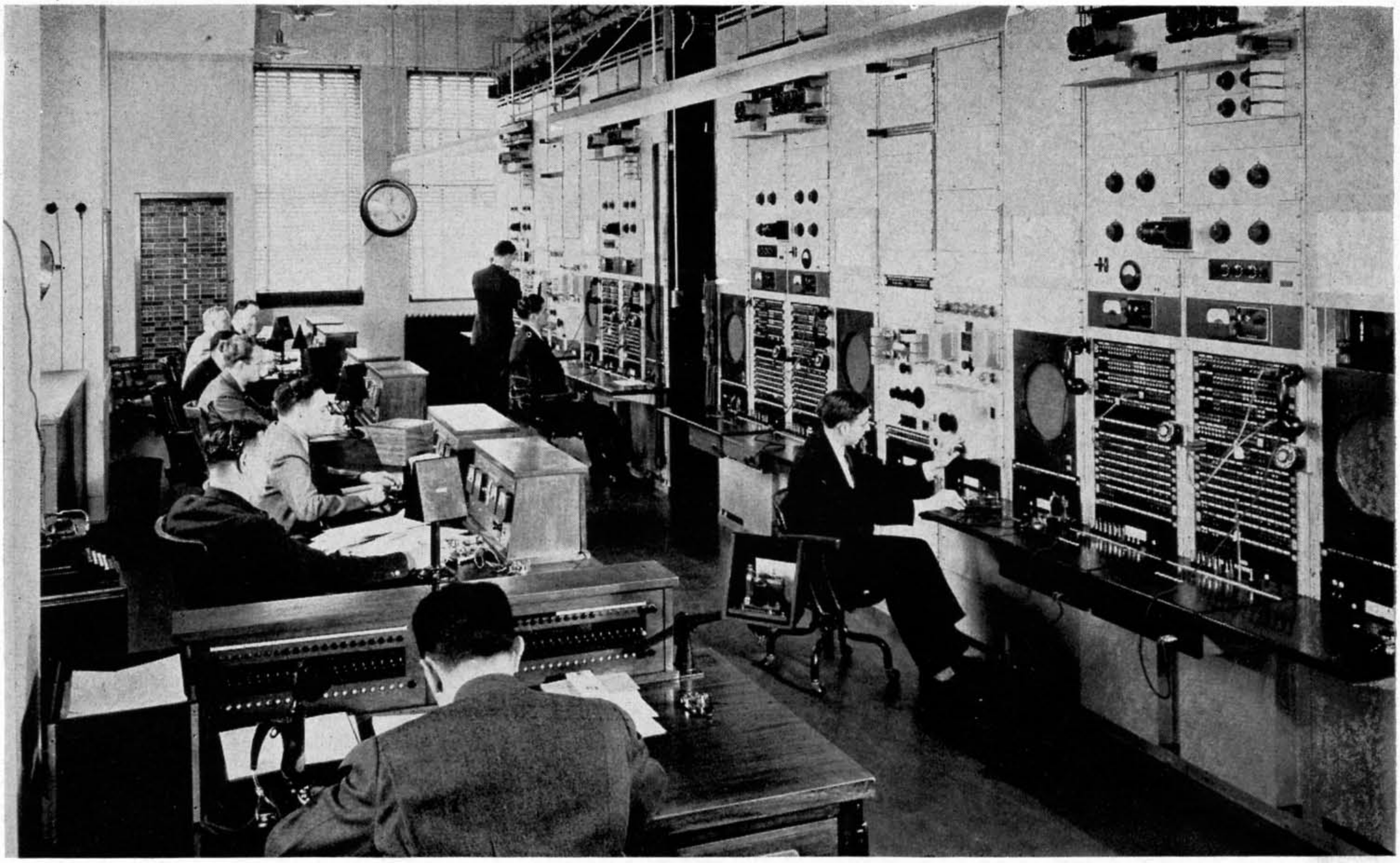


"NR" — Broadcasting network control room where A. T. and T. Long Lines technicians monitor nationwide network programs. From here, technicians are in constant touch with headquarters offices of the broadcasting companies and with key points along the networks, thus keep check on functioning of wire circuits.

