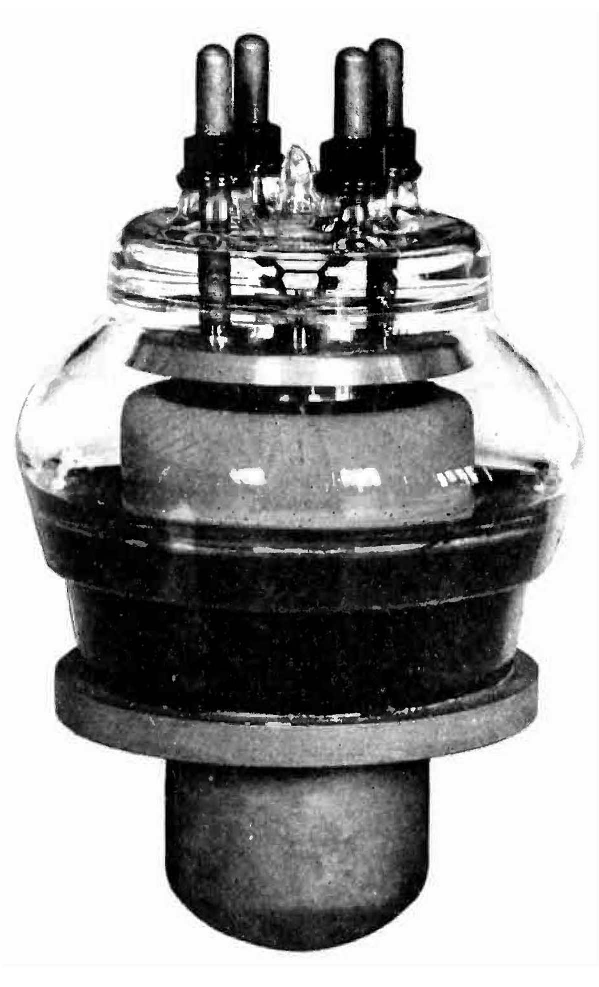
FREQUENCY MODULATED TRANSMITTERS

Twenty-five broadcast stations are making active preparations to go on the air with frequency-modulated transmitters in the near future—and the list is growing. The equipment used, now commercially available, is here reviewed

FREQUENCY modulation has changed its status almost overnight in the minds of broadcast engineers. A few months ago, the system was discussed as an interesting and highly successful method of high fidelity broadcasting which might eventually cause a revolution in the radio industry. Then, suddenly, the interest took on a warmer tone. Now many broadcast engineers are actively considering the system as an operating reality. At the present writing there are about 25 broadcast stations who either have a frequency-modulated station in operation, have received a construction permit, or have applied for a permit, and the list is growing at the rate of two or three stations a week. There is a strong temptation to state that an avalanche of activity in frequency-modulation is now gathering momentum, and indeed every indication points to it. But predictions in the radio industry have a habit of backfiring, so we will content ourselves with a review of the facts as they exist. This review is designed especially for the broadcast engineers and operators who may now be considering applying for a f-m license and who want to know what commercial f-m transmitting equipment is in operation, how much it costs.

