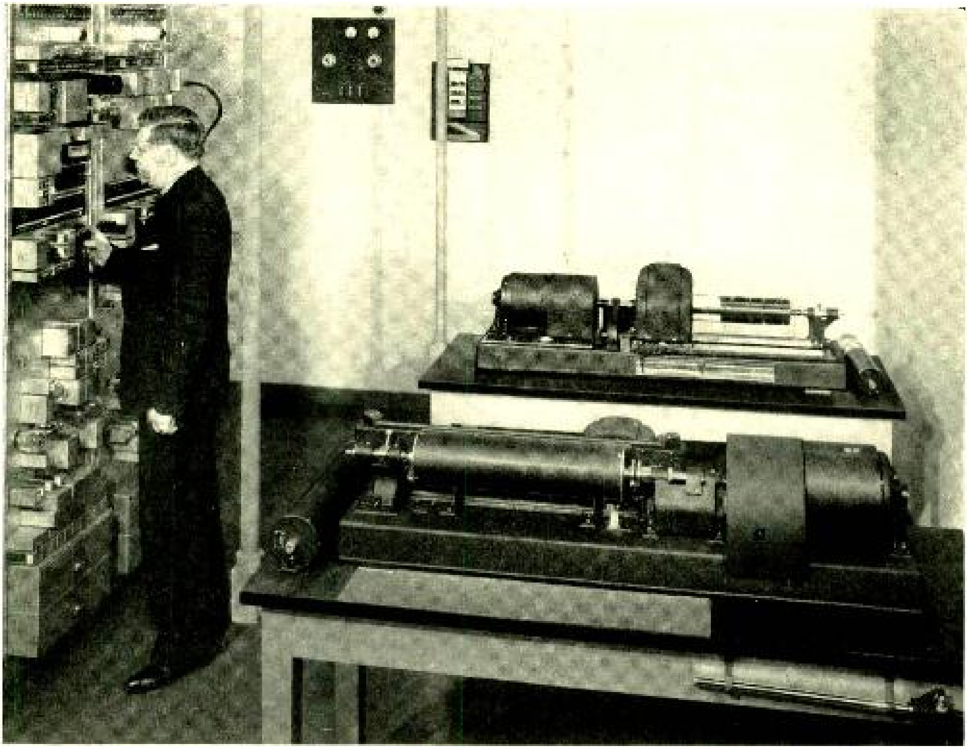
Test specimens are generally dried by exposing them to air over a desiccator or to moderately high temperatures. The latter is preferred whenever practicable since it requires less time.

Exposing materials to controlled humidity and temperature is far more difficult since large testing apparatus frequently necessitates conditioning a room of substantial size, in which the temperature and the relative humidity can be closely maintained. For less extensive but more precise work, such as the measurement of critical electrical properties, the vapor pressure method is widely used. This consists of exposing the specimens in a closed chamber which contains a dish of sulfuric acid or salt solution. The air above such a solution will be humidified a definite amount, depending on the kind of salt used or the concentration of the acid solution. In such a closed chamber the relative humidity will stay constant as long as the temperature does.

Although drying and humidifying are highly significant for many materials, there are notable cases where other forms of conditioning are necessary. Hard rubber, for example, which is extensively used as an insulating material, is very sensitive to light. In studying its physical and electrical properties samples are exposed to the radiation from a quartz mercury-vapor lamp, or, if more time is allowed, to sun lamps or natural sunlight. The lamp shown on page 273 illustrates the mercury vapor type whose photo-chemical action is primarily due to ultra-violet light. Since this short wavelength radiation is not present in sunlight at the earth's surface, however, the results obtained with this kind of lamp have to be used with discretion. For exposure to direct sunlight, apparatus and materials are mounted on racks and exposed on the roof or some other outdoor place. Sometimes it is desirable to protect the racks by housings to keep out rain.

It is frequently necessary to combine drying, humidifying and exposure to light in one conditioning cycle. In other cases the specimens are exposed continuously to high humidity for long periods while in still others the humidity is varied daily.

In determining how a material should be tested many factors have to be taken into account such as expected service life, the kind of acceptance tests required and the means of obtaining reproducible data with the minimum of time and effort. The results justify the effort, however, since they are essential to establishing the requirements for the quality control of insulating materials.



Telephotograph Transmitter and Receiver

By H. PFANNENSTIEHL
Special Products Development

"IN his eightieth hour on duty at the Wirephoto control board in New York the AP's photo editor, Wilson Hicks, heard the loudspeaker near his desk clear its gurgling throat. From 3,000 miles away, Sears, in San Francisco, his words tumbling, told of the arrival of the negatives, said they were in the darkroom and that the first would be on the transmitting drums in a minute. Then Sears was back again with the picture identification: 'New York—San Francisco. Schedule FX. An eight-by-ten W print (meaning quality flat) showing Rogers and Post laughing beside the plane at Fairbanks before the take-off for Point Barrow—last photograph of the men alive.' Hicks, 'calling all points,' meaning Washington and Cleveland and Detroit and Chicago and Kansas City and Miami and the rest of the twenty-six stations in the network, repeated the message. At all these places traffic men fiddled with dials, made adjustments to harmonize with the tentative spurts of power that San Francisco shot through the circuit, corresponding to the lightest and darkest values of the oncoming picture. Then the push of a button in San Francisco set the twenty-six receiving machines, each with a blank negative on a drum, into synchronous