"And now we take you to—!"

By George de Mare

• • A picture of the organization of the "wire network" behind broadcasting and what the experience gained in present program transmission may mean in the putting together of future FM and television networks • •

It is the end of the last program of the day — at one or two in the morning. The air, once filled with radio's evening programs, is silent now, but unheard by the great listening public a coast-to-coast program of tests and adjustments in preparation for the start of network broadcasting service in the morning commences. Radio is clearing its throat . . . and to assist in the process it calls upon its "silent partner"—the Bell System's vast wire network organization — to perform one of its most important functions. . . .

Everybody in broadcasting probably knows how network programs are distributed and something about this giant wire system — equal in actual money value to about half of all the equipment owned by the broadcasting companies it serves — but how many know how intricate is the organization necessary to keep network programs coming through at the level of performance Broadcasting demands, or how exacting are the problems which this wire network must solve? A more detailed review of the operation and organization of the wire network may be useful at this time in throwing some light on the problems that will confront broadcast engineers in putting together possible FM and television networks.

The present wire network service, the "silent partner" which makes all chain broadcasting possible, involves a great deal more than merely providing wire channels from studio to transmitter or from one broadcasting station to another. It means, among other things, maintaining great central switching and control points throughout the nation. It means having a staff of engineers to see that programs are going on the split-second schedules required. It means maintaining repeater stations all along the lines, operating a telegraph and teletype network totaling some 70,000 miles of circuits to transmit to all major telephone company offices information on every program — what stations are to be cut in and what switches are to be made, and it involves keeping a corps of "monitors" busy listening at key points for the faintest flaws in transmission. Finally, it means constant research to improve the quality, dependability and life of the lines and transmission equipment — research which draws constantly upon the great resources of the world's largest electronics and communications research center—Bell Telephone Laboratories.

As an example of the functioning of this "silent partner" let us go back for a moment to that program of tests and adjustments of which we were speaking and continue briefly the account of what happens on a typical network before the first announcer of the day signs on. . . .

This morning, for instance, amplifier tube tests are to be made at all offices between New York and Chicago from 2:00 to 3:00 a.m. These tests completed, still other tests must be made to assure transmission of program with unimpaired volume and quality. Each control office measures its own section, including the circuits kept ready for special services or emergencies, and sees that it is fit for broadcasting.

With section tests complete, the network is put together and New York pumps out a succession of different tones over the entire chain. Measurements and necessary adjustments are made at a score of places. Promptly at close of business, the telephone staffs send in by teletype reports on the service furnished, and yesterday's comments from the radio stations.

Let us say that an important news program is to start from New York at 8:00 o'clock in the morning over one of the networks. As usual it will be started on its way by the broadcasting station's technicians in the control room, from which it will be fed to the nerve center of the Bell System's web of broadcasting channels in New York's Long Lines Building, known by the call letters *"NR"*. There a corps of technicians will have already "lined up" the wires and equipment over which the show is to travel and have subjected them to certain exacting tests. From *NR*, the show is carried out over the great trunk routes of communication set up by the American Telephone and Telegraph Company's Long Lines Department and Bell System offices. These will carry it to the hundred or more stations that are taking the program in New England, the South, the Middle West and the West Coast.

Now, therefore, at 7:30 in preparation for this, each office checks its setup in accordance with the schedule sent out by the broadcasting company, to be sure the stations slated to receive the show are cut in. At 7:45 the New York studios of the network start transmitting test programs to their chain. By means of a control telegraph wire, New York receives telegraphic reports from along the line that a program of satisfactory volume and quality is being received. It is now 8 o'clock and the broadcasting network is ready for operation.

130,000 Miles of Circuits

This, briefly, is the bare outline of one of the major functions of the wire network during the silent hours, but it gives very little hint of the elaborate maintenance, the highly involved organization or the intricate equipment which must perform this essential function.

