3XN

A booklet prepared for members

of the

Institute of Radio Engineers

upon the occasion of their inspection

of the

Fifty-Kilowatt Broadcasting Transmitter

developed by

Bell Telephone Laboratories

and located at

its Experimental Radio Station

3XN

Whippany, N. J.

January 9, 1928

Power Rating of Broadcasting Transmitters

THE real work of the broadcaster, is to make possible the flawless reception of programs and to provide from his station an unfailing service over as large an area as possible. For broadcasting purposes no advantage can be taken of the vagaries of transmission or of any directive effects and, therefore, improved reception and reception over greater areas must be had either by the generation of more power or by the more effective utilization of the power that is generated. There are certain obstacles, such as fading and interference, which cannot be wholly overcome by the expedient of using a large amount of power, but high power tends to mitigate their effects as well as to increase the area of high grade reception.

It is possible that the maximum power to be used in broadcasting will eventually be fixed primarily by technical difficulties, but at present the determining factors are largely economic. In general, the cost per unit area served decreases as the power and area are increased, so that with the present trend toward the broadcasting of better and more expensive programs, economic considerations point to increasing the areas regularly reached by most stations. Although the situation as it confronts each broadcaster must be analyzed by himself, taking account of the extent and character of the population which it is useful for him to reach, there seems little doubt but that the future will bring with it an increase in the power of most broadcasting stations.

In this connection the general adoption of a comprehensive method of rating the output of broad casting transmitters is important. A rating now commonly used merely expresses the unmodulated high frequency power delivered to the antenna and on this basis broadcasting transmitters are referred to as one-kilowatt sets, five-kilowatt sets, and so on. This method of rating, while it is based upon a definitely measurable quantity, is quite inadequate, failing as it does to take into consideration the maximum obtainable percentage of modulation. This is an equally important factor in determining the effectiveness of the power in the distribution of a program, and the complete specification of the performance capabilities of a transmitter must be expressed in terms of both of these factors: power output and percentage of modulation.

Most listeners have observed in tuning radio receivers that the presence of a carrier even when unmodulated can be detected by an increase in the noise received. Most of this noise is static or local electrical disturbances "beat in" by the carrier, although the latter in itself is inaudible. The loudness of this noise is proportional to the carrier amplitude and independent of modulation. The program signal on the other hand is proportional to both the carrier power and the percentage of modulation. To obtain the best signal-static ratio, therefore, it is important that a high degree of modulation be attained. It can be shown that from a signal-static ratio standpoint a one-kilowatt broadcasting transmitter capable of one hundred percent modulation is substantially equivalent to a five-kilowatt broadcasting transmitter capable of forty per cent modulation. The importance of complete modulation has not yet been generally realized among broadcasters or listeners and it is probable that the modulation of most of the existing stations can be increased, thereby affording greater coverage without the radiation of any more carrier power.

It is not a simple matter, however, to adapt the apparatus of a given station to a higher percentage of modulation. It may mean certain new equipment capable of handling the greater peak power which increased modulation entails. Of two stations, each capable of generating the same carrier power, that possessing the greater degree of modulation will, in general, be more expensive to build especially in the larger units.

The question is sometimes raised as to the extent to which modulation can be carried without loss of quality. Recent tests conducted by Bell Telephone Laboratories indicate that modulation at peak values of the audio wave may be carried to one hundred per cent without perceptible sacrifice in this respect. The new fifty-kilowatt set which is now under test at its laboratory in Whippany, N. J., is capable of this performance and extensive investigations have proven that its quality is excellent.