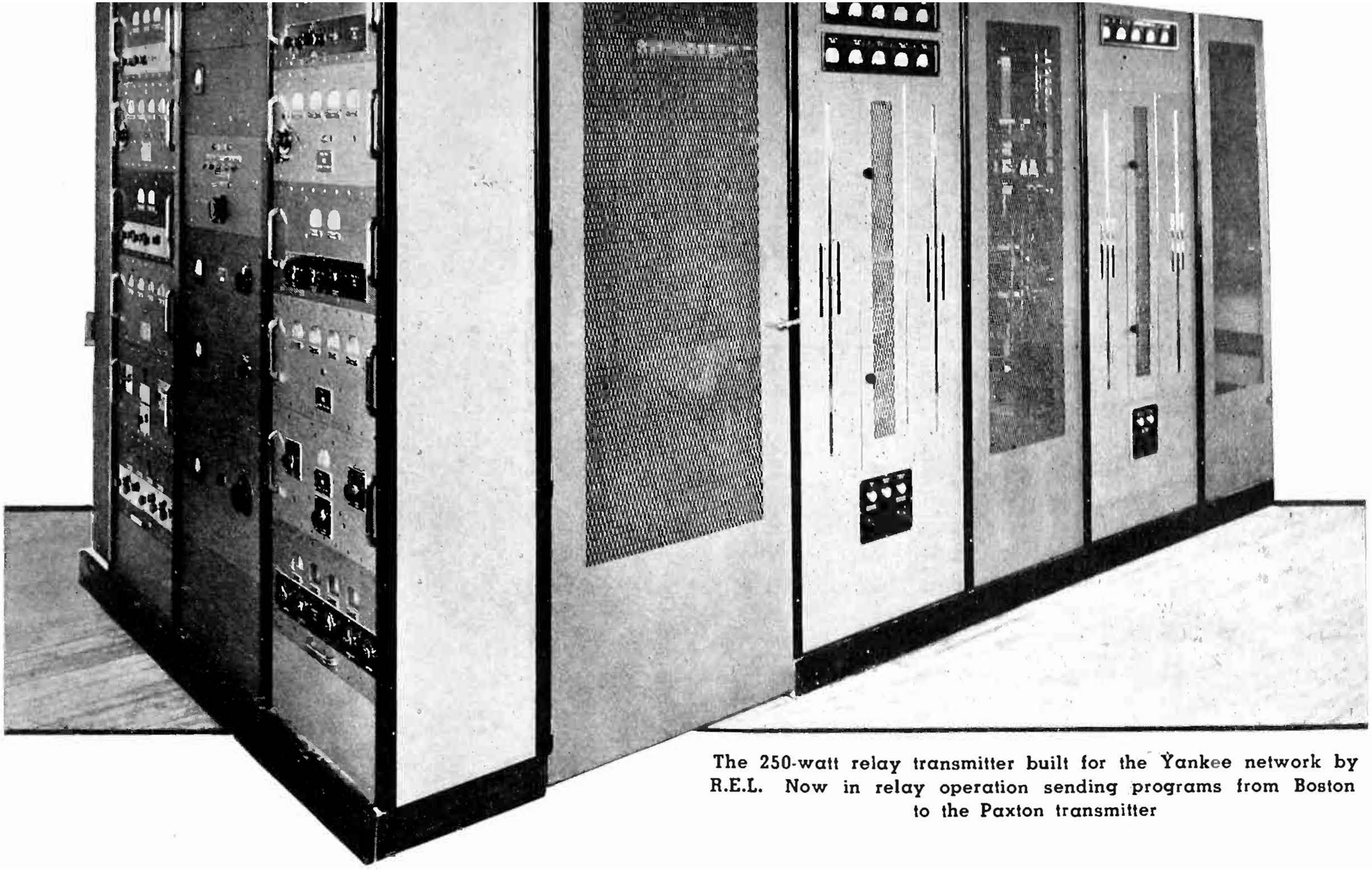


The G. E. "king's crown" tube, type GL-880, developed originally for television, now a part of G.E. f-m transmitters of over 3 kw power

As a preliminary, we can review the status of stations in operation, those in construction and those whose applications are pending. The outstanding transmitter is W2XMN, the 40 kilowatt set owned and operated by Major E. H. Armstrong at Alpine, N. J. This station is now on regular schedule with 30 kw output (40 kw occasionally) from 4 to 11 pm, except Saturdays and Sundays, with the regular programs originating from WQXR and WABC.

In power it will shortly be eclipsed by the Yankee Network Installation, W1XOJ, at Paxton, near Worcester, Massachusetts. At present this station is operating at 2 kw output, broadcasting all the regular programs of the Yankee Network on 43 Mc. Soon a 50-kw amplifier will be added to bring this installation up to its full authorized power. John Shephard, Jr. of the Yankee network has also applied for two *commercial* licenses, one for 5000 watts atop Mount Washington (altitude 6300 feet), and one for 50 kilowatts at Alpine, N. J. These non-experimental applications have not yet been acted upon, but they show the way the wind is blowing. Mr. Shephard, in his applications, states that the period of experimentation with frequency modulation is past, and the time for commercial service has come.

