BELL LABORATORIES RECORD

THE COMPANDOR
N. C. NORMAN

SOLAR CORONA BY TELEVISION
A. M. SKELLETT

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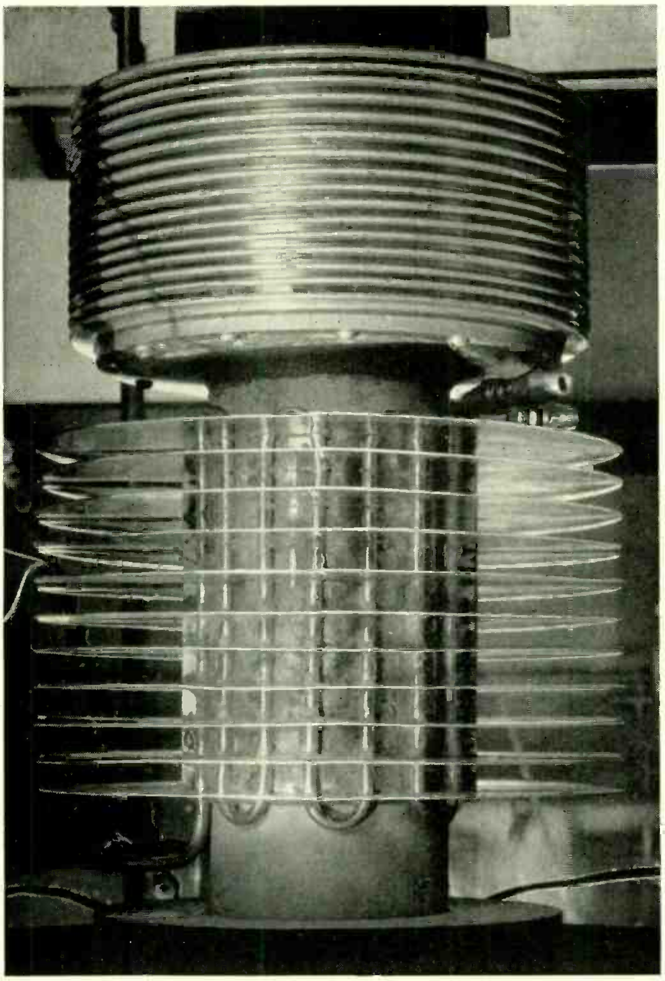
BELL LABORATORIES RECORD



Cooling unit of a heat-treating furnace used for experimental purposes

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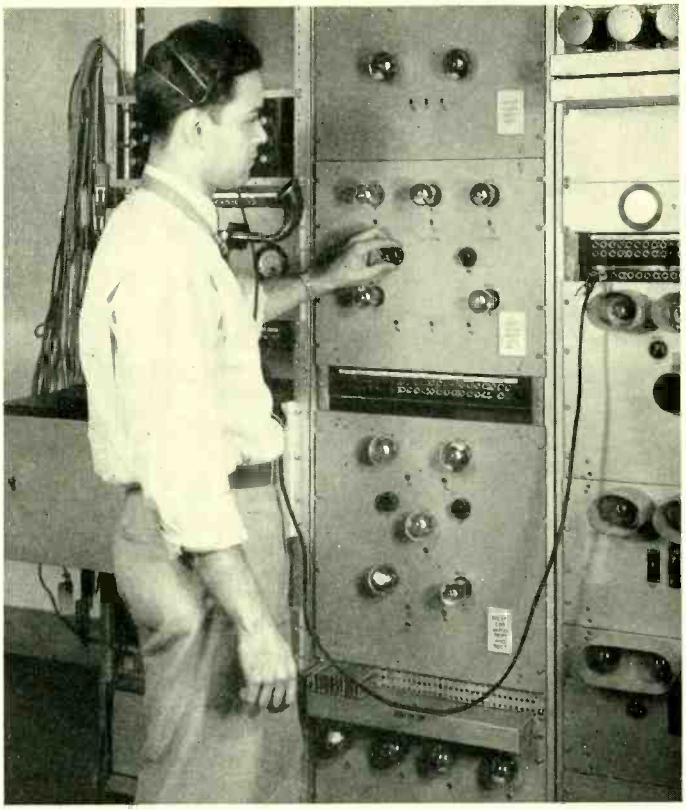
DECEMBER

1934



The Voice-Operated Compandor

By N. C. NORMAN
Transmission Research

TELEPHONE history records a steady extension of the distance over which it is possible to convey the spoken word with enough of its original character to make the speaker as well as the message readily recognizable by the listener. Such extension is beset with certain difficulties which are due as much to the varied characteristics of speech as to the limitations of the means of transmission available.

In long telephone circuits of all sorts, the input signal energy received from the subscribers varies over a wide range. The power ratio of the strongest to the weakest significant sounds often amounts to ten million to one or 70 db. This range may be considered to consist of two components. One, the volume range, of 40 db, is due to the differences in the speech powers of different talkers, in the ways they talk into the transmitter, and in such variable circuit characteristics as the lengths of terminal circuits and the properties of transmitters. If necessary these volume differences can be reduced to a considerable extent by manually operated gain controls.

Even when these differences have

been eliminated, however, there remain the other variations, of about 30 db, due to the natural differences in energy intrinsic to different speech sounds, modified by variation in emphasis, and variation in the efficiency of the transmitter with frequency and load. These variations are great enough so that, on such circuits as the transatlantic radio-telephone channels, there is danger that the intensity of the strong vowel sounds will overload the amplifiers when speech is transmitted at high enough volumes so that weak consonant sounds are above the noise level.

The telephone engineer is thus faced with the problem of providing transmission facilities which will carry not only a wide enough frequency range but which will also convey in unimpaired ratio both strong and weak speech sounds. The intensity range of a circuit may be expressed as the difference in decibels between that lower extreme at which speech sounds would be masked to an objectionable degree by noise or crosstalk and that upper extreme at which the circuit begins to introduce noticeable distortion due to overloading. Obviously, when the intensity range of a circuit is in the neighborhood of 30 db—the same range as that intrinsic to speech sounds—very careful regulation is needed to insure transmission without loss in speech intelligibility. When the intensity range of a circuit becomes less than this figure, as it often does on radio-telephone circuits, transmission degradation of some sort seems unavoidable.

Up to the present time, improvement in this situation has been along two lines. The intensity range of the circuit has been increased either by reducing noise or crosstalk, or by using amplifiers and other equipment which will carry more power without distortion. But there are circuits where further extension of the intensity range by either of these two methods would be very costly.

For such cases, a third method of improving transmission has been devised and is now in commercial operation over the long-wave radio-telephone channel between New York and London. This method consists of automatically compressing the intensity range of the speech before transmitting it, and expanding it to its original intensity range after it has traversed the transmission medium. One device which accomplishes this improvement in signal-to-noise ratio without overloading the circuit equipment is called the compandor. The name is a combination of "compressor" and "expandor," suggesting the functional operations of the two component parts of the apparatus.

The advantages to be gained by compressing and expanding the speech volume range can be seen from Figures 1 and 2. Figure 1 shows a one-directional speech transmission circuit consisting of a transmitter, a gain control, an amplifier, a long line or radio channel, another gain control, another amplifier, and a receiver. The gain controls are so linked together that when either one is set at maximum the other is at minimum. The range of gain of the gain control and associated amplifier at the transmitter is from 15 db to zero, and at the receiver from minus 15 db to zero. Thus the equivalent of the circuit is zero at all settings of the gain controls. The overload point of amplifier A is arbitrarily taken as a reference point and the noise level on the channel is assumed to be 25 db below this point.

Now suppose speech currents varying in intensity between 0 db and minus 30 db are coming from the transmitter. If the gain controls are set in position 1 the speech will be amplified 15 db, and the weak sounds will enter the noisy circuit at minus 15 db intensity, 10 db above the noise level. But the strong sounds of speech will be 15 db above the overload point of amplifier A, and consequently will be distorted. Intensity ranges assumed to illustrate this condition are shown graphically in Figure 2-A.

If the gain controls are set in position 2, shown by the dotted lines, the speech will encounter no gain, and amplifier A will just transmit the strong speech currents without overloading, but the weak speech currents will be 5 db below the noise level as heard at the receiver. Transmission under this condition is shown in Figure 2-B.

But if the setting of the gain control is varied continuously between position 1 for weakest speech currents and position 2 for strongest speech currents, and proportionally between these positions for intermediate currents, no overloading will occur, and the received speech will be at least 10 db above the noise level at all values of signal intensity. Transmission conditions on the noisy circuit with such a system of operation are shown in Figure 2-C. As the gain controls operate slowly and simultaneously in opposite senses, there is no effect on speech quality or intensity variations as heard in the receiver.

The operation of the gain control at the receiving end of the noisy circuit causes the noise at the receiver to vary between minus 25 db and minus 40 db. The received noise will have the higher value only when the speech currents are strongest, and will be masked by the speech. When speech currents of minus 30 db intensity are transmitted, the noise at the receiver will be minus 40 db. In effect, the speech intensity range at the input of amplifier A has been compressed from 30 db to 15 db and then expanded at the input of amplifier B from 15 db back to 30 db. Amplifier A and its associated gain control form a compressor, and amplifier B and its gain control an expandor.

The compandor now in use compresses and expands the speech-intensity range automatically without the use of a mechanical link or an auxiliary pilot channel between the sending and receiving ends of a circuit. Distortion in the transmission circuit is minimized by making the compression and expansion nearly linear when measured in db. Other considerations made it desirable that the compressor halve the volume variation in db and the expandor double it. As an insurance against loss of speech quality due to distortion, caused by the limited frequency range of the circuit between the compressor and expandor, it was necessary to make the corresponding gain changes follow the envelope of the speech wave, rather than the instantaneous current values.

Simplified schematics of the compressor and the expandor are shown

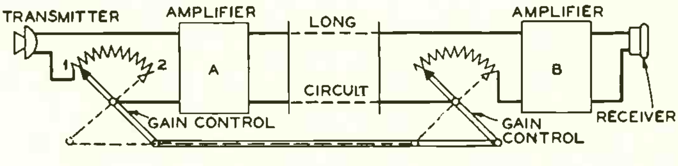


Fig. 1—The compandor is not unlike a pair of gain controls, one at each end of a circuit, so connected that when one is at maximum the other is at minimum and vice versa

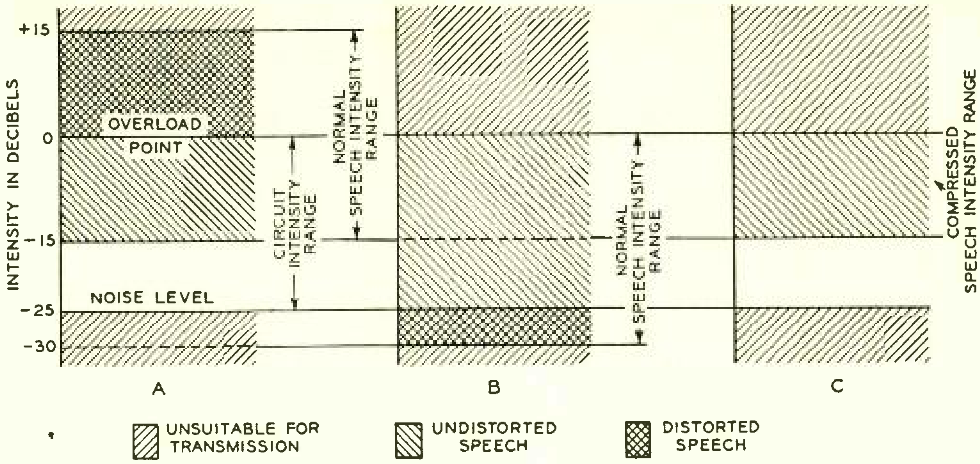


Fig. 2—If the controls of Figure 1 are permanently set in position 1, the strong speech sounds would overload the amplifiers (A); if set in position 2, the weak sounds would be masked by noise (B); but if varied from 1 for the weakest sounds to 2 for the strongest, transmission will be neither distorted nor masked (C)

in Figures 3 and 4. Each consists of a voice channel, and a branch circuit which controls the gain or loss in voice channel.