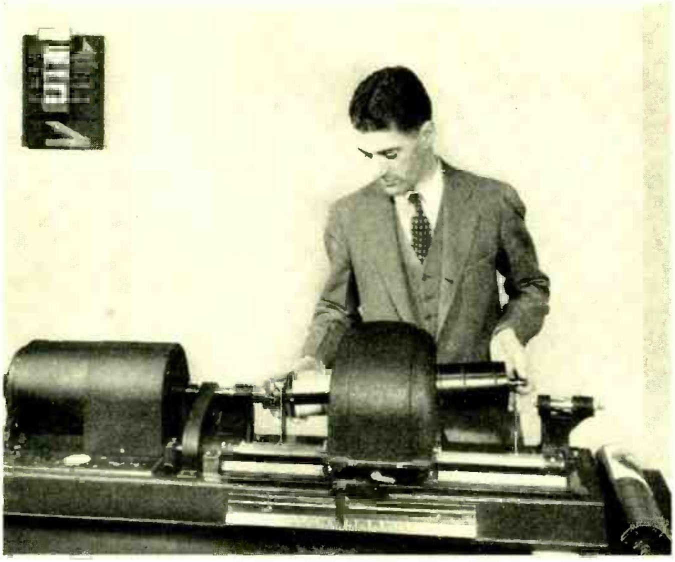


Fig. 1—The telephotograph transmitter showing the cylinder being removed after the transmission of a picture

and leisurely turning. In ten minutes the sending was done, in twenty-five minutes more each of twenty-six finished pictures was out of the dark-room and on its way into newsprint."

So writes *Fortune*, of the 70B1 Telephotograph System in a recent description *of the Associated Press. During two years and a half, the steady flow of pictures over the Associated Press network has had many such dramatic moments. Serving newspapers in many different cities, the network can transmit a picture from any point to all the others simultaneously. To design, install and place it in operation involved the work of many different departments and individuals, some of whose contributions have already been described in the RECORD.† The present author and several of his associates were immediately responsible for the mechanical design of the transmitting and receiving machines.

Both transmitting and receiving machines are alike in providing a means for rotating, at a constant speed, the drum on which the picture or film is wrapped, and for moving the carriage with the optical system along the axis of the cylinder at an accurately controlled rate. Their construction is essentially that of a lathe. Each consists of a rigid base on which is mounted a driving motor, a clutch for connecting it to the main driving spindle, and a set of gears connecting to a lead screw that moves the carriage along accurately machined guide ways. The cylinder is mounted between centers: one fixed as a tail-stock dead center, and the other rotated by the motor as a head-stock spindle. This general arrangement may be seen in Figure 1, which shows the transmitter.

The general requirements for these machines are that the cylinders shall rotate at a constant speed with respect to each other so that each succeeding line of exposure shall start on the same point of the circumference and be completed in the same time. The lead screw must be so designed that each band of exposure shall be laid adjacent to the previous one without overlapping or underlapping more than one ten-thousandth of an inch. Each of the receiving machines must be in phase with the sending machine at the start to $\pm\frac{3}{16}$ inch on the circumference of the cylinder.

The driving motor rotates at 100

*Fortune, February, 1937, p. 89.

†RECORD, February, 1935, p. 171; January, 1936, p. 154; February, 1936, pp. 178 and 193.

r.p.m., and is directly coupled to the spindle driving the cylinder. It is essentially of the d-c shunt type, but in conjunction with its control apparatus, it operates as a self-starting synchronous unit. Within the motor housing, and on the same shaft with its armature, is an inductor-type generator which, at the normal speed of the motor, furnishes an alternating current of 300 cycles per second. The output of this generator is coupled to a tuning-fork generator, which maintains its 300-cycle frequency to high precision. The connecting circuit is so arranged that if there is any difference in phase between the motor-generator and fork, due to a change of speed in the motor, the current in the armature of the motor is altered sufficiently to bring the motor speed back to normal. The frequency of the tuning-fork generator is held constant to within a few parts in a million, which is the precision required to keep all machines of the system in proper synchronous and phase relationship to produce satisfactory pictures.

While the machines are in operation the motor runs continuously, and the picture cylinder is coupled to it on receipt of the start signal through an electro-mechanical clutch. The weight of the cylinder is considerable, and unless some cushioning were provided, the cylinder load would throw the motor out of phase with the other motors in the circuit. The clutch is therefore arranged to absorb the starting shock through a spring which, as the clutch operates, is wound up until it produces sufficient tension to start the picture cylinder, the gear train, and the lead screw. During this wind-up period, the cylinder is moved out of the correct phase relationship with the motor shaft, but the action of the spring unwinding under the control of an escapement accelerates it until it regains its proper position. A photograph of this clutch mechanism with its spring cushioning device is shown in Figure 2.

The close requirement on underlap and overlap of the exposed strips of film is taken care of by a precision lead screw which has an accuracy of ±0.0001 inch per quarter turn of the thread. Special precision manufacturing methods had to be employed to obtain this accuracy. The scanning carriage of both sending and receiving machines is carried along the screw by a drive unit which is arranged to be manually disengaged so that the carriage may be quickly moved to the start position from any place along the cylinder. Adjustable trips are provided which may be set to stop the machine at the end of any desired

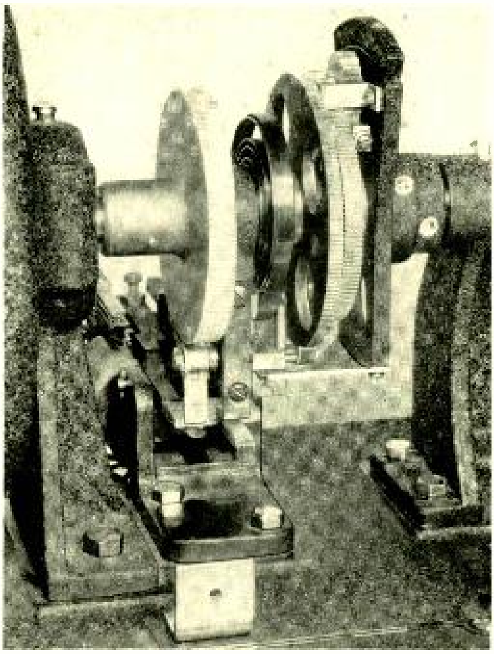


Fig. 2—The clutch used to connect the driving motor to the picture cylinder is equipped with a spring cushioning device to prevent the motors from being thrown out of synchronism while starting

length of transmission up to seventeen inches. With these arrangements pictures of any length up to seventeen inches may be transmitted without wasting time.