Experimental transmitters now in operation include 1000 watts in Washington (W3XO) operated by Jansky and Bailey. Another consulting firm, McNary and Chambers, are preparing to experiment with the system. Dr. Doolittle, owner of WDRC in Hartford, Conn. has a frequency-modulated station in operation atop the Meriden mountain. The ex-amateur W2AG (now experimental W2XCR), in Yonkers, N. Y., is on the air occasionally, usually as an adjunct to W2XMN in Alpine. A construction permit has been granted



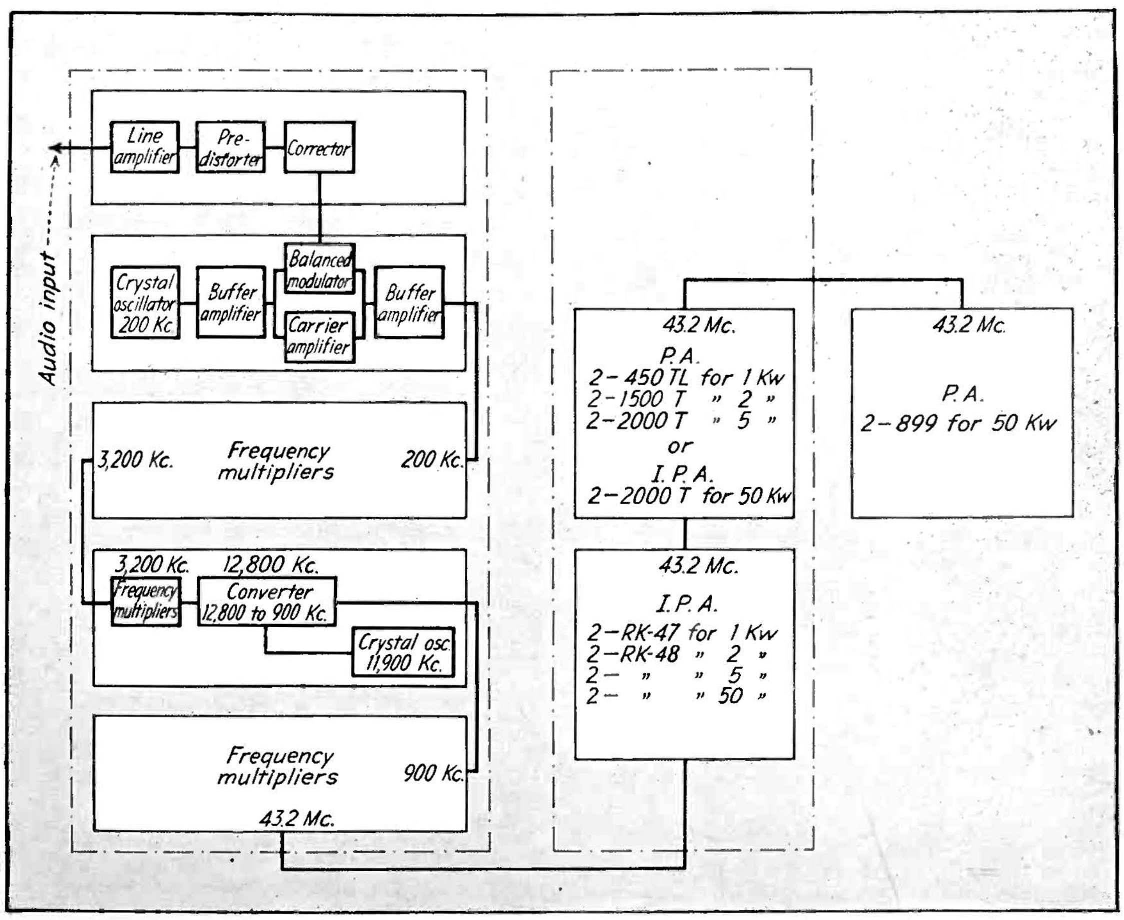
The 250-watt relay transmitter built for the Yankee network by R.E.L. Now in relay operation sending programs from Boston to the Paxton transmitter

to Stromberg-Carlson in Rochester (their 2-kw transmitter will be ready for demonstration to the engineers at the Rochester Fall Meeting, November 13–16). Other c-p applications granted are for WTMJ, Milwaukee, WHEC, Rochester, both 2 kw; WQXR, New York, 1 kw; for the Bell Telephone Laboratories, for the National Broadcasting Company, for the Mutual Broadcasting System (WOR). It was recently announced that the Columbia Broadcasting System has applied for a 50-kw authorization for New York City. WTIC in Hartford, WEBC in Duluth, Minn., WTAG in Worcester and WGAN in Portland, Maine, have permits for construction granted. WFBL, WHDH, and WHIO have applications on file. A Westinghouse station in Springfield, Mass., is in regular operation. Zenith, Chicago, has applied for a 5-kw permit. Before these words can be printed, it is safe to assume that five or ten more applications will be in.