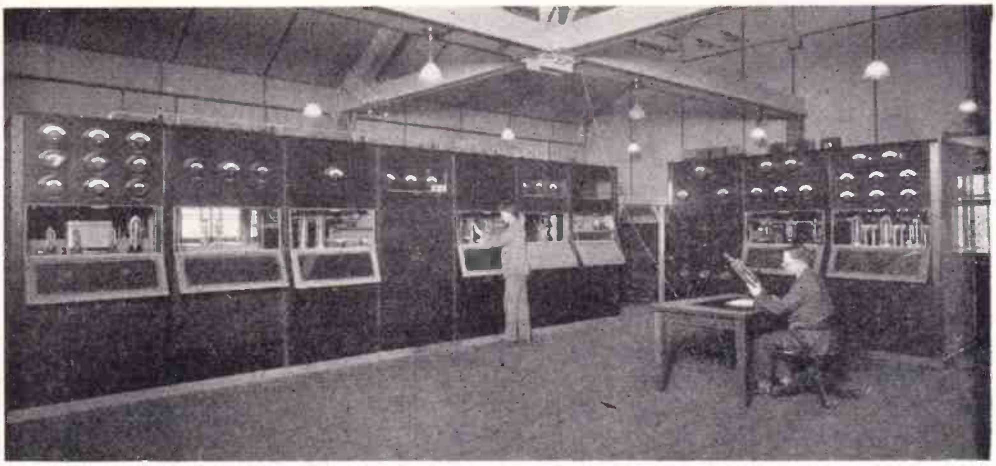
The Fifty-Kilowatt Radio Transmitter of 3XN

MANY late-at-night radio listeners during the past months have been surprised at hearing, with more than ordinary volume, music and speech which in due course they find to have been transmitted from 3XN, Bell Laboratories' experimental station at Whippany. These listeners have been scattered over a considerable portion of the United States and some have been located at far distant points outside of this country. Reports of reception have been particularly gratifying since the tests have been carried on during the summer, a time generally unfavorable to good radio reception.

The particular equipment used in the tests at Whippany is the development model of the Western Electric 7-A Radio Broadcasting Transmitter, rated at 50 kilowatts. It has been created to make possible the provision over areas of reasonable magnitude of broadcasting service consistent with the ever growing requirements of the art.

The transmitter uses twenty-five vacuum tubes, of which fourteen are water-cooled. These tubes and their related circuits are mounted on and behind ten panels; on a floor below are installed some of the bulkier pieces of apparatus such as transformers, generators and filters. While the normal unmodulated output to the antenna is fifty kilowatts the tube capacity is adequate to deliver the 200 kilowatts which are

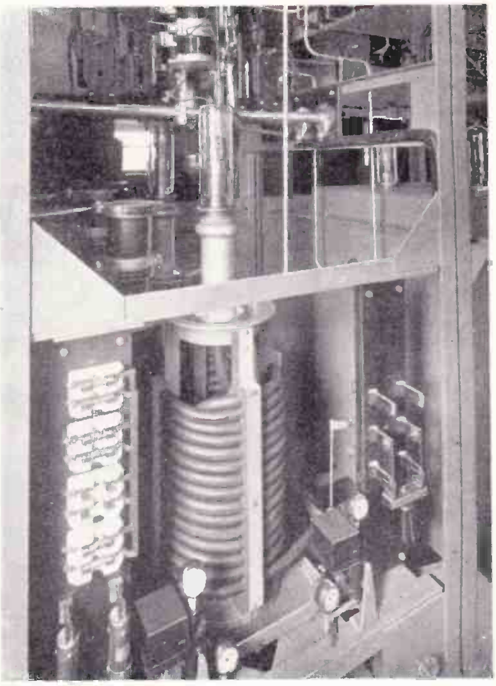
General view of the Whippany Station, 3XN



A general view of the transmitter room at Whippany

required during peaks of modulation.

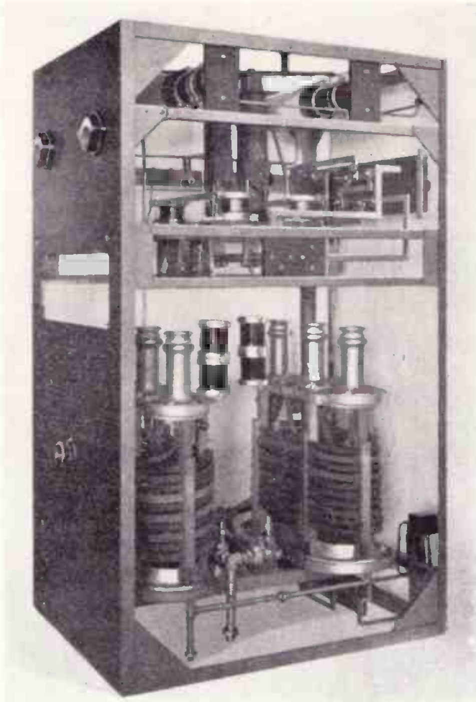
With so many broadcasting stations on the air, it is of first importance that each one maintain its carrier frequency constant at the value assigned by the Federal Radio Commission. To this end, the frequency of the carrier-wave is controlled by the oscillation of a small quartz plate. Cut from a single crystal, with proper orientation as to the crystalline and optical axes, the quartz plate, carefully ground to a thickness determined by the desired frequency, is then associated with a master oscillating circuit. As one precaution to ensure constant frequency, the plate is mounted in a container where its temperature is held constant.