To permit the receiving machine to be operated under ordinary light conditions, the cylinder is enclosed in a housing with a narrow slot running the full length through which light from the optical system in the carriage can pass to the film on the cylinder. Before this housing is removed from the machine this slot is covered by a metal shutter sliding in light-tight grooves. When the housing is in the machine, the slot is closed by a movable shutter, which consists of a thin, flexible ribbon of metal running in a frame attached to the base of the machine. The lens tube of the optical system projects through a hole in this shutter, which is moved along with carriage during the scanning process. Two spools, one at each end, wind up or unwind the shutter ribbon as it is moved by the carriage. The general features of the receiving instrument can be seen in Figure 3.

The loading of both sending and receiving cylinders is done with a loading machine which wraps the picture or film tightly around the cylinder with a soft-rubber roller. In this process the cylinder is mounted between centers and rotated by a hand wheel. A picture for transmission can, of course, be loaded under lighted conditions, but loading with film for reception must be done in the dark, and for this reason the loading machine is usually kept in the darkroom, which is adjacent to the telephoto room and used for developing the films of received pictures.

In New York the pictures are sent and received from machines located at the headquarters of the Associated Press. The installation shown at the head of this article is the control office at 32 Sixth Avenue used for maintaining the network.

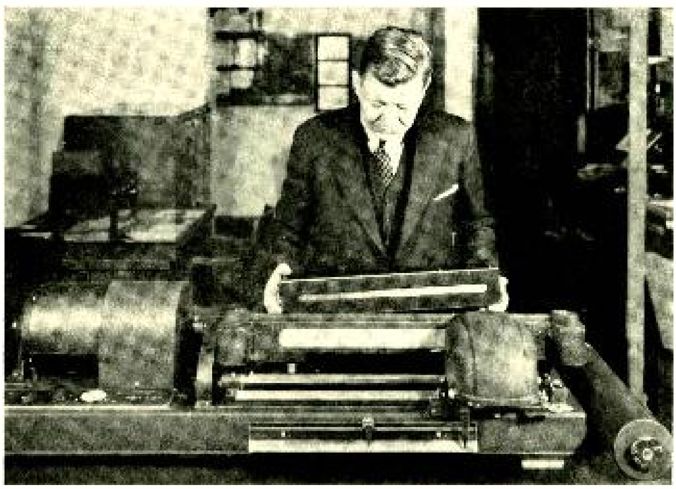
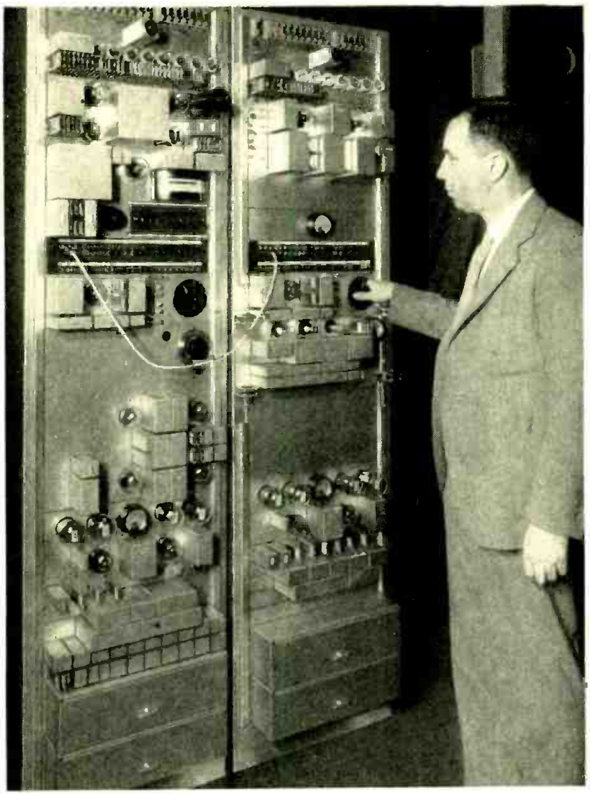


Fig. 3—The telephotograph receiver, with cylinder being removed. Both the sliding shutter in the cylinder and the ribbon shutter operated by the optical system are shown closed



Terminal Equipment for Telephotography

By J. A. COY
Equipment Development

ONE of the features of the new telephotograph system that strikes a visitor to the terminal room is that the receiver as well as the transmitter operates under normal lighting. A small adjoining dark room is required for developing the films, but all the telephotograph apparatus is in lighted surroundings—an arrangement that appreciably simplifies the operation. This has been made possible by enclosing the cylinder of the receiving machine, a construction that has already been described.* Other changes, besides the major system changes, are a reduction in the number of the separate power supplies required, and a redesign of the control bays and all accessory equipment to incorporate recent advances in apparatus and construction. In general a terminal room includes a power-supply cabinet and a control board in addition to the telephoto machines. The space required is about twelve by eighteen feet.

Two types of terminals are provided: one for a subscriber who is to receive pictures only, and another for one who is to receive and transmit. For receiving only, the terminal includes a receiving telephotograph machine, a power-supply cabinet, a re-

*Page 289, this issue.