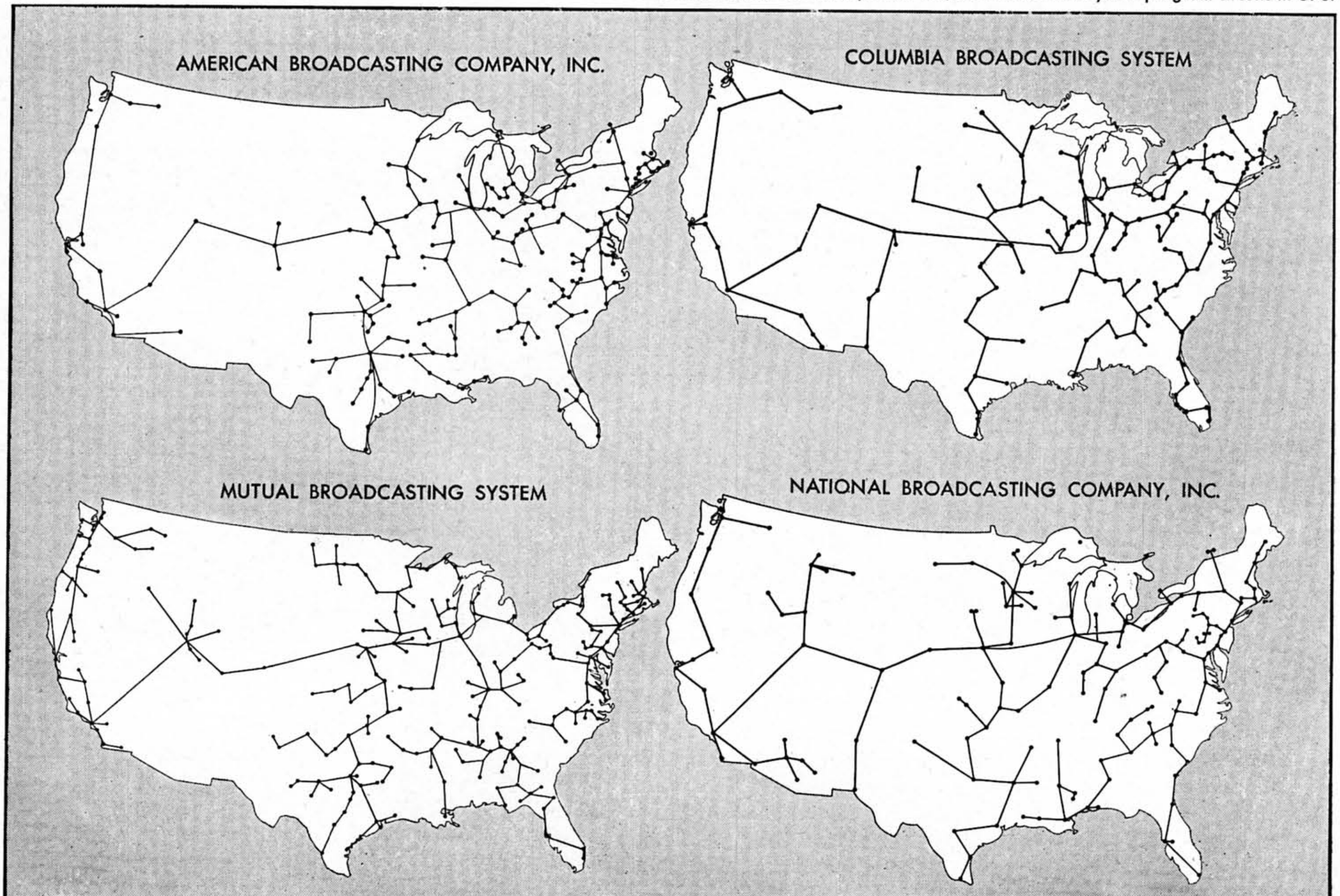
First, what is the "organization"?