The voice channel of the compressor contains a "vario-losser," an amplifier, and a high-pass filter. The vario-losser is made up of a pair of three-electrode vacuum tubes with their plate circuits bridged across a section of the voice channel which has an impedance high compared to the impedances of the tubes. The voice-channel gain is dependent on the voltage applied by the branch circuit to the grids of the vario-losser tubes, which are biased normally to operate near their cut-off point.

The branch circuit of the compressor contains an amplifier, a linear rectifier, and a low pass filter. It picks off part of the output of the voice channel, rectifies the speech voltage linearly, filters out the speech-frequency components of the rectified voltage, and applies the resulting envelope voltage to the grids of the vario-losser tubes. When the input voltage to the compressor increases, the grid biasing voltage applied by the branch circuit also increases and thus tends to cause a decrease in the gain of the voice channel. Proper adjustment of the gain of the branch circuit amplifier insures that this decrease will be so related to the increase in input voltage that the output intensity range of the compressor will be only half the input intensity range. The cut-off point of the low-pass filter in the branch circuit is made lower than that of the high-pass filter in the voice channel in order to prevent regeneration.

The voice channel of the expandor (Figure 4) contains a "vario-repeater" and an amplifier. The vario-repeater is a push-pull amplifier so connected that the plate circuits of the tubes are effectively in series with a transformer whose input impedance is low compared to the impedance of the tubes. The tubes are biased to a point near the cut-off, so that when no voltage from the branch circuit is applied to their grids, they afford so

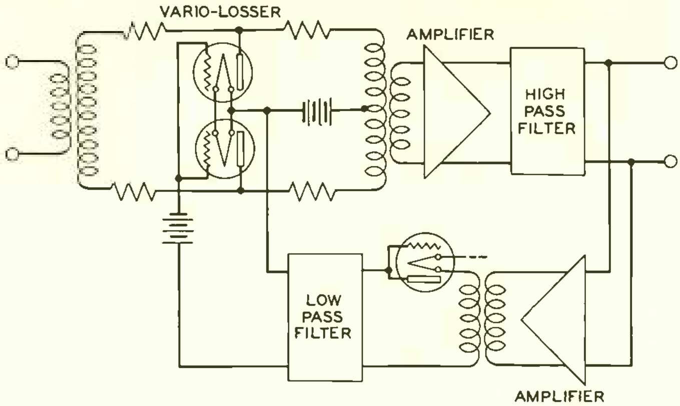


Fig. 3—In the compressor the intensity of the voice current in a branch channel controls the gain in the main voice channel

little gain that the loss through the vario-repeater is high, just offsetting the initial gain in the compressor. When a positive potential is added by the branch circuit to the initial negative bias, the series plate impedance of the tubes decreases, and the loss decreases in the same manner that the gain decreases in the compressor. Both the incoming speech and the branch circuit output are applied to the grid circuits of the vario-repeater tubes. But the negative magnitudes of the voltages applied to the grids from these two sources are such that only the branch circuit output can cause any appreciable variation in vario-repeater gain. This condition is obtained by using a step-down transformer at the input of the vario-repeater and a step-up transformer at the input of the branch circuit.

The branch circuit of the expandor performs the function of picking off a portion of the speech current at the input, and applying the demodulated and filtered speech-voltage fluctuations to the grid circuit of the vario-repeater. The variation in gain of the vario-repeater expressed in db equals the variation in input to the expandor for expansion which will offset the compression previously accomplished. The circuit contains an amplifier, a linear rectifier and a low pass filter. It applies an opposing grid bias to the vario-repeater, which is high when the speech current received is strong, and proportionally lower when the current is weak, thereby causing a higher gain in the vario-repeater for strong speech sounds than for weak ones. Thus the expandor undoes what has been done by the compressor.

Commercial operation of the compandor on the long-wave radio circuit to London has yielded encouraging results. Soon after the compandor was placed in operation, it was found

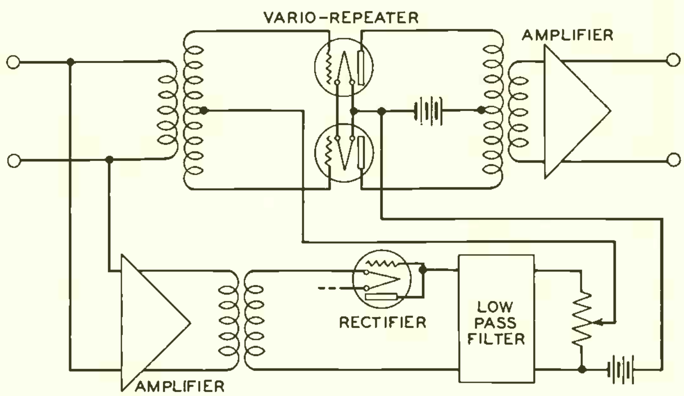
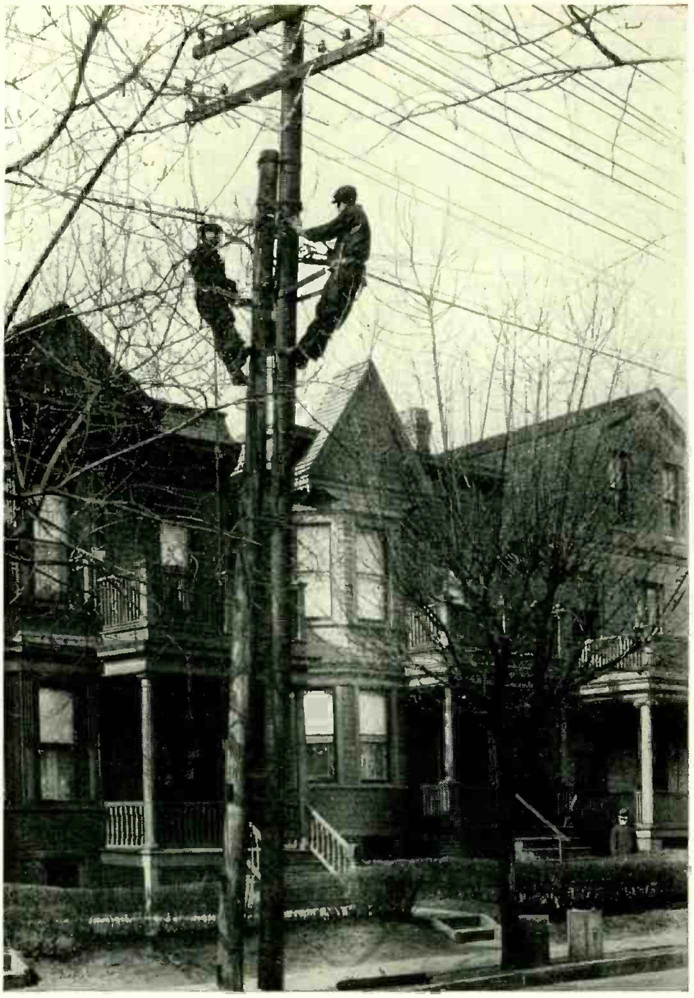


Fig. 4—The expandor, at the receiving end of the circuit, consists like the compressor of a main voice channel controlled by a branch channel

that under most conditions satisfactory service could be given with static 5 db stronger than the old commercial limit. Because of the improvement in signal-to-noise ratio due to the compandor, it is usually possible to deliver at least 5 db more volume to the subscriber without failure of the voice-operated switching devices at the terminals, a factor of great importance when long extension circuits are involved. Another important advantage gained is the reduction of the usual background noise at noise levels somewhat below the old commercial limit, which markedly increases the ease of conducting conversations under such conditions on the long-wave transatlantic radio channel. This improvement, while difficult to evaluate quantitatively, is probably equivalent under these conditions to increasing the power of the radio transmitter considerably more than would suffice to raise the commercial noise limit by 5 db.

BEFORE A SHORT WAVE ANTENNA GOES ALOFT

Among the bushes of a Cape Cod hilltop sixteen copper rods, each a half wavelength, were mounted at one end of a hundred-foot pole. Raised into position, they radiated energy toward Green Harbor.



The Lineman's Leather Lifeline

By D. T. SHARPE
Outside Plant Development

AS comfortable as a pair of old shoes, as handy as a shirt pocket, and absolutely safe. Anything less in a body belt or safety strap will meet the disapproval of a telephone lineman, for he uses the combination as a lifeline, a tool carrier, and a sort of chair. While working on a telephone pole the lineman wants safety, convenience and comfort. The less he is conscious of these needs the better has been the development engineer's success in giving them to him.

Such a tool presents a development problem requiring patience and perseverance, for the judgment of these qualities has something of a personal slant to it. The jury which finally decides on the excellence of body belt and safety strap design is a fair and practical one; but like most juries it often disagrees. It is scattered all over the country and court is held under many a different telephone pole, and in many a locker room where installers, repairmen, combination men, and others who use these tools foregather.

In handing down its decisions this jury has been very helpful to the engineers in developing the present combination of body belt and safety strap used in the Bell System. Men with specialized vocations usually acquire more than a mere workaday interest in the equipment peculiar to their specialty, and with telephone linemen this trait seems to result in a keen interest in belt and strap design.

The present safety strap is a length of leather two inches wide, of which one end is fastened to a snap hook and the other is looped through a snap hook stirrup and terminated by a pronged buckle for adjustability. The body belt consists of a piece of leather three inches wide, with dee rings secured to each end. A longer and narrower strap is riveted to the belt proper, forming a series of raised loops in which to carry tools. This strap also serves to fasten the belt around the hips. The safety strap encircles the pole and its snap hooks engage the dee rings of the body belt.

Safety is built into belts and straps by the proper choice of materials and by fastening these materials together in such a way that the best use is made of their tensile strength. No other material has been found as satisfactory as leather in fabricating body belts and safety straps for the use of Bell System employees who work aloft on poles. It is strong and durable, and its flexibility is coupled with a certain firmness. Substitutes for leather have been proposed and a number of them have appeared promising, but most have lacked some quality, generally flexibility, necessary to a good belt and strap material.