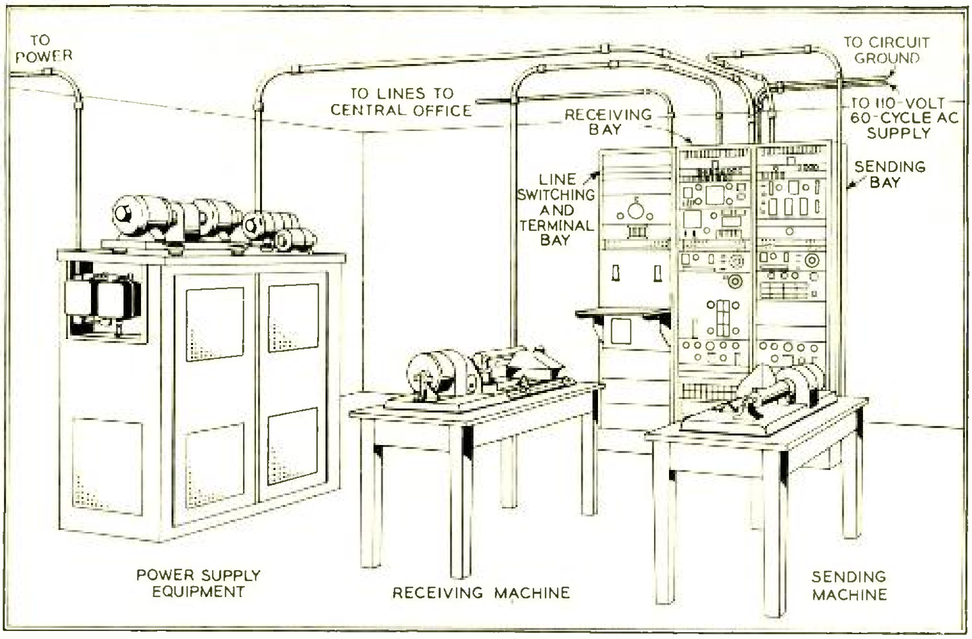


Fig. 1—Typical layout of telephoto terminal room

ceiving bay (which includes amplifying, filtering, and rectifying equipment) and a line-switching bay, which includes talking and monitoring equipment. The receiving bay includes equipment common to both sending and receiving as well as that for receiving only. Terminals for both transmitting and receiving include, in addition to the above equipment, a telephotograph transmitter and a sending bay.

The arrangement of a typical terminal room for both sending and receiving is shown in Figure 1, and the electrical association of the apparatus, by the schematic of Figure 2. The grouping of the various pieces of apparatus on the sending and receiving bays is shown in Figure 3. The common equipment, mounted on the receiving bay, consists of the carrier and motor-control oscillator. This oscillator supplies a 300-cycle current and its eighth harmonic of 2400 cycles—both frequencies being held constant to better than one part in 200,000, by a tuning fork control. The fork, supported in a vibration-proof mounting, is held at a uniform temperature in an atmosphere of constant pressure.

The 300-cycle current from this oscillator is carried to the motor-control panels of both sending and receiving bays where its phase is compared with the output of a small generator on the shaft of the respective picture machines. The equipment of these motor-control panels acts to raise or lower the armature current of the motor driving the machine—and thus to increase or lower the machine speed—whenever there is a phase difference between the outputs of the oscillator and the small generator. The frequencies of these control oscillators at various stations are compared from time to time by running a test strip through the sending machine at one station and the receiving machines at all others. Any slight corrections in frequency found necessary are made by adjustments on the oscillator panel.

The function of the other apparatus on the two bays is fairly obvious from Figure 2. Current from the photoelectric cell of the sending machine passes to the photoelectric cell amplifier on the sending bay, then through a band-pass filter and an equalizer, which selects and equalizes a single side band for transmission, and then through the sending terminal amplifier. Incoming signals pass through the receiving terminal amplifier and then through a band-pass filter to eliminate possible extraneous currents. They then pass through the amplifier-rectifier, a low-pass filter, a light-valve equalizer, and on to the light valve itself.

Arrangements for telephonic communication between picture stations on the telephoto circuit have been included for the purpose of coördinating the transmission of pictures. By pressing a key and speaking into a transmitter or handset, the attendant at any station can talk to all the others. By the operation of another key, the entire network is put in a one-way condition from the station where the key is operated to all others. This gives improved transmission for broadcasting announcements of the pictures to be sent. The loudspeaker, which is mounted on the line-switching bay, remains connected when a picture is being received, and gives audible monitoring, which enables interruptions, crosstalk, or other dis-