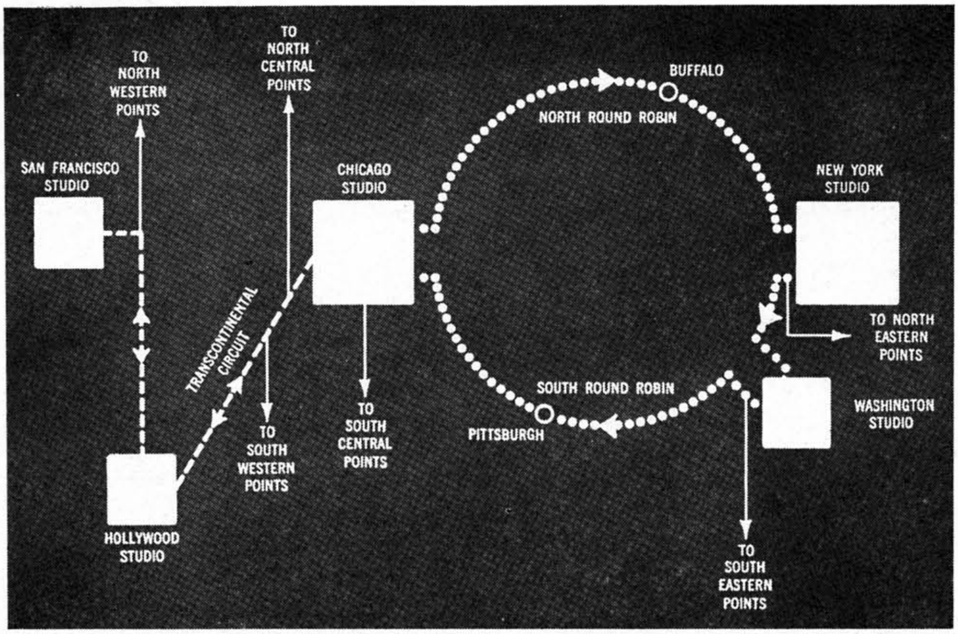
Physically, the wire organization consists of more than 130,000 miles of telephone transmission circuits linking into various networks over half of the 900 broadcasting stations in the United States. These circuits are permanently and exclusively devoted to this service, including some 31,000 miles of wire lines set aside for use in special features, "repeat" programs, unusual hookups and in such emergencies as storms, floods, fires and disasters.

Each major broadcasting company is provided with its own separate and complete network (see maps below). Circuits are one-way over special high-quality cable which will transmit a frequency band up to 5,000 or 8,000 cycles in width according to indicated preferences of the broadcasting companies under the circumstances. It may be noted that as early as 1933 the Bell System successfully transmitted frequencies up to 15,000 cycles over circuits between Philadelphia and Washington. In the postwar period this type of circuit will be widely available to serve broadcasters who may have a need for 15,000-cycle FM intercity channels.

The wire channels of the present network run through about 300 telephone offices; use over 2,500 of the special-type vacuum tube amplifiers designed for this network and in addition to the four major coast-to-coast chains, knit together approximately 30 regional webs. Hundreds of

Wire networks used to connect affiliated stations of the four nationwide broadcasting systems. These are part of 130,000 miles of Bell System program circuits in U. S.





Simplified diagram indicating the two essential elements forming the central nerve system of network broadcasting: the "round robin" from Chicago east and the "quick reversible" circuit from Chicago west.

Bell System transmission specialists are engaged in operating this nationwide system supporting the excellent engineering and monitoring facilities maintained by the broadcasting companies themselves.

The central nervous system for chain broadcasting in the case of three major networks (Mutual uses the quick reversible type exclusively) includes two important features. The first is the so-called "round robin" which is a major closed circuit running from New York to Washington to Chicago and back to New York. The second major element is the "quick reversible" or "Type 1 Reversible" circuit which links the round robin terminal at Chicago with Los Angeles and other points west (shown at top of page). These two elements, in fact, make network broadcasting possible, in that a progam originating anywhere in the network can be fed into the round robin and thus reach all points along the round robin circuit, and from the round robin circuit the program can be fed through the Type 1 quick reversible circuit to Los Angeles, any points along the way and north up the Pacific Coast. The quick reversible, as its name implies, although one-way, can be reversed in 15 seconds or less, depending upon the length and facilities involved. Thus a program originating on the West Coast can be carried east on the quick reversible to the round robin terminal at Chicago and from there fed through this central circuit to all points in the East. If desired, southern legs can be attached at the Washington or Chicago terminals of the round robin linking up the South Atlantic and Deep South regional circuits. The total effect is to make it possible to put together at any time in a matter of seconds a nationwide network into which a program from any part of the nation or the world may be fed.