The F-M station most truly representative of the latest practice, from the broadcast engineer's viewpoint, is the transmitter at Paxton, Mass. operated regularly by the Yankee Network. While less powerful, at present, than Major Armstrong's transmitter, it is newer equipment and most significant, it was purchased by an established broadcaster under very much the same conditions which face the rest of the industry.

The Paxton installation makes use of two F-M transmitters. The first is the relay transmitter at Boston, which shoots the programs directionally over the 45-mile path to the Paxton transmitter. The relay equipment has 250 watts power and operates on a center frequency of 133 Mc. The complete relay system is flat, so far as the audio system goes from 30 to 15,000 cps within 1.0 db, and the noise at all times is −65 to −70 db, Distortion at maximum modulation at the low frequencies is measured under one per cent. The claim of the engineering is that this relay system does a better job than a wire line could possibly do, and at considerably less expense. The relay transmitter has two complete modulators, with a change-over switch between them. In the event of failure the switch may be flipped from one modulator to the other in less

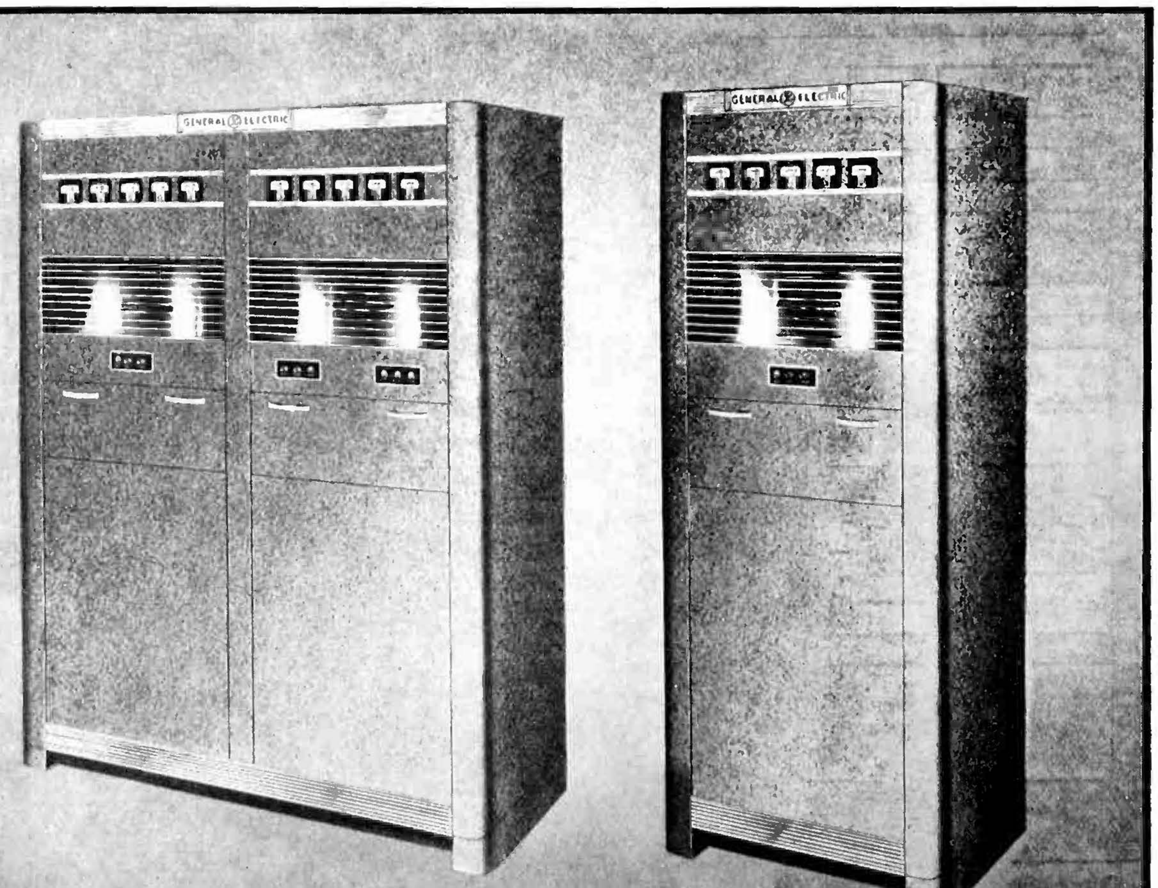
Block diagram of the Armstrong circuit as applied in the R.E.L. equipments from 1 kw to 50 kw output. The 50-kw version is scheduled for early installation at Paxton, Mass.



than a second's time. Thus far in the several months since the station went on the air, this change from one modulator to the other has never been required, but has been carried out to permit checking and maintenance of both units. The transmitting antenna at the Boston end is 4-bays of three elements each, (reflector, radiator, director) horizontally polarized. The receiving antenna is a double V, one V above the other, with reflectors spaced 0.1 wavelength behind each. The length of each leg of the V is about 10 wavelengths. The efficiency of the directive system is such that the final amplifier of the transmitter may be disconnected without observable decrease in the signal-to-noise ratio. Likewise a failure of the V receiving antenna does not interrupt the service.