Leather, however, is a product of nature and varies widely in quality as it comes from the tanner. It is a by-product of the meat-packing industry, and at least up to the time it reaches the tanner no real control is exercised over its quality. As a consequence, many hides reach the tanner with physical characteristics which prevent them from being processed into the kind of leather considered desirable for belts and straps. Even a tanned hide of the best quality varies in different portions through a rather wide range, and after hides containing leather free from defects have been selected, belt and strap leather can be taken only from certain portions of them.

The quality of the leather which the manufacturer selects for fabrication depends greatly on the judgment and experience of his cutters. It is important that they reject all inferior leather. As a check on the cutters' skill these Laboratories have established chemical requirements limiting the content of epsom salts, glucose, free acid, ash, and total water-soluble materials, with which the physical character of leather has been correlated. A tensile-strength requirement complements the chemical requirements, and all leather is required to be free from visible defects such as brands, soft or spongy spots, grub holes, barbed wire scratches, and the like.

The leather used in body belts and safety straps is vegetable-tanned harness leather made from the back sections of green-salted "packer" hides. Leather tanned by the vegetable process, with substances leached from bark, wood, and the like, has been found by experience to produce a leather more suitable for this purpose than some of the faster, more modern methods, and the back section of the hide is used because it produces a firm, dense, and strong leather. Green-salted hides are preferred to dried hides because hides may partially decompose while drying, developing weaknesses which no amount of skill in tanning can overcome. Salting the hide soon after it is removed from the animal removes this danger. Packer

hides are those secured from the large packing plants, whose curing, grading, skinning, and handling practices are more standardized and generally more efficient than those of the small meat producer or the farmer.

The snap hooks of the safety strap and the dee rings of the body belt are drop forgings made from mild steel. Their generous size makes them strong and rugged, and several shock and bending tests are applied during inspection to insure their ductility and freedom from brittleness. To reduce the tearing stresses at the buckle holes of the strap, the buckle is provided with two prongs, which work in unison so as to make adjustment simple. The holes are so located that no section containing them will come in contact with the snap hook roller regardless of which set of holes is occupied by the prongs. The snap hooks are of the duck-billed type, offering less chance of malfunction and accidental disengagement than any other simple type of hook.

The snap hooks and dee rings, and the metal clips reenforcing the part of the belt looped back to secure the dee rings, form several long electrical paths leading to exposed rivet heads on the inside of the belt. To reduce the possibility of a lineman's receiving a slight electrical shock which might cause him to lose his balance, these rivets are insulated from the metal

clips by fiber bushings. The heads of the rivets are made flush with the inside surface of the belt so that they will not chafe the wearer.

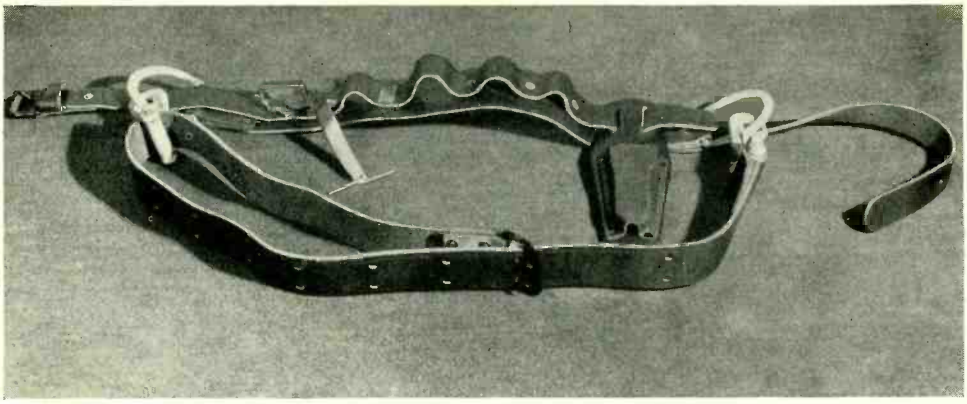
In making the top strap continuous, so that it encircles the entire belt, the valuable psychological effect of such a design was one of the features considered. Completely embracing the body and passing through the dee rings, the top strap contributes an appearance of greater safety which helps to make the lineman more confident in the belt than he might otherwise be.

Linemen sometimes do not realize that a damaged belt or strap was originally sound, for the damage is often inflicted unconsciously or through failure to appreciate what constitutes abuse of leather. Heat is one such abuse; standing near a fire, or placing a wet belt near a hot radiator to dry it, will quickly destroy the leather.

A lineman may not be able to detect inferior material in his body belt or safety strap, but if the design does not permit of maximum efficiency and comfort, he knows it and wants the condition corrected. The Bell System organization is such that these views and opinions are promptly transmitted to the designing engineer, who thus has the benefit of field experience in developing improvements. Stiffness, and improper fitting to the wearer, sometimes made the older designs of belts uncomfortable. The present method of securing the dee rings, by looping back the ends of the belt over the dee ring bars and riveting them, and better methods of attaching the tool carrying facilities, have been found to improve the flexibility considerably. Previously belts were given size designations corresponding to a waist measurement, but because the

belts are worn around the hips in a low position and the position of the dee rings on the wearer's body affects the comfort markedly, the size designation now corresponds to the distance between rings. When ordering a new belt a lineman knowing where he likes the rings to come on his body can order a belt having the preferred separation.

The lineman of course likes to be able to draw his pliers and other hand tools from his belt with maximum convenience, but in the design of the belt this ease of removal of the hand tools must not be secured at the expense of safety, since insecurely held tools are a hazard to anyone standing below. In addition to the loops formed by the top strap, the tool carrying facilities include a plier pocket somewhat resembling a revolver holster, a metal loop for a lineman's wrench, and a tape holder. The plier pocket may be removed if desired and something else used in its place. Since the belt is reversible, the



The lineman's body belt and safety strap are fabricated from firm, dense and strong leather. The two are attached to each other by snap hooks on the strap and dee rings on the belt, which are drop forgings of mild steel, generous in size

pocket can be worn on either side.

Normally the Bell System consumes about 7500 body belts and 10,000 safety straps per year. Although the amount of leather required for these belts and straps is not large compared to this country's total leather production, it does represent a substantial percentage of the high-grade leather considered suitable for this purpose.

Cumulative Index for the RECORD

A cumulative index grouped by authors and by subjects is now available for BELL LABORATORIES RECORD *covering the issues from September, 1929, to August, 1934, inclusive (Volumes VIII-XII). Copies may be secured from the Bureau of Publication.*

Spot Welding

By LAWRENCE FERGUSON
Chemical Research

THE application of spot welding to the diversified product of the Bell System has required considerable research and development. To weld two pieces of iron together is quite simple with ordinary precautions, but it has been found very difficult to produce satisfactory welds between some of the diverse metals used in telephone apparatus. Each combination of metals may require different welding conditions, and to determine the optimum treatment has necessitated extensive study. During the course of some of these studies the welding peculiarities of 250 different combinations of metals have been examined. Which of these can and which cannot be welded at the present time are shown in Figure 1.

● GOOD WELD
• COMPLETELY MISCIBLE, BUT BRITTLE WELD
⊕ POOR WELD
○ NO WELD
BLANK SPACE — COMBINATION NOT TRIED

	IRON	STAINLESS IRON	ALLEGHENY METAL	COBALT STEEL	NICKEL	NICHROME	MONEL METAL	NICKEL SILVER	BRASS	BRONZE	MANGANIN	EVERDUR	COPPER	ALUMINUM	MAGNESIUM	MOLYBDENUM	LEAD	TIN	CADMIUM	ZINC	GALVANIZED IRON*	TIN PLATE*	CHROMIUM PLATED STEEL*	NICKEL PLATED BRASS*
IRON	●																							
STAINLESS IRON	●	●																						
ALLEGHENY METAL	●	●	●																					
COBALT STEEL	●	●	●	●																				
NICKEL	●	●	●	●	●																			
NICHROME	●	●	●	●	●	●																		
MONEL METAL	●	●	●	●	●	●	●																	
NICKEL SILVER	●	●	●	●	●	●	●	●																
BRASS	●	●	●	●	●	●	●	●	●															
BRONZE	●	●	●	●	●	●	●	●	●	●														
MANGANIN	●	●	●	●	●	●	●	●	●	●	●													
EVERDUR	●	●	●	●	●	●	●	●	●	●	●	●												
COPPER	●	●	●	●	●	●	●	●	●	●	●	●	●											
ALUMINUM	●	●	●	⊕	○	•	⊕	⊕	•	⊕	•	•	•	●										
MAGNESIUM										⊕				●	●									
MOLYBDENUM	●	●	●	●	●	●	●	●	○	○	●		○	⊕		●								
LEAD							⊕	●	○	○	●	●					●							
TIN	○	○			⊕	○	●	●	●	●	●	●	●	○			●	●						
CADMIUM	●				⊕	○	●	●	●	●	●	●	●	○			●	●	●					
ZINC	⊕				⊕	⊕	•	•	•	•	•	•	•	●			⊕	⊕	⊕	•				
*GALVANIZED IRON	●	●	●	●	●	●	●	●	●	●	●	●	●	⊕			⊕	●	●	⊕	●			
*TIN PLATE	●	●	●	●	●	●	●	●	●	●	●	●	●	●			●	●	●	⊕	●	●		
*CHROMIUM PLATED STEEL	●	●	●	●	●	●	●	●	⊕	⊕	●		●	○							●	●	●	
*NICKEL PLATED BRASS	●	●	●	●	●	●	●	●	●	●	●	●	●	⊕		●	○	●	●	⊕	●	●	⊕	●

* IN THE COURSE OF SPOT WELDING COATED MATERIALS, THE COATINGS FREQUENTLY DISSOLVE IN THE OTHER METALS PRESENT OR BURN AWAY

Fig. 1—The welding characteristics of some 250 combinations of metals have been studied in the Laboratories

The usual method of making a spot weld is indicated by Figure 2. A large localized current is passed through the parts to be welded between two electrodes. Under the influence of this

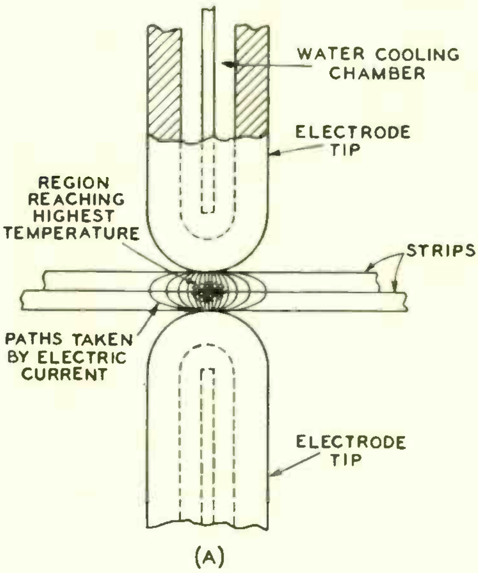


Fig. 2—In a spot weld the heating is localized over a very small area

current, the metal pieces heat up rapidly in a small region between the electrode tips. At the right moment, the pressure applied completes the weld. Welding machines, largely automatic in their operation, have been developed, which regulate and control such variables as pressure, duration and strength of current, and the sequence of pressure and current flow. Apart from these variables controlled by the welding machine, however, there are other factors such as size, shape, and composition of the pieces to be welded, contact resistance, and distribution of current. The nature and strength of the weld obtained depend not only on how well these variables are adjusted to each other, but also on the strength of the materials after the heat treatment caused by the welding process, the degree of alloying of the materials welded, the strength of the alloy formed by welding, the cleanness of the pieces, and the size of the weld.