Along this central nerve system, four major control point offices are set up: in New York, Chicago, Denver and Los Angeles. Offices controlling regional webs or parts of the main webs are set up in such cities as Boston and Washington; Atlanta and New Orleans; Cincinnati, Indianapolis and St. Louis; Minneapolis, Kansas City, Omaha and Dallas; Salt Lake City, San Francisco, Seattle and Portland and many others. These and subsidiary control and switching offices permit any desired combination of stations and quick changes from one hookup to another.

In the operation of this vast network, much skill and care are involved.

Two elements are perhaps most typical of operational requirements: "flexibility" and "speed". Broadcasters expect the organization to maintain standards that will permit quality transmission of a sufficiently wide frequency range, free from noise or interruption. Yet it is obvious that the specialists who operate any organization of this type are dealing in variables. Broadcasting networks vary in size from a handful of stations to more than a hundred. The number of programs varies. In a 17-hour day it is possible to have 68 fifteen-minute programs, and some stations approach that. Some programs are local shows; some regional and some coast-to-coast. In addition, there are last-minute changes: man-made, particularly during wars and elections, and finally there may be last-minute changes, caused by nature, when an aerial cable is blown down in a storm or a twister, a cloudburst or an explosion rips a line or two. Yet the major requirements remain the same, and the lines must never go silent.

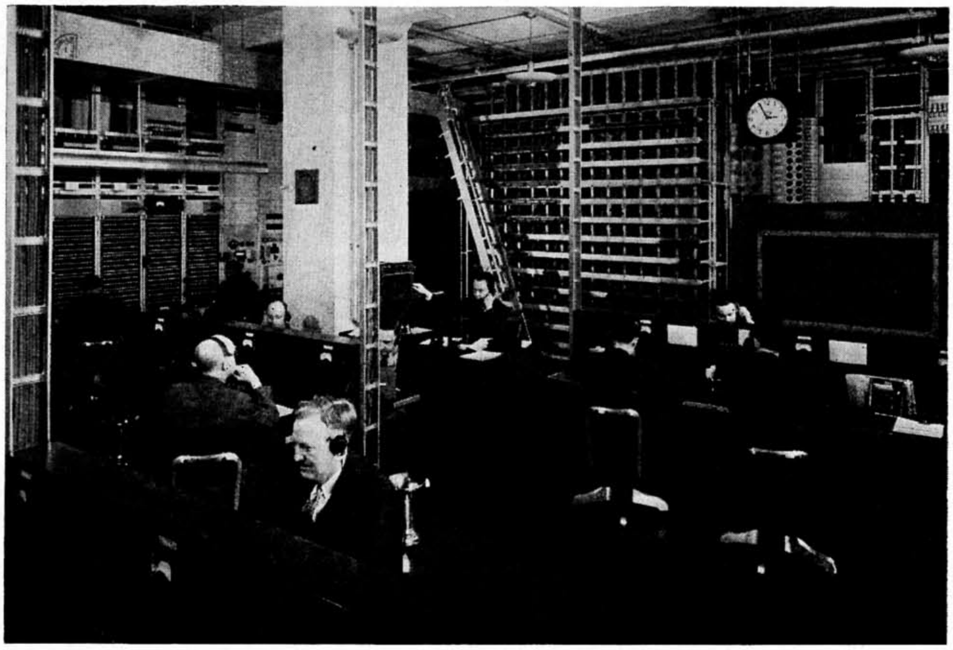
Let's take typical examples of the problems that occur during a day in the operational life of the wire network. . . .