The transmitting equipment at Paxton is very similar to that of the relay transmitter, so far as the modulating equipment is concerned, but the r-f stages operate at 43 Mc, and the final power output is now 2 kw. The audio input (applied at 0 db) is first put through the predistorter and corrector amplifiers, which employ receiving type tubes. This function is carried out in the uppermost panel of the modulator rack, and takes a total of seven tubes. The audio is then applied to the balanced modulator in the second panel which applies the audio to the output of the 200 kc crystal and buffer stage in such a way that the phase of the output of the modulator shifts by a maximum phase angle of 30 degrees, at the audio frequency rate. Thereafter, this signal with its varying phase shift is multiplied in frequency a total of approximately 3000 times. This seems like a tremendous amount of frequency-multiplication, and judged by ordinary standards it is a very large amount. Nevertheless a multiplication of 1000 times is carried out in but three panels, all of which employ receiving tubes, except the last which employs 807 beam power tubes. In the Paxton transmitter, the 807's operate at one third the carrier frequency but in later models of the same equipment, the full carrier frequency is attained in the 807 stage. In the Paxton transmitter, the modulator output, at one third the final frequency, is fed first to a pair of 807's then a pair of RK-48's and then to a power tripler stage, which produces the carrier frequency in a pair of 1500T tubes and gives a two or three times power gain at the same time. The final amplifier is also a pair of 1500T's. The antenna is a 4-bay turnstile mounted on the top of Mount Asnebumskit, at a total elevation of about 1400 feet above sea level. Signals from this station are received regularly at New York, over a distance of roughly 150 miles. In Boston, at a distance of 45 miles, the signals are so strong as to provide a better service, hour by hour, than that offered by the local Boston stations. When the 50 kw amplifier is added, it is expected that an equally excellent signal will be available in New York, although at present the New York reception does not constitute a regular high fidelity service because of occasional fading and an inadequate signal-to-noise ratio.

Two General Electric transmitters. On the right is the 250-watt modulator-exciter which can act as a low-power transmitter, or, as shown at left, as an exciter for a 1-kw amplifier