The first essential for making good spot welds is to work only with clean metal parts. The best technique is practically useless against grease, dirt, or scale. The higher and uneven contact resistance between unclean parts greatly increases the likelihood of having the bulk of the welding current surge through whatever small area happens to weld first. Scale and dirt also mix in the weld material, making it brittle and porous.

Another essential detail is the choice of an electrode tip material that will not alloy with, or adhere to, the pieces being welded, and that will aid in keeping the outside surface of the welded pieces as cool as possible. Large scale commercial use also frequently requires a material that does not soften or lose its shape during continuous operation. In normal practice, for welding high resistance materials such as iron, nickel, nichrome, and nickel-silver, electrode tips of copper are suitable. Where greater

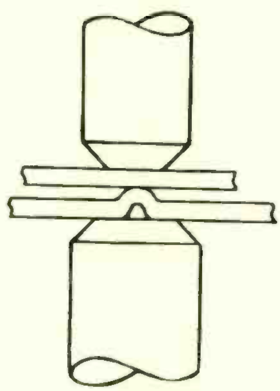
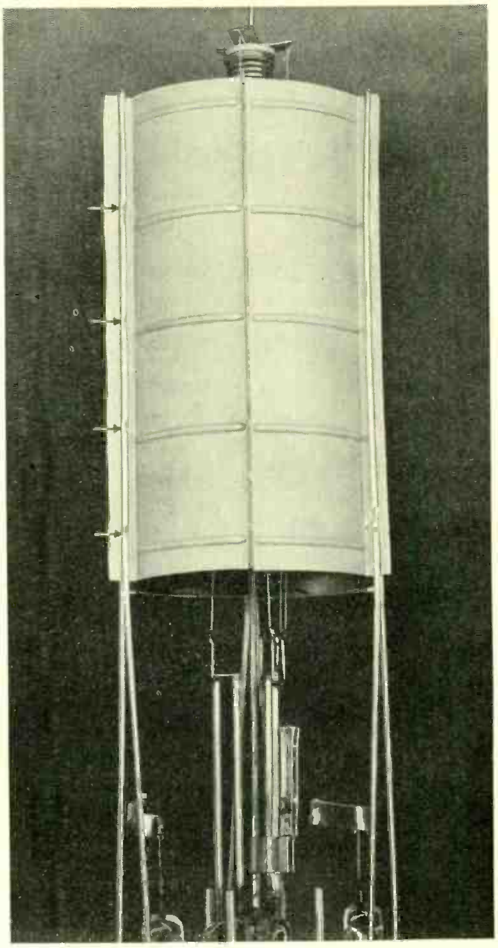


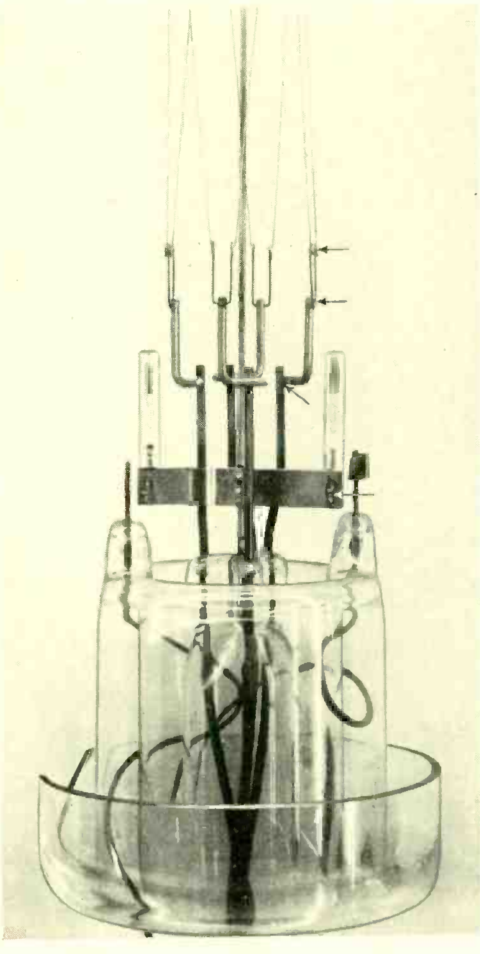
Fig. 3—In a projection weld the area of heating is further localized by a small projection formed in one of the parts before the weld is made

strength or longer life is required, however, a copper rich copper-tungsten alloy is advisable. For welds between low resistance materials such as copper or aluminum, so high a welding current must be used that the electrode tips themselves become very hot. Under this condition, tungsten tips are best because they do not easily alloy or weld at ordinary welding temperatures.

Two strips of metal of radically different thickness present a problem in spot welding which is solved by the control of current distribution af-



The supporting wires of the cylindrical plates of certain types of vacuum tubes are run the full length of the plate, and the sections of the plate are welded by the same operation that welds the supports to them



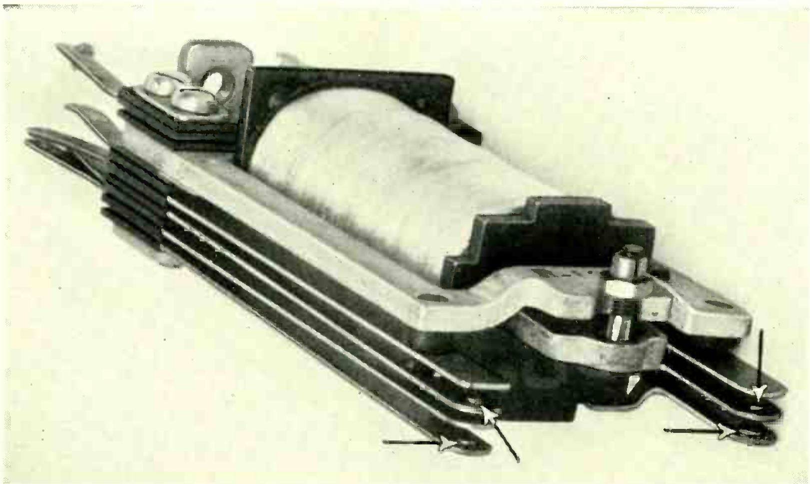
Spot welding is widely used to weld filaments and supporting wires in vacuum tubes

forded by the size of electrode tips used. Since current density is greater near a smaller tip, and cooling by conduction is less, a small electrode tip is used against the thin piece to be welded and a large one is placed against the thick piece. This same control of current density and cooling by conduction may be used also for welding a material of high electrical resistance to one of low resistance or for welding a low melting point material to one having a high melting point. The small electrode tip is here placed against the low resistance or the high melting point material. For these latter problems, however, there is another solution, called projection welding, which may be more satisfactory.

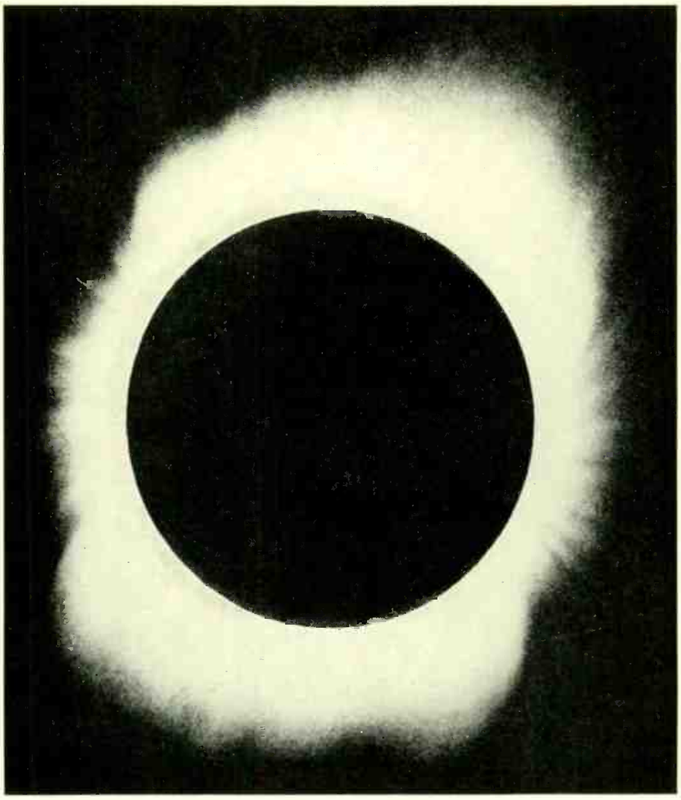
Projection welding receives its name from the small bump or projection raised between the pieces to be welded, as shown in Figure 3. This projection drastically reduces the area of contact between the metal parts and causes a correspondingly great increase in current density and heating power at the exact spot where it is most desired. Moreover, when the projection softens and welding occurs, the electrode pressure, by flattening the projection, enlarges the contact area and thus reduces the current density and prevents overheating.

One disadvantage of any form of welding is the possible harmful effect of the intense local heating necessary. Although in spot welds this effect is greatly reduced, it cannot be entirely eliminated. Thus zinc is recrystallized and made brittle, iron may be slightly oxidized, zinc may be partly distilled out of brass, and duralumin and tool steels may be given an undesirable heat treatment. The area of local heating and undesired effects can be reduced considerably, without reducing the actual size of the spot weld, by using a high welding current for an extremely short time and by making welds under the surface of a cooling and protecting liquid such as water.

Within the telephone industry spot welding has been of increasing importance. Among the many uses which have resulted in considerable economies are the formation of vacuum tube assemblies, the fastening of precious metal contacts to relay springs, and the manufacture of sheet metal cases for various purposes. Some of the various uses are shown in the accompanying photographs.



An extensive application of spot welding is to fasten the precious metal contacts to the springs of relays



Observing the Corona

By A. M. SKELLETT
Radio Research

ONE of the most alluring problems of solar research has been that of observing the details of the corona without an eclipse. During the past fifty years, various able investigators have attacked it with great care and skill but without success. M. Bernard Lyot, the latest to make the attempt, was able to see the prominences* for the first time without spectroscopic aid. The prominences are, however, considerably brighter than the corona. Apparently the goal is just beyond the reach of ordinary optical methods.