In all offices, switching schedules are constantly being received from the broadcasting companies. There are three classes of switches involved: (1) those at main studio points made by the broadcasting engineers (2) those in toll test rooms so set up that they can be operated by remote control from radio stations and (3) those in toll test rooms on the great national and regional circuits made by the wire network engineers. These operational orders covering the switching schedule may be more or less elaborate, and different offices will use different standard methods of handling them. They generally come in an abbreviated or code form. In offices where the schedule is heavy, the operations may be tabulated or charted and put on the bulletin board or in the order book. Vast improvements in facilities and the installation of much automatic equipment have made switching relatively simple in many offices. However, all orders must be carefully analyzed and carried out with split-second exactness.

"Army Hour" Set Travel Record

Switches are generally made during the 20 seconds or so allowed for local station identification or, as in "running switches" during the program, when the announcer gives the cue: "And now we take you to ——— . . ." Those little words may mean cutting in circuits from Manila, from European capitals, from Saipan, from Honolulu, from Alaska, from Tokyo, from anywhere our Armies and Navies may be, in all the corners of the earth. One program, the famous "Army Hour" presented by the United States War Department over NBC traveled during its first eighteen months on the air *within the United States alone* a distance of 560,000 miles — taking its listeners to Washington, D. C. a total of 140 times. The total number of miles the Army Hour traveled in switching *to points outside the United States* in those eighteen months was 1,061,000 — making a grand total of 1,621,000 miles traveled during the 78 hour-long broadcasts. This distance is equal to 65 times around the earth at the Equator or almost seven times the distance to the moon. The studio portion of the Army Hour originates at NBC in New York, and the switching setup operated by NBC and supported by the wire network is very elaborate. One example will indicate the extent of this setup. On October 24, 1943, Guadalcanal went on the air for the first time in history. To prepare for this entrance during the program, an NBC engineer spoke into his microphone in New York. His voice traveled over 3,000 miles of the wire network, then leaped by short-wave from San Francisco to Guadalcanal and issued from a loud speaker set up on the island.

A return circuit had been set up so that the production man on Guadalcanal could converse with the NBC man, but while the NBC man was giving his directions on cuing and timing for the broadcast to take place within a few minutes, checking quality and volume of signal and finally giving the correct time to within a fraction of a second, he could hear not only the production man's replies from Guadalcanal but *even the echo of his own voice* as it came from the loudspeaker on Guadalcanal and entered the production man's microphone set up nearby! Thus his words traveled out and back to him halfway around the world in that split-second of time. The only reason there was any difference of time at all was because of what is known as "delay" which occurs when telephone currents pass through complicated circuits and many units of wire.



Chicago control room — a focal point in A. T. and T.'s intricate wire network for broadcasting — where important switching operations are made linking major circuits between Eastern and Western network stations.

"Quick Reversible" in Action

Thus when the announcer finally said: "And now we take you to Guadalcanal!" the circuits were connected, the operation of switches reversed every amplifier along the line from San Francisco to Los Angeles, the operation of a key locked these amplifiers and as the words from Guadalcanal flowed in at the San Francisco short-wave receiving stations, they were carried by wire to the Los Angeles control room. Then they flashed along the quick reversible circuit to Chicago and the round robin and went to the NBC stations in the regional legs attached to the round robin. The network was functioning . . . and listeners all over the country could hear the voices of men and sounds of battle half a world away.

This might be one of the more complicated switching operations for the wire networks control offices during a typical day. There would be many others.

What does the experience of this wire network organization mean in the building of possible FM or television networks?