Rear view of the tube unit for the next-to-last stage

Speech currents from the control room are amplified by two stages in the set proper; the output voltage from the last of these is used for modulation. The radio frequency generated by the vacuum tube under control of the crystal is amplified in five stages. On the plate voltage of the second-stage tube is superposed the audio-frequency voltage for modulation. The audio-frequency voltage is sufficient to effect complete or one hundred percent modulation of the carrier. The modulation stage is followed by three more stages of radio frequency amplification, each of which is a push-pull circuit. Water-cooled tubes are used in the last two stages: two in one and six in the other. Tuned circuits form the interstage couplings and also transfer the output power to a transmission line which leads out to the antenna system. In the final tuned circuit, currents as great as one hundred amperes may flow through the heavy copper tubing of the inductance coils.

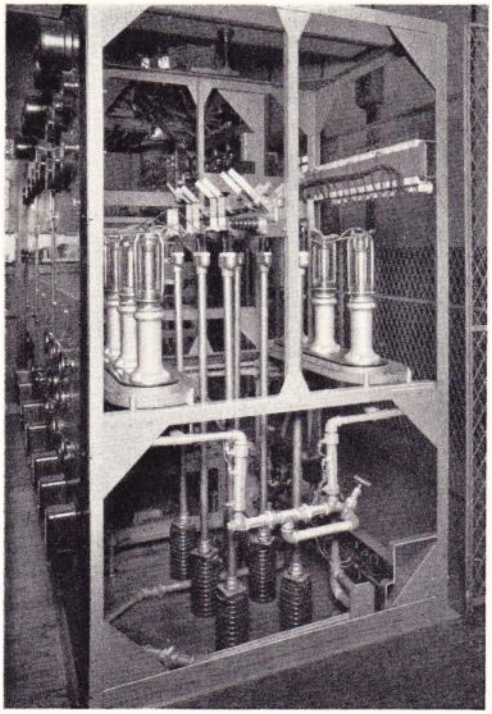
Power for the set, amounting to about 250 kilowatts, is drawn from central station lines as 440 volt, 60-cycle, three phase alternating current. A major portion of this power goes to a six-phase vacuum-tube rectifier which supplies direct current at 17,000 volts to the last two radio stages. Direct current from a 1500-volt rectifier is supplied to the other stages. One motor-generator set supplies about 550 amperes direct current to the amplifier filaments; another set supplies grid-bias voltages. Outputs of both these generators pass through filters, that for the filaments using electrolytic condensers and a large choke coil.



A side view of the last-stage tube unit before the tubes were placed in their jackets

To prevent excessive heating and consequent damage to the vacuum

Cooling water from the tube jackets in turn gives up its heat to the air blown through these radiators