The problem is not one of academic interest only. As long as thirty years ago, E. W. Maunder identified the streamers of the corona with the hypothetical streams of particles emanating from the sun which are commonly believed to be the cause of magnetic storms, disturbances in telegraphic and radio transmission and like phenomena on earth. Whether that identification is correct can only be determined by a more complete knowledge of the coronal streamers. It is known that the primary cause of

*Surrounding the sun's most brightly luminous region, the "photosphere," is the "chromosphere," a ruddily luminous region of incandescent gases from which flame-like protuberances called "prominences" extend outward. Outside of the chromosphere is the still fainter "corona."

magnetic storms must be of solar origin, but, short of maintaining a continuous watch of the sun spectroscopically, the possibility of finding the causes of all individual disturbances with present equipment does not seem promising. Perhaps the solar phenomena which have been observed in the past are not as directly associated with terrestrial disturbances as others which might be discovered if the corona could be observed at any time. Such observations might provide the "missing link" between solar activity and terrestrial disturbances.

The difficulty is to separate the image of the corona from the diffuse glare which masks it. This glare is due to the scattering of sunlight in the earth's atmosphere and in the telescope, and under ordinary conditions it may be a thousand times as bright as the corona. This ratio may be reduced (to as little as ten to one) by the proper selection of the observing site—for example, the top of a high mountain—and by the skillful design of the telescope. Exhaustive trial of these means, however, has made it apparent that a method of greater discrimination is needed.

If the coronal image and the glare had identical characteristics, it is obvious that no means could be devised to separate them after the composite image of both had once been formed. Fortunately, however, this is not so. The coronal image is complex, being made up of streamers, arches and other features distributed around the sun, whereas the glare image is simple, with only a slight radial variation decreasing outwardly from the edge of the sun's disc. If it were possible to devise a method to take advantage of this inherent difference in the two images, it should be possible to separate them.

There are reasons for believing that television may furnish such a method. In present television technique, an image is converted from an optical state into an electrical one, and then back into the optical state. While it is in the electrical state it can be altered by electrical means to produce results in the final optical state not attainable by optical means alone. Here, then, is a new tool for making changes in an optical image.

If the image of the sky around the sun's disc were scanned spirally out from the solar disc and thus converted into the electrical state, the resultant photoelectric current would be made up of several parts. There would be a large direct current due to the masking glare, a smaller low frequency component due to the variation of brightness of the glare as the scanning spot moves out from the sun, and a spectrum of high frequency components of relatively low intensity, caused by the passage of the spot over the hoods, arches and streamers of the coronal image. By passing this composite current through appropriate electrical filters, the high frequency components due to the corona could be separated from the low frequency and direct current components due to the glare. The coronal components could then be amplified and reconverted into an optical image. Thus the glare would be eliminated and the new image would show the corona on a black background. If bright stars were present in the field, they would also appear in the final image, since their light would give rise to high frequency components in the photoelectric current. It should be possible, therefore, to reproduce the major features of a solar eclipse whenever the sky is clear, provided that spurious patterns can be avoided.

Fortunately little time and effort were required to make a laboratory trial of the method. The apparatus used in the Laboratories' past television demonstrations lay to hand, and with the cooperation of Dr. Ives and the electro-optical group a test was conducted with equipment employing a seventy-two hole scanning disc. A lantern slide of a coronal photograph taken at the eclipse of 1908 furnished the coronal image. The illumination used was just sufficient to give such a brightness of image as would be obtained from the corona with a telescope of moderate size. The field scanned was a rectangle, approximately one and a half degrees square (the solar diameter is ½ degree as seen from the earth), and the size of the scanning holes corresponded to about one minute square. Under these conditions excellent images of the moon's disc and of the corona were obtained at the receiving apparatus.

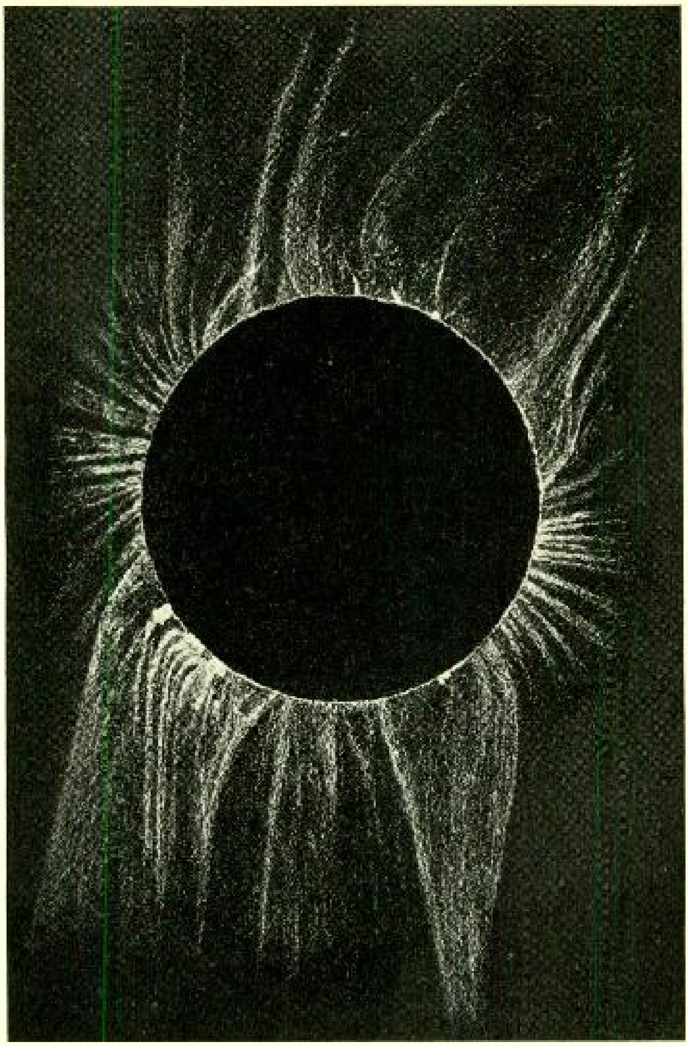


Fig. 1—From the negative of the photograph shown in the headpiece, and other similar negatives taken at the same time, H. R. Morgan drew this picture of the inner part of the solar corona

In order to introduce the glare, the photoelectric cell was directly flooded with light, behind the scanning disc, so that a very great ratio of steady to intermittent photoelectric signal was obtained. The flooding light was increased until the electrical "noise," which at high levels causes a scintillating speckled appearance, became great enough to spoil the discrimination of the coronal features. In these experiments, the flooding light could be increased to about 10,000 times the normal television level before discrimination was seriously impaired. The brightness of the halo surrounding the sun's image which is produced by a clean telescope objective of the simple lens type is less than a thousand times the brightness of the corona on a clear day. Apparently the method is adequate for producing the required discrimination with only the simplest precautions.

It must be recognized, however, that the conditions of the laboratory trial were somewhat more favorable than those which would be encountered in an actual test in an observatory. There the glare would also be scanned, and any irregularities of field intensity introduced by the image-forming and scanning devices would cause variations in the direct current produced by the glare. Even though such irregularities were quite minute, they would generate signals whose relative intensity would be large because of the high level of the general glare, and which could easily swamp the coronal image. Apparatus meeting the requirements however, appears to be entirely possible of construction.

Another disturbing element and possible cause of irregularities which would be encountered in an actual test would be "poor seeing." Temperature variations in the air and other atmospheric vagaries, constitute ever-present sources of difficulty for all classes of astronomical observation, and should their effects be greater than anticipated the remedy is at hand in the reduction of glare by means already mentioned. Indeed the glare may be reduced by optical means until its brightness is only about ten times that of the corona. Moreover, since poor seeing is a constantly varying phenomenon, irregularities due to it would not be confused with the stationary corona.

A drawing of the corona, made from negatives obtained at the eclipse of May 28, 1900, is shown in Figure 1. The negatives show all of the details of this drawing but do not give as good contrast. Since the proposed method would essentially operate by enhancing the contrast, it seems possible that even better images of the corona may be obtained by its means than are afforded by photography at the time of an eclipse. Another advantage which this method might have over photography lies in the possibility of reproducing in one image both the inner and the outer regions, which differ so greatly in intrinsic brightness that photography requires separate exposures. This leveling action might be realized by scanning spirally outward from the edge of the image of the sun itself, and applying to the resulting signal the method used for automatic volume control on radio receivers.

Since the brightness of the corona decreases greatly with its distance from the sun, the light collecting power of the telescope, and thus its size will limit the extent of the outer corona that may be observed. As seen through small telescopes of only a few inches aperture, the brightness of the outer corona is not great enough to give usable currents with the photoelectric cells now available. Telescopes of the sizes ordinarily found in observatories seem adequate, however, to give workable currents from the corona out to distances approaching the radius of the sun. By increasing the size of the scanning hole, details at greater distances might be observed, such as the enormous streamers which sometimes extend for millions of miles.

The Holmdel Laboratory

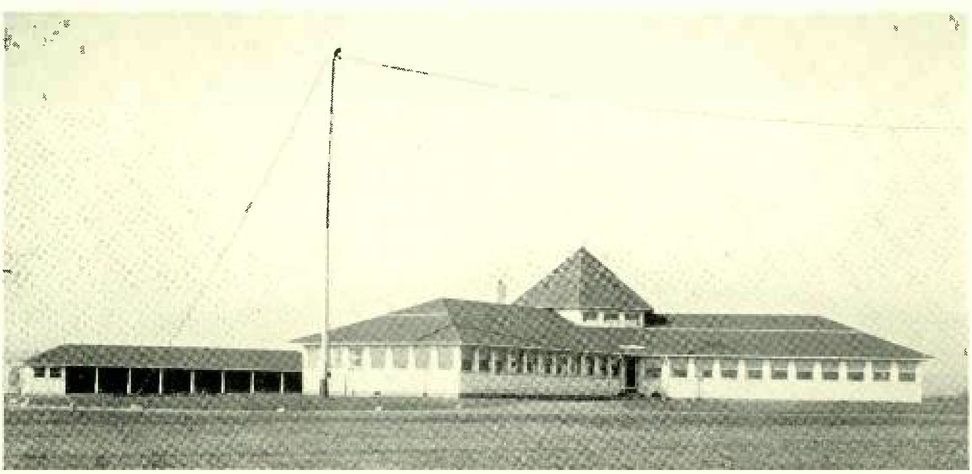
By H. T. FRIIS
Radio Research Engineer

WITHIN the last few years, short-wave communication has been rapidly assuming a very important rôle in the radio telephone field. Commercial installations of the Bell System began with the short-wave channels to England in 1928, and the following two years conclusively proved the value of these additions to the radio family. The last four years have seen commercial installations* to South America, Bermuda, the Caribbean countries, the Hawaiian Islands, Java, and the Philippines. In addition to these land links, short-wave telephone communication has also been provided to ships at sea; to harbor craft and the nearby fishing fleets; for the Cost Guard, for police patrol cars, and for aeroplanes. These commercial installations were preceded by years of study of short-wave transmission — studies which have been continued unremittingly ever since, and which have led to many improvements and extensions of the service.