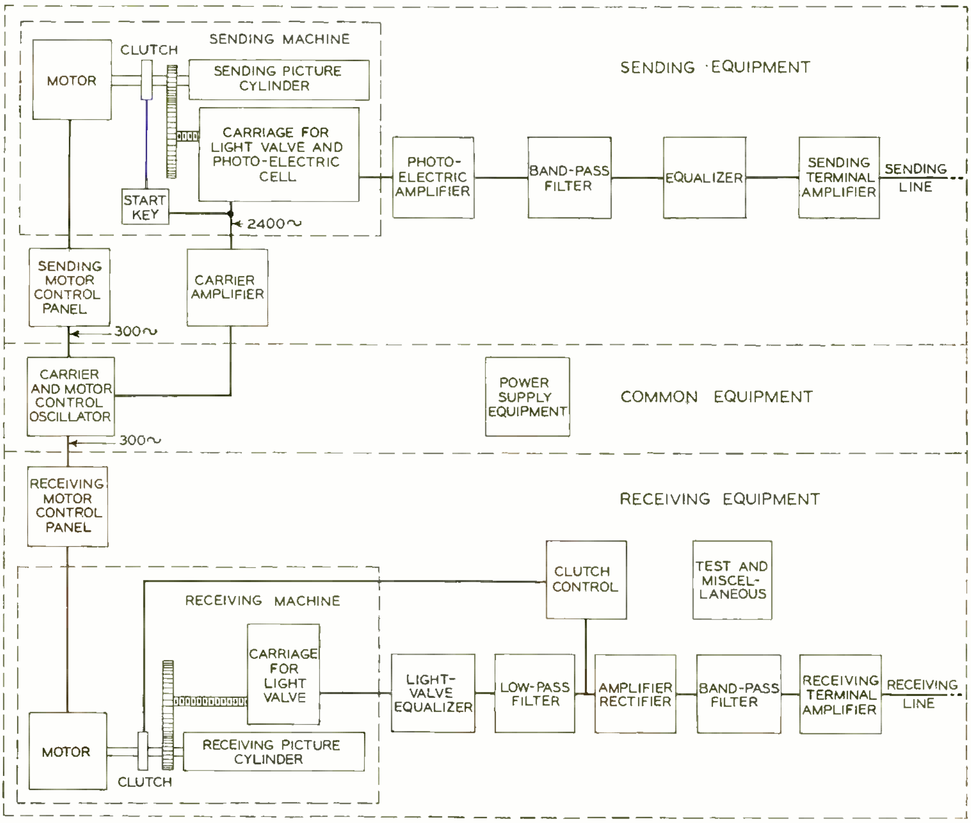


Fig. 2—Electrical layout of telephotograph apparatus

turbances to be quickly detected.

For reasons already discussed* it is important that all possible disturbances be kept out of the telephotograph circuits. As a result special attention has been given throughout the design to secure a high ratio of signal to noise. The photoelectric cell amplifier, for example, is mounted on rubber and the vacuum tube of the first stage is held in a cushion type socket.

*Record, *February*, 1936, *p.* 178.

RECEIVING BAY	SENDING BAY
FUSES, LAMPS, RESISTANCES AND RETARDATION COILS	FUSES, LAMPS, RESISTANCES AND RETARDATION COILS
AMPLIFIER-RECTIFIER PANEL	CARRIER AMPLIFIER
TEST AND MISCELLANEOUS PANEL	
JACKS	JACKS
TERMINAL AMPLIFIER	TERMINAL AMPLIFIER
CARRIER AND MOTOR CONTROL OSCILLATOR	PHOTO-ELECTRIC AMPLIFIER
MOTOR CONTROL PANEL	MOTOR CONTROL PANEL
SIGNALING	SIGNALING
LOW-PASS FILTER	EQUALIZER
BAND-PASS FILTER	BAND-PASS FILTER
LIGHT-VALVE EQUALIZER	
GT. BATTERIES	GT. BATTERIES
GT. BATTERIES	GT. BATTERIES

Fig. 3—Arrangement of apparatus on sending and receiving bays

Wiring which might be sensitive to external influence is kept as short as possible, and where necessary is supplied with a woven copper shield which is grounded at only one end for the most sensitive conductors. To secure extreme quietness a dry-cell battery supplies the plate current of the photoelectric cell amplifier and a storage battery operated on a charge and discharge basis is employed to light the picture machine lamp and to heat the filaments of the photoelectric cell amplifiers. So far as is practicable, the grounding of all apparatus is centralized at the receiving bay, and one lead is run from this bay to the building water pipes. In addition, the power plant received special attention to reduce to the lowest possible value any voltage fluctuations due to motors, generators and voltage regulators, and to filter out as much as practicable of those remaining.

Two types of power plant have been made available: one for alternating and one for direct current. Each includes batteries for three different voltages, and the necessary charging apparatus. Two twelve-volt batteries are provided for supplying the picture-machine lamps and the filaments of the photoelectric cell amplifier. These batteries are normally operated on a charge and discharge basis—one battery being charged while the other is in use.

A twenty-four-volt battery, floated across the terminals of a generator, supplies the filaments of the other tubes and miscellaneous circuits, and a 130-volt battery—also floated—is employed for clutch operation and plate supply. A twenty-four-volt and a 130-volt motor-generator are the primary source of power, and the twenty-four-volt generator is also employed to charge the twelve-volt battery. Each generator is supplied with a voltage regulator of the centrifugal type.* The two motor-generators and the voltage regulators are mounted on top of the cabinet that houses the batteries.

The direct-current plant is similar except that a single three-unit motor-generator set is employed instead of two two-unit sets. With this plant a small inverted converter is added to supply alternating current for heater control on the carrier and oscillator panel. The power cabinets are assembled in the shop and all equipment except the batteries and motor-generator sets is mounted and wired before shipment of the apparatus.

The sending and receiving picture machines are mounted on tables similar in size and shape to the usual office table. The framework, however, is of steel with legs of tapered square tubing and an apron of sheet metal. The tops are of fibre faced wood. This construction is strong and rigid, as required for this service, and the fibre surface will stand very hard wear. The tops are black and the framework is aluminum finished like the cabinets and panels.

The bay equipment, instead of being mounted on the conventional type relay rack, is mounted in a cabinet. Apparatus requiring occasional inspection or adjustment, such as vacuum tubes and potentiometers, is mounted facing outward on a panel that forms the front of the cabinet, while the wiring and miscellaneous equipment is on the rear. This arrangement brings all soldered connections inside the cabinet where they are protected from mechanical injury. A door closes the rear of the cabinet and affords access to the wiring and equipment mounted inside. Metal strips cover the ends of the panels and the heads of the screws holding the panels to the bay, and give the fronts a finished appearance.

Like the power cabinet, the bays are shop assembled and wired, and are completely shop tested with the picture machines. In this way a complete terminal unit, fully pre-tested, is furnished, and only inter-unit wiring and connections to commercial power supply and telephone lines need be made on the customer's premises.

*Record, *October*, 1935, *p.* 53.