The answer involves several factors. One source for such an answer might be in the experience of the Bell System, for no matter whether telephone circuits transmitting 15,000 and more cycles or radio relay circuits, or both, are used, the same operating principles will hold. Based on this experience, these principles may be here briefly summarized:

1. To be suitable for network operation the transmission circuits must be kept at a very high level of maintenance. Interruptions or impairments in a single link may affect a large part of the entire network. Whether a nation-wide network is made up of wire lines or radio relay circuits or part of each, a great deal of maintenance would be necessary. The coaxial system, for example, involves cable and equipment all along the route and repeater stations, including equipment and sources of power, at intervals of 50 to 150 miles. The radio relay system avoids line maintenance all along the route, but will involve repeater stations with sources of power and with their associated antenna structures at intervals of about 30 miles. In any case, a comprehensive and highly trained maintenance force is necessary for continued satisfactory network operation.
2. The standards of design applied to each link of the network must be much more severe than would be necessary for the operation of the single link by itself. Each link must be so designed that it will work satisfactorily with many other links in a wide variety of connections. The distortion effects are cumulative and the maximum distortion between any two points of the network must be kept within satisfactory limits.
3. Throughout the country bridging equipment must be installed to enable the reception of a program over one link of a network and its transmission at that point to a number of others with proper transmission levels on each. One bridging point may supply as many as 10 branches of a network.
4. Arrangements must be provided for instantaneous and often very complicated switching to rearrange the networks for successive programs. Much of this switching is done at the studios and a great deal is done at key points of the telephone system. In many places where the switching problem is complicated, arrangements are provided so that while one program is in progress the connection of the network for the next program is preset without interfering with the program. Upon the receipt of the proper cue, the attendant, by throwing a single remote control key, instantaneously completes the rearrangement.
5. It would be necessary to build an organization of engineers and attendants at key points to monitor the programs, and to carry out routine tests and adjustments to insure the continued operation of the network at broadcasting level. The amount of this work in the present wire organization is equivalent to about the full time of 400 men. The total involved is, however, much larger, as many men spend only a part of their time on this type of work.
6. To assist this operating force in making its work most effective, key points must be connected together by a network of telegraph circuits devoted entirely to network operation. In the present wire organization the Bell System calls on 70,000 miles of these telegraph circuits.

(*Continued on page 37*)

will be limited, as in all "hot wire" devices, by the convection currents produced by the heated thermistor.

Experimental Applications

From the preceding applications there is ample evidence that thermistors as control elements have a place in almost every type of electronic circuit. Scores of other applications, however, remain to be tested and put into practical use. For example, the negative resistance characteristic exhibited by direct or self heated thermistors suggests their use as generators of low frequency alternating voltages and as low frequency power modulators for various purposes. Specially designed thermistors have been made to oscillate over the entire voice frequency range when placed in appropriate circuits. This characteristic also suggests their possibilities as amplifiers and in low frequency filters, replacing large and cumbersome components. Again, thermistors of the directly heated type have provided an effective method of amplitude stabilization of various high and low frequency oscillators. Details of this latter application will be found in papers by Meacham(1) and Shepherd and Wise(2).

Other promising applications of thermistors are as relays and switching devices. In such applications, use is made of the characteristic that the voltage drop across a thermistor passes through a maximum and then decreases with increasing current, thus having a pseudo "break down" analogous to that of a gas filled tube. This feature permits a thermistor, in a low voltage circuit, to be locked-in by the application of a higher voltage and to continue to pass a large current after the high voltage is removed. In a parallel arrangement of thermistors, it also permits any one thermistor to lock-out the other thermistors. It is evident that a wide variety of lock-in, lock-out and selective switching applications could be devised. However, at the present time, these applications are largely experimental, but do have a promising future.

Many other ingenious applications will occur to development engineers, and as they gain experience, it is anticipated that numerous other, as yet unconceived applications, will emerge.

(1) The Bridge Stabilized Oscillator, L. A. Meacham, Proc. I.R.E. Vol. 26 Oct. 1938 pp. 1278-1294.
(2) Frequency Stabilized Oscillator, R. L. Shepherd and R. O. Wise, Proc. I.R.E. June, 1943 pp. 256.