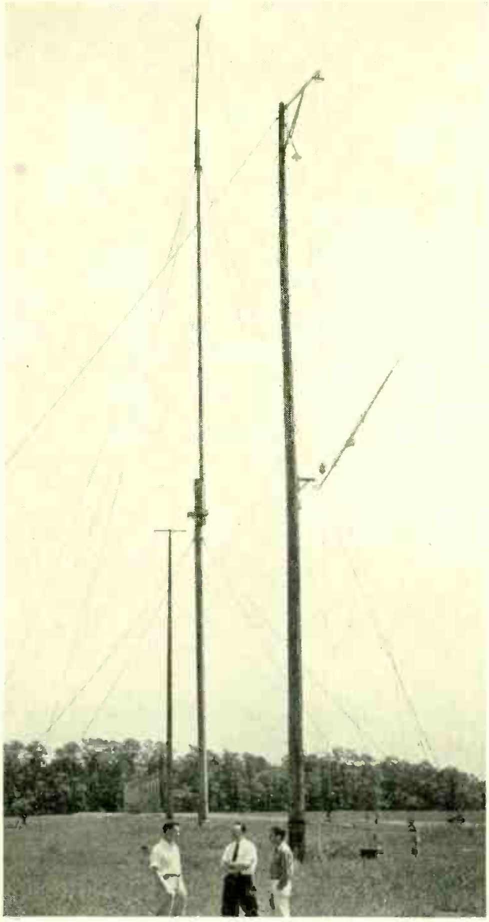
Some of the research work on short-wave transmission can be carried on at the laboratories in New York City, but for much of it outlying sites are needed where antennas may be erected free from local disturbances. For some years the Laboratories have been operating two such research outposts for short-wave studies: one at Deal Beach, N. J., carries on studies of short-wave transmitters, and one at Holmdel, N. J., investigates short-wave receivers and short-wave reception phenomena.

Short-wave studies had been car-

*References to RECORD articles on these installations are given at the foot of this article.



The main laboratory building



Several antenna supporting structures. Horizontal dipole suspended in foreground. Left to right: E. Bruce, A. C. Beck, L. R. Lowry

ried on first at Cliffwood, N. J. The site there became inadequate for the extensive studies required, and in 1930 the work was moved to Holmdel, where a large tract of fairly level ground had recently been purchased. Holmdel is in that section of New Jersey southwest of Sandy Hook, and lies about ten miles south of New York's lower bay. A single story frame building, shown in the photograph at the head of this article, serves as the main laboratory, while scattered around the property are various antennas and small buildings for testing apparatus.

In general, short-waves include all wavelengths less than 200 meters, or frequencies greater than 1½ megacycles. Specifically, however, this short-wave realm is divided into two parts: short waves proper, with wavelengths from 10 to 200 meters or frequencies from 30 to 1½ megacycles; and ultra-short waves, with wavelengths less than 10 meters or frequencies greater than 30 megacycles. The work is carried on under the joint direction of C. R. Englund, who has charge of ultra-short-wave research, and the writer, with special supervision over short-wave research.

In short-wave work, E. Bruce heads a group developing the horizontal rhombic antenna. Antennas of this type have been employed for the more recent short-wave channels as already described in the RECORD,* and studies are being continued to improve their characteristics.

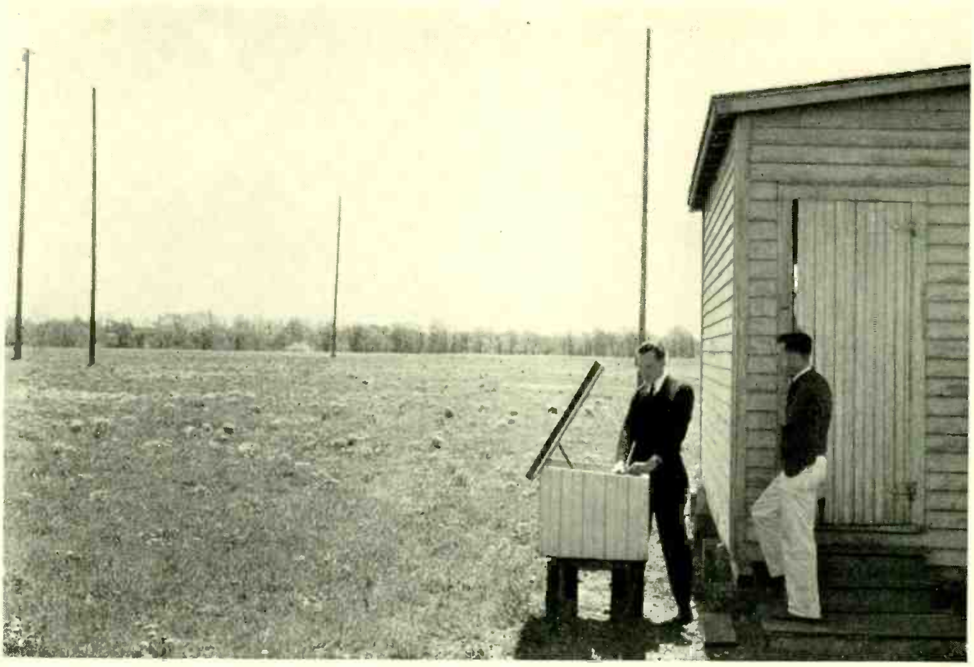
The effectiveness of directional antennas depends on an accurate knowledge of the direction of arrival of the radio waves. The horizontal angle of direction is that of the great circle passing through the transmitting and receiving stations, but the vertical angle depends on a variety of factors, and requires considerable investigation for its determination. Studies of the direction of arrival of radio waves are being carried on by C. B. Feldman. Some of the progress made in these studies has already been recounted in the RECORD.† Mr. Feldman is also studying the effects of the ground‡ on radio waves.

To reduce short-wave fading, studies have been carried out by R. S. Ohl and his assistants on the combination

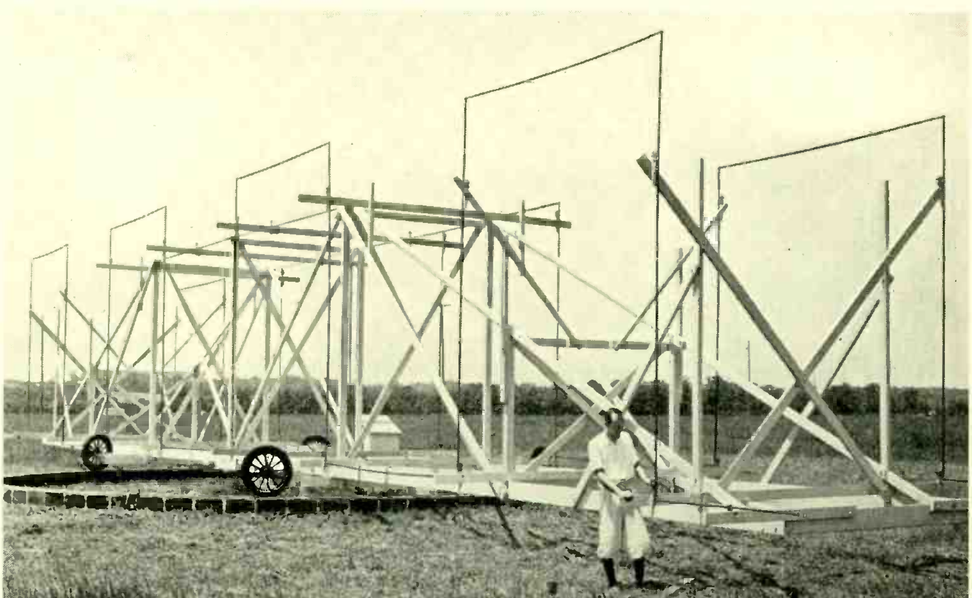
*RECORD, *May*, 1932, *p.* 291.

†RECORD, *June*, 1934, *p.* 305.

‡RECORD, *August*, 1934, *p.* 372.

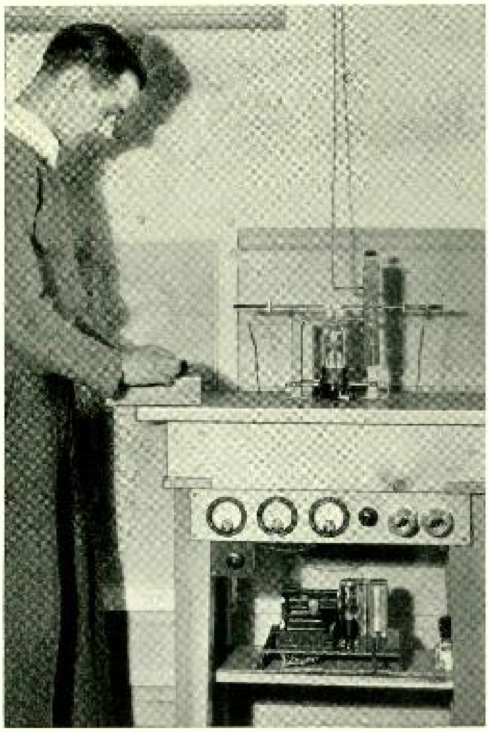


Terminal end of an experimental rhombic antenna—A. C. Beck and L. R. Lowry



Rotating antenna for measuring static reception—K. G. Jansky of signals from spaced antennas. K. G. Jansky, who measures and studies the effects of short-wave static, has discovered an unusual static disturbance that seems to arise from beyond the solar system. It has been commented on widely in the press and over the radio broadcast.

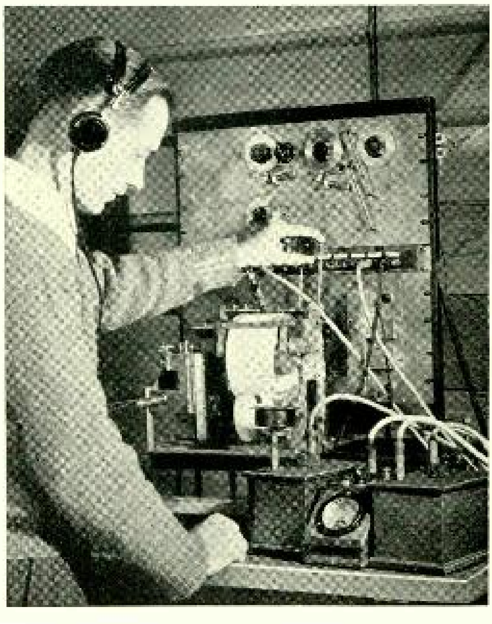
With the general commercial employment of short waves for radio telephone communication, greater attention is now being paid to the region of ultra-short waves. For waves shorter than ten meters, the transmission characteristics differ considerably from those of longer waves. These ultra-short waves are not reflected by the Heaviside layer but pass through it. They are thus not returned to earth at various distances, as are the longer waves, but travel more nearly in an optical path. The range for ultra-short waves is thus quite short, but the transmission is exceptionally free from fading and static except that generated nearby. For communication between points fairly near together, but which cannot be easily connected by land lines, ultra-short waves appear to be ideal. Some of the characteristics of ultra-short wave transmission have already been discussed in the RECORD*. Extensive studies have been carried on during the past year between ultra-short-wave transmitters located just north of Seabright, N. J., and receivers in the Laboratories' plane flying at various heights above the south shore of Long Island. Wavelengths of 1½ and 4½ meters were employed, and good reception was obtained as far away as Montauk Point.