Regulated Plate Supply

By D. E. TRUCKSESS
Equipment Development Department

AT the present time most amplifiers and oscillators for radio and commercial applications, and some of those used in the telephone plant, obtain their plate supply from commercial alternating-current circuits through rectifiers and filters. As a result their plate potential varies both with the load on the amplifier and with the voltage of the a-c supply. In many cases the load is more or less constant, and the variation caused by changes in line voltage has no serious effect; but for amplifiers used for measuring purposes and for all oscillators, the accuracy of the measurement, or the closeness with which the frequency is held, depends to an important degree on the plate voltage of the rectifier tube, so that a supply of constant potential is of considerable importance.

Batteries could be used but their operating cost is high; to provide a less expensive installation for such services, a regulated rectifier unit has recently been developed. It is designed for operation on 115 or 230-volt a-c circuits, and supplies 100 milliamperes of plate current at potentials from 130 to 180 volts, and 50 milliamperes at 250 volts, constant to within a quarter of one per cent regardless of changes in load or in supply voltage. The entire unit is assembled on a chassis only seven inches high and of a width suitable for mounting on a standard 19-inch relay rack. Its appearance is shown in Figures 1 and 2.

A simplified schematic of the circuit is shown in Figure 3 to indicate the principle used to obtain the regulation. In brief, the rectifier and filter supply a potential considerably higher than needed for the d-c output. The rectified current is passed through the regulating tube, which inserts a voltage drop that, by means of the control tube, is made to vary with variations in the d-c output voltage. The action of the circuit with variations in load is indicated by Figure 4. The upper curve is the potential of the output of the rectifier and filter for various loads in milliamperes. The lower curve is the voltage drop of the regulating tube for the same loads, while the middle curve—the sum of the other two—is the regulated d-c output voltage. The upper and lower curves are complementary so that

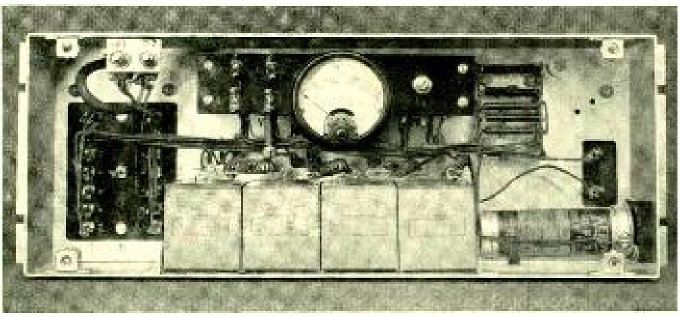


Fig. 1—Front view of rectifier unit with cover plate removed

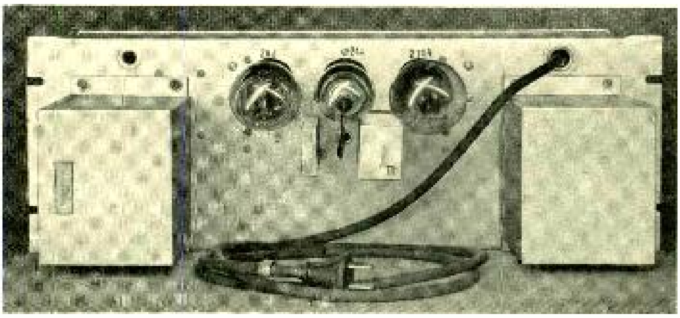


Fig. 2—On the rear of the unit are mounted the three tubes, the input transformer (right), and the retard coil used for the filter

duces a relatively large change in the plate current of this tube.

The grid voltage of the control tube is produced by the sums of the voltage of its "C" battery, which is constant and acts as the standard of regulation, and the voltage drop across R_1 and R_2, which varies with the output

their sum is of essentially constant value. A similar set of curves could be drawn for variations that occur in the a-c line voltage.

For close regulation, a very small change in d-c output voltage must be able to produce a relatively large change in the voltage drop across the regulating tube. If, for example, the drop in the potential of the rectifier and filter from no load to full load is 100 volts, and if the d-c output voltage is to be held to half a volt, then the sensitivity of the circuit must be such that a drop of half a volt in the d-c output will decrease the voltage drop of the regulating tube by approximately 100 volts. This multiplication of effect is secured by the regulating and control tubes. A small change in the potential applied to the grid of the regulating tube produces a relatively large change in the drop across the tube, and this effect is enhanced by the control tube, since its plate current produces the grid potential of the regulating tube, and a very small change in the grid potential of the control tube pro-

voltage. The drop across R_1 and R_2 would make the grid positive with respect to the cathode but the voltage of the battery, added to it, makes the grid about two volts negative with respect to the cathode. When, for example, the d-c output voltage decreases by a very small amount, the current through R_1 and R_2, and thus the voltage drop across them, will decrease correspondingly. This makes the grid potential of the control tube more negative and its plate current decreases to a greater degree. The reduction in control-tube plate current correspondingly changes the grid potential of the regulating tube, making the grid more positive with respect to its cathode, and produces a still greater effect on the voltage across the tube.

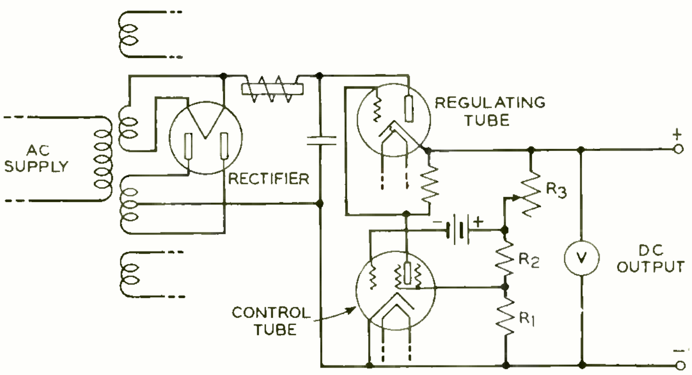


Fig. 3—Simplified schematic of the regulating rectifier of Figure 1 showing connections to regulating and control tubes