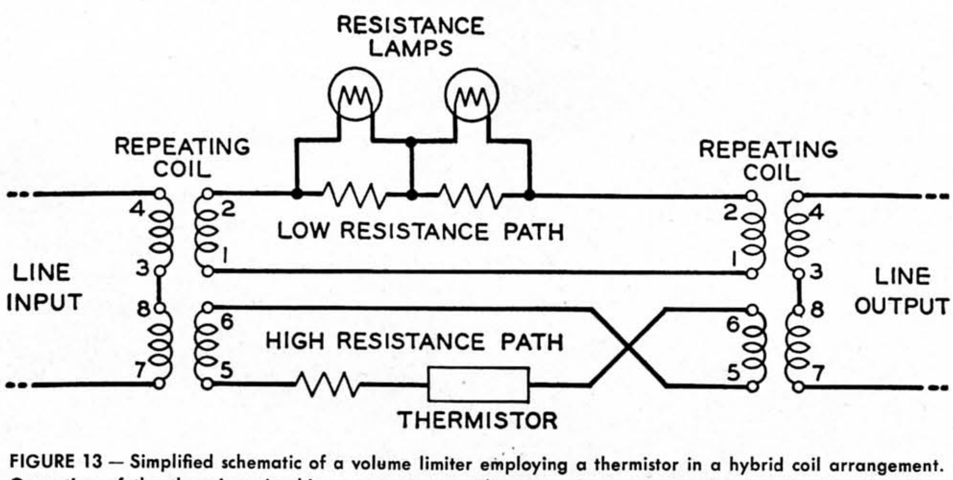


FIGURE 13 — Simplified schematic of a volume limiter employing a thermistor in a hybrid coil arrangement. Operation of the thermistor in this arrangement results in constant output without noticeable distortion.

Ads Tells History of Musical Instruments

Do you know that Nero may have played the bagpipe — not the fiddle — while Rome burned? that the first xylophone had human legs? that Plato didn't approve of the harp? that the French horn was once used for hunting?

Filled with such little known facts about today's major musical instruments, a series of 25 unusual advertisements placed by the Western Electric Company in *Broadcasting* Magazine has elicited instant response from broadcasting people — particularly program directors and script writers who find the information the ads contain a useful addition to their file of program material.

The ads — one column in length — treat each instrument from its beginnings down through its various modifications and changes to its modern development. Starting with the violin, the "singing voice" of the symphony, each ad tells a story of the instrument's name, its use during major historical events in its evolution, and many colorful modern facts about it, including some of the names "hep cats" and other cognoscenti give their instruments, such as the term "licorice stick" for the clarinet, the "wood pile" for the xylophone and the "plumbing" for the saxophone. Also indicated in many cases are the frequency range of the instrument and the type of music it produces.

The research involved in securing the information for these ads was extensive. Many books and manuscripts on old musical instruments were pored over, and a mountain of background material was read to garner the most interesting facts. All the more common instruments are included, plus others less well known, such as the carillon, ocarina, bagpipe and xylophone.

For the convenience of broadcasting people, this series of 25 ads is available in a booklet entitled *Grace Notes*. The historical information contained in this booklet may be used freely for program material. A copy may be secured by writing to the Electrical Research Products Div., Western Electric Co., 233 Broadway, New York 7, N. Y.

"And now we take you to—"

(Continued from page 13)

7. At times of emergency the affected sections of network must be reestablished in the briefest possible time by stand-by circuits and by spare equipment or by the use of alternative routes. Under such circumstances the existence of a large program transmission network forming a part of a much larger telephone network — a telephone network having in service 10 million miles of long-distance telephone circuits terminating in 2,400 switching centers — has been of great importance. Numerous alternative routes were thus made available and stand-by circuits and spare equipment were used in common to meet the needs of any individual network.

Tests underway now will determine what methods, whether wire or radio relay or both are best suited to FM and television transmission, but whatever method turns out best, there is the vast experience in present network operation available to broadcasters everywhere to use as they will in building the FM and television networks of the future.

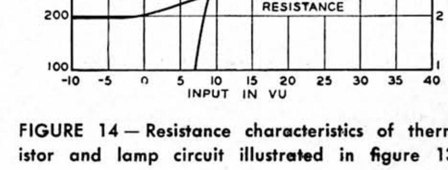


FIGURE 14 — Resistance characteristics of thermistor and lamp circuit illustrated in figure 13.