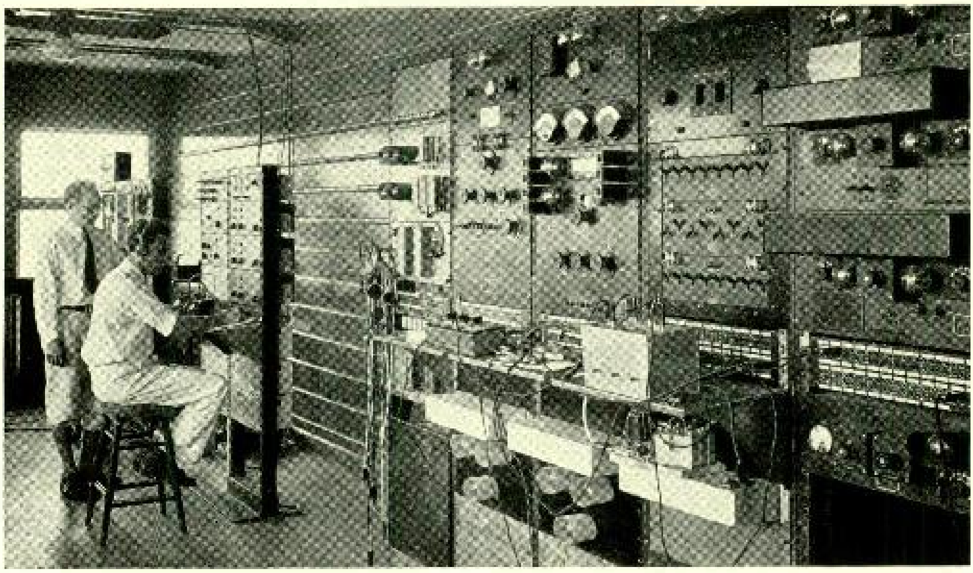
A. B. Crawford with the 1.5 meter generator equipment

The importance of these various short-wave studies cannot well be

*RECORD, *November*, 1933, *p.* 66.



Receiving apparatus employed for 1.5 meter tests

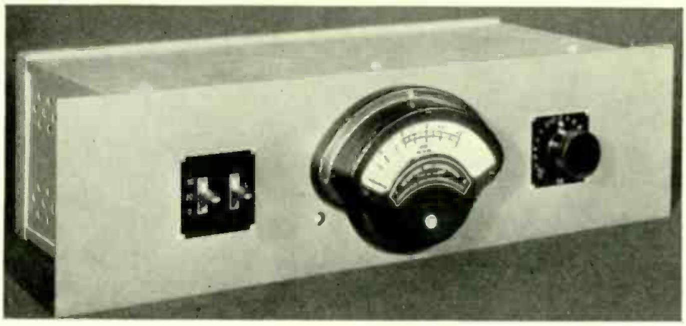


Special antenna combining and measuring equipment in main laboratory building—R. S. Ohl and A. P. King

overestimated because the expansion of radio communication undoubtedly lies largely in the short-wave and ultra-short-wave realms. This is due to the fact that the number of communication channels in the long-wave spectrum is decidedly limited. There is about nineteen times as much "frequency space" in the short-wave spectrum as in the long-wave and over 183 times as much in the ultra-short-wave spectrum down to about one meter. While it may be more difficult to develop extensive use of frequency space at the shorter waves, it is nevertheless a physical fact that the greater part of the future radio communication channels must be found outside of the long-wave spectrum.

Record Articles on Short-Wave Installations

Transatlantic—RECORD—July, 1929—p. 435.
South America—RECORD—Aug., 1929—pp. 489-518.
South America—RECORD—May, 1930—p. 405.
South America—RECORD—Sept., 1930—p. 21.
Bermuda—RECORD—Nov., 1931—p. 66.
Caribbean—RECORD—Aug., 1933—p. 365.
Honolulu—RECORD—Nov., 1931—pp. 66-305.
Philippines—RECORD—June, 1933—p. 278.
Ship-to-Shore—RECORD—Jan., 1930—p. 204.
Coast Guard—RECORD—Feb., 1932—p. 205.
Police—RECORD—Aug., 1932—p. 428.
Airplane—RECORD—Sept., 1932—p. 21.
Airplane—RECORD—May, 1933—p. 262-278.
Harbor Craft—RECORD—Nov., 1932—p. 63 and p. 77.



An Improved Volume Indicator

By R. E. KUEBLER
Radio Apparatus Development

WHEN speech and music are picked up for electrical transmission there are wide differences in the loudness of the various sounds at the microphone. Some speakers will stand at a distance, others will prefer close talking; some orchestral selections will be loud or possibly cover a wide range of intensity from the soft to the loud passages, others will be soft. For satisfactory and economical transmission, volume adjustments must be made in the amplifiers from time to time depending upon the nature of the program, and volume levels must be established at various points in the program system so that each element, whether it be an amplifier unit or a repeater, a telephone line, or a radio broadcast transmitter, may be used most effectively. While the human ear is quite sensitive to changes in loudness, its accuracy in estimating the magnitude of the changes is not sufficient, and the monitoring facilities, loud speakers or headsets, are supplemented by a visual measuring device known as a volume indicator.

The volume indicator is essentially a high-impedance voltmeter of the vacuum-tube type. Since the power flowing into a constant impedance is proportional to the square of the voltage the meter scale can be graduated in power units. The instrument is principally used as an indicator in maintaining a definite maximum volume at the point where it is connected. In this case it is most convenient for the operator to hold the needle to a certain relationship with a zero mark at mid-scale. As a preliminary, attenuators incorporated in the volume indicator are set for the volume desired and the amplifier system is then adjusted by a gain control to obtain that volume.

In the form manufactured by the Western Electric Company for many years and widely known as the No. 203 type, the volume indicator consists of a grid-bias rectifier tube with an input transformer coupling and a direct current galvanometer in the plate circuit. Figure 1 shows the schematic circuit of this instrument. It is designed for operation across circuits of 500 ohms impedance. A No. 102D Vacuum Tube is used as the rectifying element. The grid bias applied to the tube is adjustable by means of a potentiometer in the negative branch of the filament circuit so that the tube operates on the most suitable part of its characteristic.

In calibration the usual procedure is to adjust the grid bias so that the meter needle rests on a red arrow near the lower end of the scale. With the dial switch and the key K1 each on "0," a 1000 cycle sinusoidal voltage of 1.73 volts applied to a 500 ohm resistance across which the volume indicator is connected should cause the needle to stand on a red dot a little more than 2 db below the central "0." When the rapidly fluctuating power of speech and music is being measured, the operator adjusts key K1 and the dial switch so that the meter will read "0" about once in ten seconds. The algebraic sum of the dial switch and the key readings is then the volume. Coarse adjustments for amounts of 0, 16 or 30 db are made by the key and fine adjustments in steps of 2 db from +10 to −10 db are made by the dial switch.

Based on investigations conducted by the Research Department of these Laboratories the 700A Volume Indicator has been developed. It is of a new type and is capable of indicating a wider range of power levels with greater accuracy. Designed primarily for use in the new speech input equipments for radio broadcasting it receives its operating power from rectifiers and transformers in the associated equipment and hence requires no batteries. A single stage vacuum tube amplifier works into a full-wave copper oxide rectifier and an associated meter. Means are provided for controlling the proportion of the input voltage applied to the grid of the vacuum tube. This control is effected in large steps by a key K1 which inserts an attenuation of either 20 or 30 db between the input terminals and the transformer T1. Control in steps of 2 db is obtained by a potentiometer P2 which varies the voltage applied to the grid of the amplifier tube. The normal range is from −18 db to +42 db and the extreme range of energy levels measurable with this instrument is from −25 db to +45 db. The frequency response characteristic of the 700A Volume Indicator is essentially uniform for all frequencies from 30 to 10,000 cycles per second. Its bridging loss on a 500-ohm circuit is approximately 0.3 db. The bridged circuit is in effect a high-quality amplifier which isolates the rectifier unit from the measured circuit. Hence the non-linearity of the rectifier does not introduce distortion into the program.

The vacuum tube is a Western Electric No. 262A* which has an indirectly heated cathode. Power for

*Record, *February*, 1933, *p.* 158.

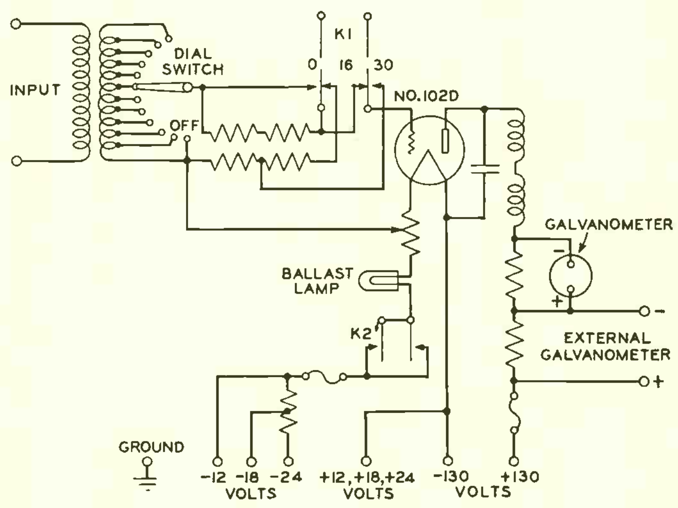


Fig. 1—Schematic diagram of the 203C Volume Indicator

the heater is usually supplied from a No. 263 or No. 264 Type Voltage Regulator Panel. In this panel a special type of transformer is supplied with commercial alternating current within a range of 100 to 125 volts and delivers 10 volts with but small fluctuations with line voltage.

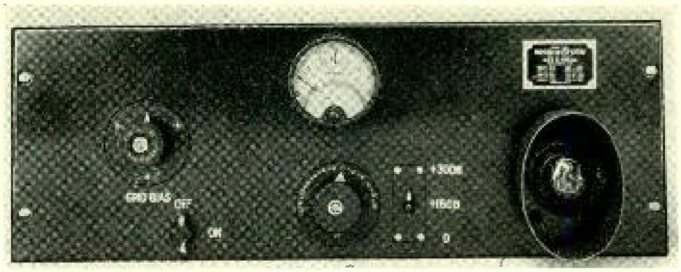


Fig. 2—On the 203C Panel the key and dial in the center are adjusted until the needle deflects to half scale once every ten seconds when measuring program energy levels

Plate current for the vacuum tube is secured from a rectifier elsewhere in the assembly of equipment. Power for the entire assembly is turned on by a single master switch in the rectifier. A time-delay relay in the rectifier delays the application of the plate voltage by approximately 45 seconds to allow the cathode of the vacuum tube to reach its normal operating temperature.