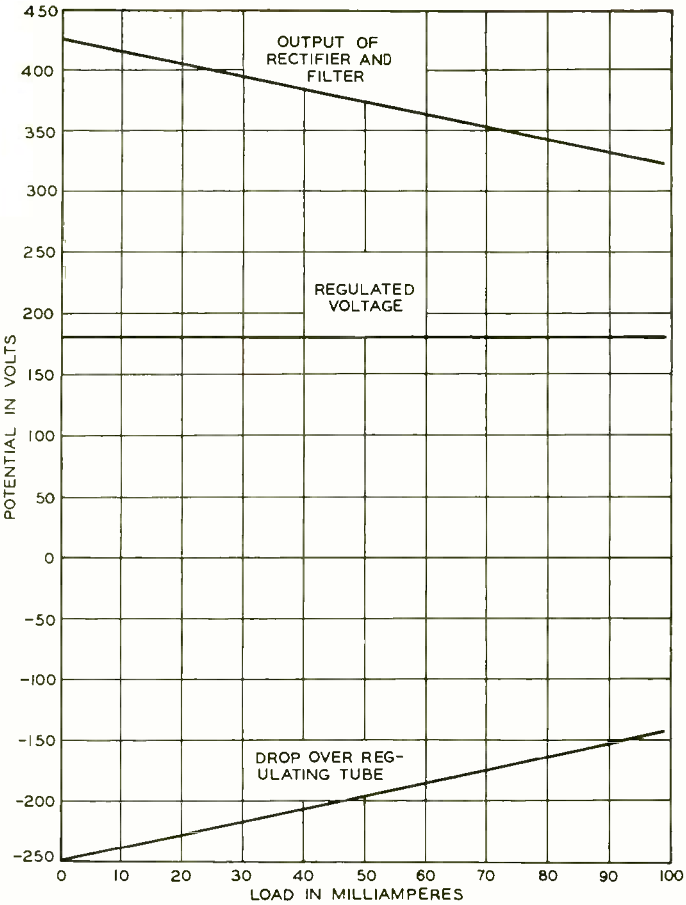


Fig. 4—The voltage of the regulating tube is complementary to that of the rectifier output so that their sum—the regulated plate voltage—is essentially constant

The overall result is that the impedance of the regulating tube is decreased, and the d-c output potential is at once brought back to practically its original value. The action is essentially instantaneous, although a transient state may exist for a period that is of the order of a thousandth of a second.

To change the value of the regulated voltage, it is necessary only to change the setting of the rheostat R_3, so that the drop across R_1 and R_2 for the new voltage will be the same as it was for the old. The voltage will then be held at this new voltage exactly as it was for the old. This makes the same rectifier unit suitable for supplying d-c output potentials from 130 to 250 volts. Provision is also made to accommodate different line voltages. The primary of the transformer has two windings, one of which is equipped with taps. With the two windings in parallel, the set is suitable for 105 to 125 volt lines, and with the windings in series, it may be used—with the aid of the tap — for voltages from 190 to 250 volts.

The constancy of regulation with the circuit given in Figure 3 is dependent on the constancy of the "C" battery voltage. This voltage remains fairly constant after a short initial period, and any change that does appear can readily be compensated by adjusting the value of resistance R_3. It has been found that the life of the battery is about two years so that battery replacement is not a matter of much importance.

This type of regulating circuit has the advantage of acting as a filter as well as a regulator. Ripples appearing in the output circuit are fed back through the control and regulating tubes in such a way that they are automatically decreased. These ripples, with full wave rectification, are double the frequency of the supply voltage—say 120 cycles—and the extremely rapid action of the regulating circuit tends to even out the periodic increases and decreases in potential as it does the changes in potential caused by variation in load. For this reason ripples, with this type of circuit, are reduced as effectively with one stage of filter as in the ordinary rectifier with two stages. Because of this feedback feature the regulator has very low internal impedance and as a result such diverse apparatus as vacuum tube oscillators and noise measuring sets may be operated from it at the same time without interference.

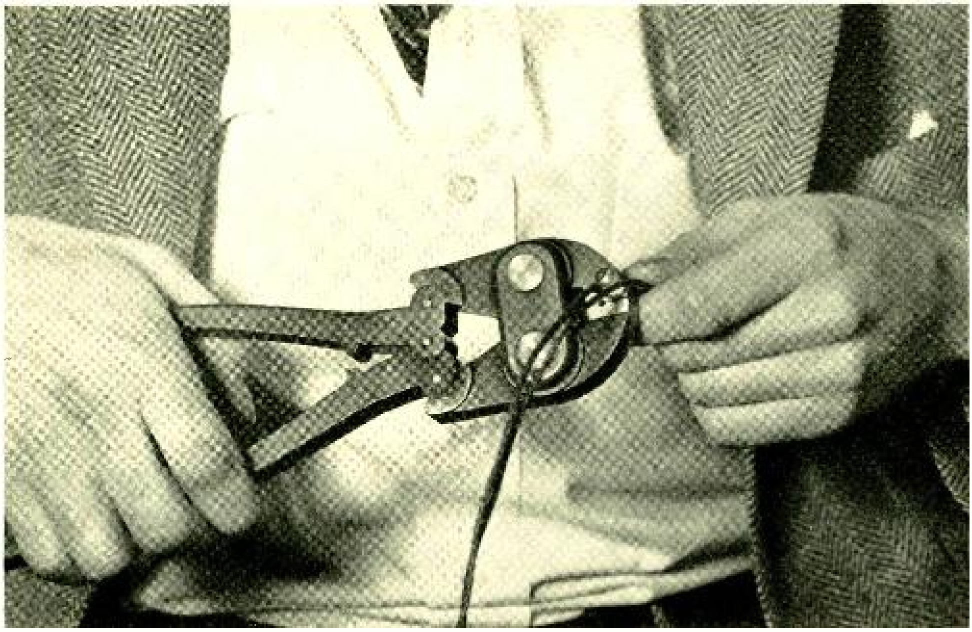
Chapel Hill's Lesson

Some four hundred papers were read before the American Chemical Society. Even the romanticist, Liebig, would have been astonished at their range. In his day it was still a feat to tear matter apart and discover its constitution or to show the relation of chemistry to agriculture or soap-making. But today? There is not a single branch of science that was not enriched by the chemists who assembled at Chapel Hill. The very depths of life were plumbed by men who described their achievements in extracting and synthesizing new hormones and vitamins.