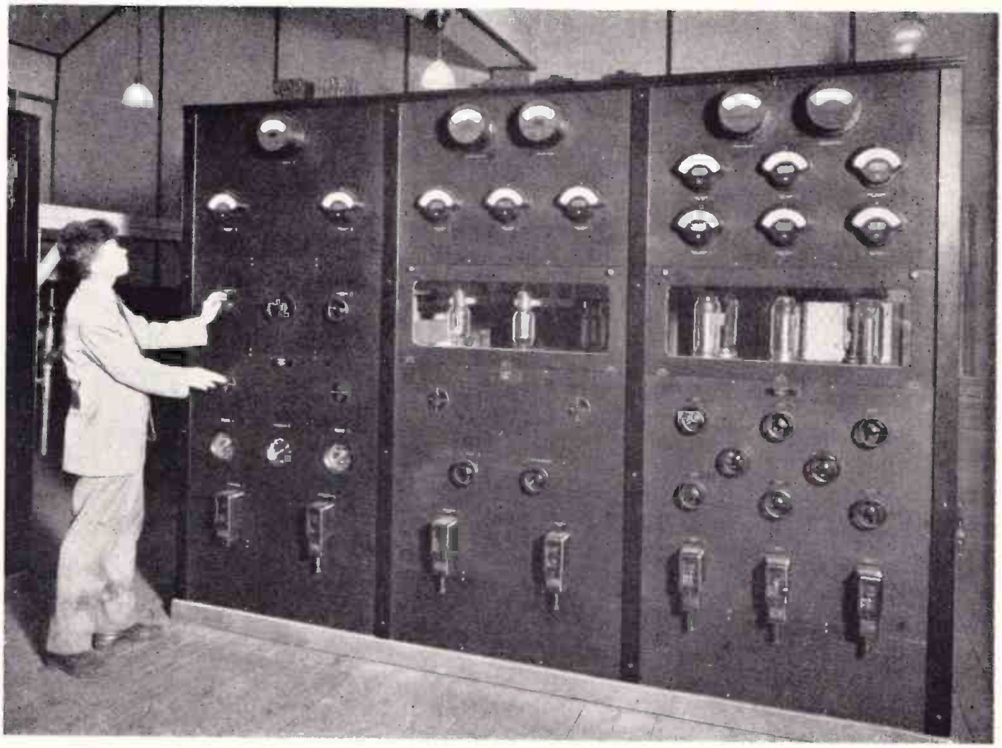
An end view of the power supply group showing the 17,000-volt rectifier tubes

tubes, provision must be made to remove the heat generated in operation. For many of the tubes, radiation into the air is sufficient, but for others water cooling is necessary. These tubes are inserted in jackets through which water flows in contact with the tube anodes. Water is led to and from the tube jackets through lengths of coiled hose. This is to provide the necessary insulation between jackets, which are connected with the anodes and therefore at high potential, and the other parts of the cooling system which are grounded. The water in turn is cooled by radiators through which air is forced by large fans. About a hundred gallons of water a minute flow through the cooling system; should the water cease to flow, or should its temperature rise beyond a safe value, power is automatically removed from the tubes.

The layout of the Whippany laboratory includes a control room where the speech input amplifier and related equipment are located. Adjoining it is the transmitter-room itself. Along one wall of this room is an assembly fronted by seven panels housing the audio and radio frequency circuits. At the end of the room is a group of three panels: one for general power control, which carries the push-buttons by which the set is started and stopped; one for the 17,000-volt rectifier and one for the 1500-volt rectifier. Tubes for these rectifiers are mounted behind their respective panels. The transformers and filtering equipment for the higher-voltage rectifier is located directly beneath, on a lower floor. On this floor are also the motor-generator sets.

In order to keep the station and its equipment outside the more intense field of the antenna, connection is made between the transmitter and antenna by a two-wire line about five

The first three panels of the transmitter



The power-supply group; the panels are respectively for power control, for the 1500-volt rectifier and for the 17,000-volt rectifier

hundred feet long. The voltage between wires is approximately six thousand and the line functions as any other though the power is transmitted at a very high frequency. The tuned circuits for coupling to the antenna are located in shielded compartments at the end of the transmission line directly beneath the antenna.

Much thought has been given to the protection of the operating staff against high voltages. Throughout the transmitter access is had to the circuits through doors and windows which must be securely locked before the circuits can be energized; in order to open these points of access it is necessary to unlock them through a mechanism which first disconnects the power supply and grounds the high voltage parts. All parts requiring adjustment or replacement are readily accessible. Other portions of the apparatus are arranged with a view primarily to the compactness of the equipment. This promotes economy in floor space, facilitates protection, and enables important elements to be observed by a minimum of personnel.

Satisfactory service to broadcast listeners—the sole justification of any station—requires that everything possible be done to minimize interference with other programs. To avoid the annoying "whistle" which results from heterodyning of its carrier with that of a station occupying an adjacent frequency-channel, the carrier must remain very close to its assigned value. This requirement is well met through crystal control. Moreover, radiation of harmonic frequencies must be as little as possible, since this is in effect a transmission of the program at a frequency which may conflict with that assigned to another station. The disturbing effect of harmonics being proportional to their absolute value, special precautions must be taken in the construction of so powerful a transmitter. Careful shielding of the circuits, together with the form of the circuits themselves, have served this purpose so well that the radiation of second harmonic is approximately one-half milliwatt—that is, one hundred-millionth of the fundamental radiation.