Coupled to the vacuum tube by a transformer is a copper oxide rectifier. Full-wave rectification is obtained in which the current through the associated meter is closely proportional to the square of the alternating voltage. Dynamic characteristics of the meter have been designed to give steady-state deflection of the needle in approximately 0.2 second, for an input suddenly applied, and also to prevent excessive overthrow of the needle. As a result, the needle follows closely the intensity pulsations of speech and music. This facilitates the reading of the meter and also gives better correlation between the readings and the relative intensities of different types of program. The meter

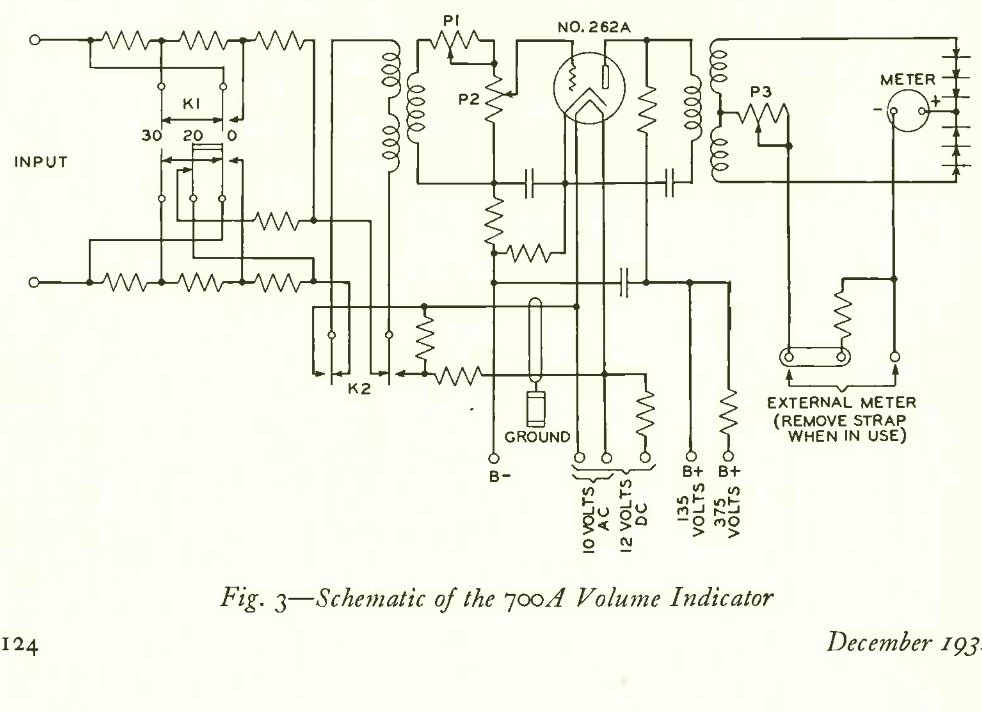


Fig. 3—Schematic of the 700A Volume Indicator

scale is graduated from −7 to +3 db, with the central part divided in one-half db steps. An additional meter may be inserted for remote indication.

No oscillator is necessary for the calibration of this instrument. A potential of 10 volts at 60 cycles is maintained on the heater terminals as already described; a portion of this potential is tapped off by a fixed potentiometer and applied to the input transformer through key K2. With potentiometer P2 set at "0," potentiometer P1 is adjusted until the meter needle reads zero. Next, potentiometer P3 is adjusted so that the meter reading will change by 2 db when potentiometer P2 is changed by a like amount in the opposite direction. An external meter, if used, should be in circuit during calibration.

Component parts of the 700A Volume Indicator are assembled on a recessed metal panel, 19¼ inches wide and 5¼ inches high, which is designed for relay rack or equipment cabinet mounting. A screwless front mat finished in dark aluminum gray is provided on the front of the panel. Here for convenient operation are located the control and calibrating potentiometers, the 0-20-30 db range key, the indicating meter and the key used in calibration. The mat is removable from the back to provide access to the terminals and to the panel wiring, which are located in the depressed section of the panel behind the mat. The transformers, vacuum tube and other large units are mounted on the back of the panel and protected from dust and mechanical injury by an aluminum finished metal cover which is removable for maintenance or inspection. From the illustrations it will be seen that the new instrument is a distinct improvement over the former type in attractiveness—a factor in broadcasting applications where appearance is next in importance to performance and operating qualities.

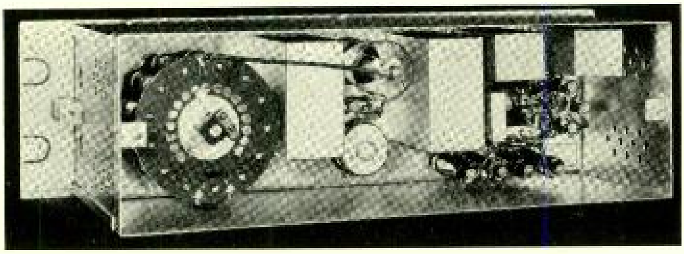


Fig. 4—Removal of a rear cover plate gives access to the vacuum tube and the control potentiometer

Contributors to This Issue

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 he describes in this issue of the Record, and installed it at 32 Sixth Avenue two years ago. He also developed the first devices for automatically adjusting net transmission loss, used on the Charlotte trial cable installation. Last summer he transferred to the special products group to study the applicability of the compressor and expandor to other problems.

After receiving the A.B. degree from Washington University, A. M. Skellett continued his studies there and spent a summer as physicist with the Westinghouse Company. In 1927 he received the M.S. degree and joined the teaching staff of the University of Florida, spending the next two years there, first as instructor in electrical engineering and then as assistant professor of physics, and acting during the latter of these years as chief engineer of Station WRUF. On joining the radio research group of these Laboratories in 1929, he engaged in the design of long-wave radio antennas, and the following year he embarked on the investigation of general problems of radio transmission. Mr. Skellett has especially contributed to our knowledge of the relationship between astronomical phenomena and radio transmission. Last year he received the Ph.D. degree from Princeton University. In October he transferred to the physical research group where he is now engaged in developing applications of atomic and electronic devices to the telephone art.

H. T. Friis graduated from the Royal Technical College in Copenhagen in 1916. After a few years of military service in his own country, he came to the United States early in 1919 and took graduate work at Columbia University. Later in the year he joined the Research Department of the Western Electric Company—now Bell Telephone Laboratories. Here he has been concerned continuously with

N. C. Norman

A. M. Skellett

H. T. Friis

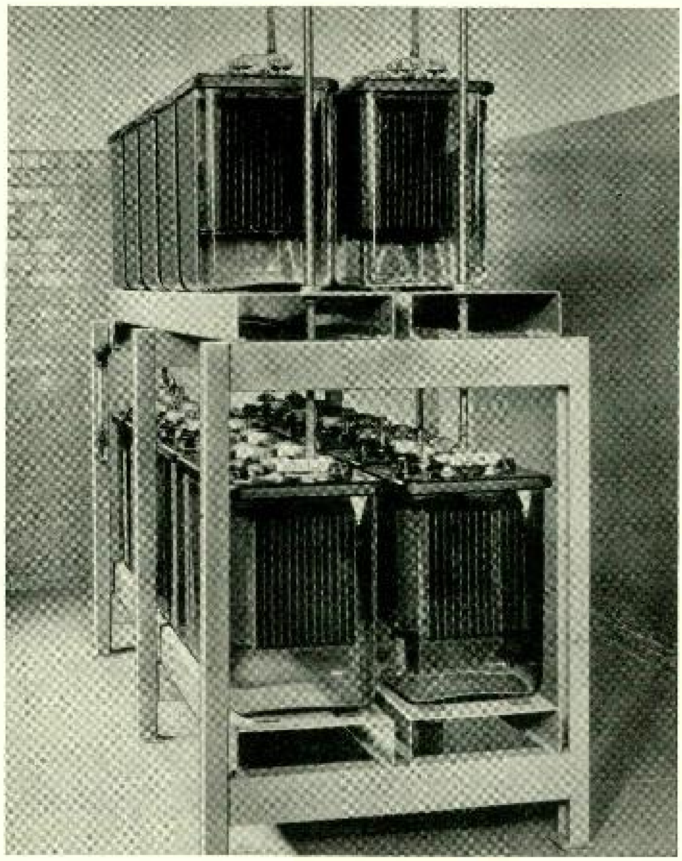
Lawrence Ferguson *D. T. Sharpe* *R. E. Kuebler*

research work on radio receivers and radio reception, including the measurement of field strength, the angle of arrival of radio waves, and allied studies. His first work was at the Elberon receiving laboratory in New Jersey on ship-to-shore reception. From 1921 to 1929 he was at Cliffwood studying both long-wave and short-wave reception. Early in this period he constructed the first broadcast receiver to employ the super-heterodyne principle. He also, with H. W. Nichols, handled the first long-wave transatlantic reception in London. Since 1930 he has been at the Holmdel Laboratory in charge of short-wave reception studies.

LAWRENCE FERGUSON joined the student assistant course of the Western Electric Company at West Street in 1923. For some three years he engaged in research work on vacuum tube filaments. In 1926 he transferred to the Chemical Department where he has been engaged in metallurgical research and development, chiefly on lead alloys for cable sheathing. During this period he studied at New York University and in 1931 received the B.S. degree.

D. T. SHARPE came to the Laboratories in 1928, from the United States Steel Corporation where he had been engaged in experimental engineering for five years. Here, in the Outside Plant Department, he was first concerned with development studies pertaining to cable joining and maintenance methods. More recently he has been occupied with design problems relating to miscellaneous items of outside plant, such as manila rope, rubber gloves, body belts and safety straps, and first aid kits.

R. E. KUEBLER's contact with speech input systems began in 1922, when as a field engineer he participated in the installation of several of the early public address systems, notably at the Copley Plaza Hotel in Boston and the Stadium at Los Angeles. From 1926 to 1932 he was concerned with recording systems for sound pictures, particularly the portable and truck mounted types. During the last two years as a member of the Radio Development group he has been active in the design of speech input equipment for radio broadcasting. Mr. Kuebler graduated from Pennsylvania State College in 1917; before entering the Laboratories in 1920 he had seen overseas service in the 305th Field Signal Battalion and had been a member of the research staff of the New Jersey Zinc Company.



The increasing use of enclosed-jar storage batteries in the telephone plant has made it desirable to support them on structures of steel rather than of wood as has been common in the past. These steel stands, which will be used for all future installations of enclosed storage batteries, were designed by M. A. Froberg to cover a wide range of size and arrangement of battery with a minimum number of separate details.

They are constructed of formed sheet steel members welded and bolted together. Any length of stand desired may be obtained, and the design allows for either two or three tiers—each for one or two rows of cells. A light gray acid-resistant paint makes the new frames match the aluminum and gray finish used for practically all other central office equipment.

An additional advantage of this type of structure is that the vertical supports may be extended upward above the battery shelves to support overhead bus bars. Such an arrangement eliminates hanger rods and ceiling supports.