University professors of chemistry and physics and doctors of philosophy who pursue their inquiries in the endowed laboratories of foundations would do well to examine the 400 papers read, not only with an eye to their content but to the affiliations of their authors. . . . We owe much to the universities for the researches that they have conducted in difficult branches of organic chemistry, but we owe as much to the laboratories maintained by the great drug houses, and, strange to narrate, to the Bell Telephone and the Kodak Laboratories.

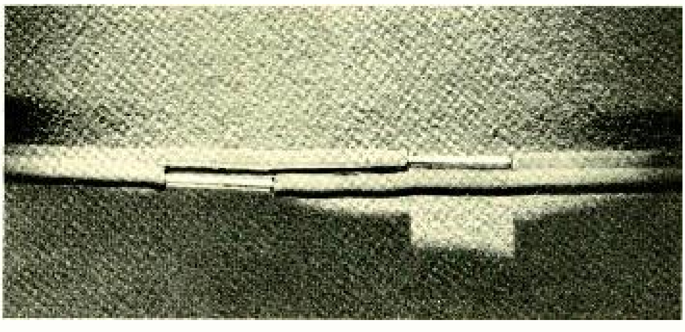
. . . Long ago the great industrial laboratories discovered that they must delve into fundamentals, that they must even explore fields neglected by the universities, if they are to serve industry adequately. . . .

—From an Editorial in The New York Times.



SLEEVE-PRESSING TOOL

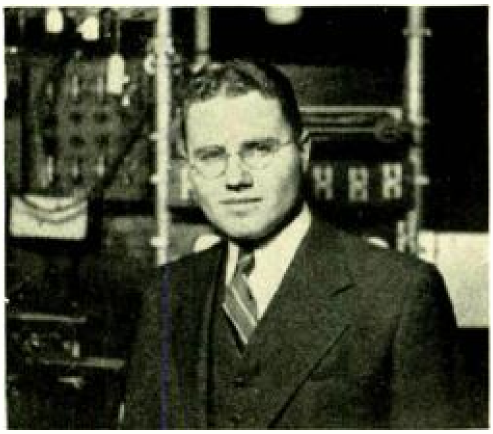
Joints are made in insulated wires with this new tool by slipping a sleeve over the ends of the conductors and pressing it firmly against them with the tool. These joints are stronger than those previously made with twisted sleeves and they are also air-tight which prevents corrosion and increase of resistance. Insulated wires for both station wiring and outside distribution can be joined with the tool



Contributors to this Issue

D. E. Truckséss received a B.S. degree from Pennsylvania State College in 1926, and joined the Technical Staff of the Laboratories in the same year. With the Systems Development Department he has been chiefly engaged in the development of power apparatus. Recently he has given particular attention to the development of regulated rectifiers.

N. C. Norman joined these Laboratories in 1925, immediately after receiving the A.B. degree in physics from Indiana University. Here he engaged in work on transmission research problems, and continued his studies at Columbia University, receiving the M.A. degree in 1928. He developed the compandor, which was described in the Record of December, 1934. Later, as a result of further studies, he suggested the employment of limited-range expansion on short-wave radio circuits, and developed the noise reducer described in this issue. He also developed the first devices for automatically adjusting net transmission loss, used on the Charlotte trial cable installation. He carried out the development of the compandor and noise reducer while with the Research Department, but at the present time is with the Special Products Development Department.



D. E. Truckséss

After receiving an A.B. degree from Westminster College in 1915, E. I. Green spent one year in graduate work at the University of Chicago. The following year he taught at Westminster College. He was commissioned an Infantry Officer in the United States Army in 1917 and served overseas, being discharged with the rank of Captain. He then studied for two years at the Harvard Engineering School, receiving the Degree of B.S. in Electrical Engineering. In 1921 he joined the Department of Development and Research, and came with that department into the Laboratories in 1934. He has been engaged principally in work on multiplex wire transmission systems.

N. C. Norman

J. A. Coy received the E.E. degree from Syracuse University in 1915 and, after one year as technical apprentice with the Westinghouse Electric and Manufacturing Company in East Pittsburgh, joined the Equipment branch of the Long Lines Department of the American Telephone and Telegraph Company. First in Buffalo

E. I. Green

and later in New York he received twelve years of wide equipment experience in the field. In 1928 he was transferred to the Systems Development Department of these Laboratories for the development of toll equipment.

H. PFANNENSTIEHL, after graduating from Lowell Institute in 1909, spent a short time with the B. F. Sturtevant Company and the Mergenthaler Linotype

J. A. Coy

Company and joined the Engineering Department of the Western Electric Company in 1911. He spent two years on the development of printing-telegraph apparatus, and in 1913 was transferred to the Bell Telephone Manufacturing Company in Antwerp, Belgium, for machine switching developments. In 1914 he returned to New York to engage in the development of apparatus for the printing telegraph, picture transmission, and sound pictures.

R. BURNS was occupied with the development of household appliances for

H. Pfannenstiehl

the first two years after he joined the Laboratories in 1919. Apparatus testing, especially on insulating materials, later occupied his time until 1928. Since then he has been in charge of a group concerned with the development of testing methods and the requirements for materials used in telephone apparatus.

R. Burns