Commercially Available Transmitters

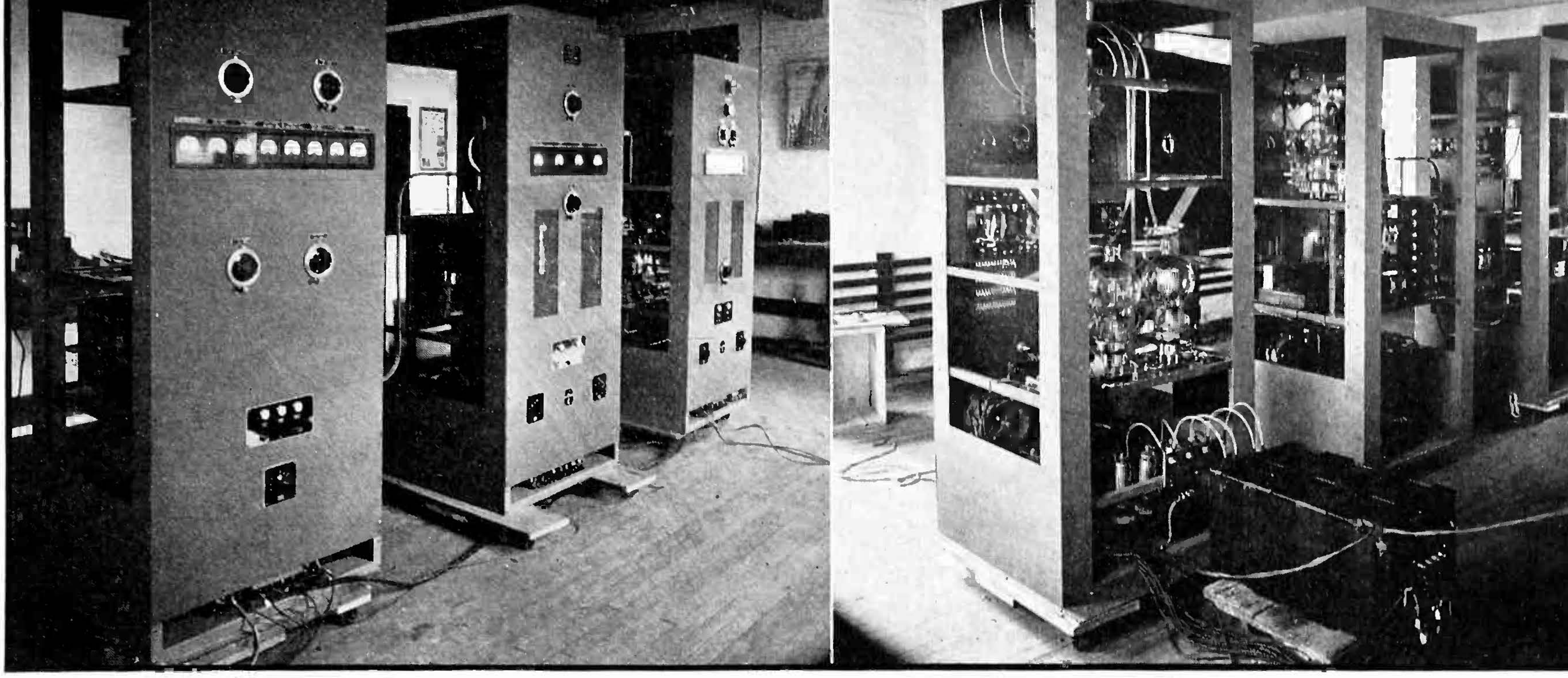
At present three names are associated with the development and manufacture of frequency-modulated transmitters. Westinghouse is building a form of frequency modulated transmitter for their own stations W1XFN at Springfield and W1XKA at Boston and Pittsburgh. It is anticipated that possibly at a later date, Westinghouse may offer commercial equipment for sale.

The General Electric Company, which has been cooperating with Major Armstrong in F-M developments for several years, offers a series of five transmitters. The smallest, 250 watts output, is complete in itself but is intended also for use as a driver stage for higher powers. Designs have been completed for 1-, 3-, 10- and 50-kw frequency-modulated amplifiers. Descriptive specification for all these units are now available.

The G. E. transmitters differ somewhat from the Armstrong method of obtaining frequency modulation in that they employ the so-called "Crosby" circuit. A single crystal is used as the frequency determining source. Feedback is used for stabilization, and reactance-tube modulation is used, which results in a material reduction in the number of tubes required in the modulator. Engineering reports indicate that high fidelity, low distortion characterize the new transmitters, and that their operation is simple, economical and reliable.

In the power amplifiers of 3 kw power and higher, the new 880 "king's crown" tube is used. This tube was originally designed for television service, and proved to have many advantages in u-h-f service. It is a water-cooled triode with a reëntrant anode shell which reduces the electrode length without reducing the cooling surface.

General Electric is now building a high power F-M station near the site of their television transmitter on the Helderberg mountains near Schenectady. The relay channel for the television sound is also operated



The 2-kw Yankee Network equipment now operating regularly from Paxton, near Worcester, Mass., as it appeared when on test in the R.E.L. plant. The addition of a 50-kw class-C amplifier will shortly increase the power to 50 kw

on a low-power directional F-M system.

The third name in the commercial picture is the Radio Engineering Laboratories in Long Island City, N. Y. This concern built the modulator and all the amplifier stages, except the final, for Major Armstrong's Alpine station, and they are also responsible for the relay and main transmitters at the Paxton location.

The R.E.L. line includes the basic modulator with 10 watts output at carrier frequency (this power output is not intended for actual transmissions, although the modulator is in itself a complete low-power F-M transmitter). The amplifiers available are of 1-, 2-, 3-, 5- and 50-kw rated output.

The stage line-up for the R.E.L. transmitters is shown in the accompanying block diagram. The modulator is quite similar to that described above (the Paxton transmitter) but the output, instead of being at one-third the carrier frequency, is at the carrier frequency itself. The final stage in the modulator is a pair of 807 beam power tubes, all other tubes in the set-up being receiving type tubes.

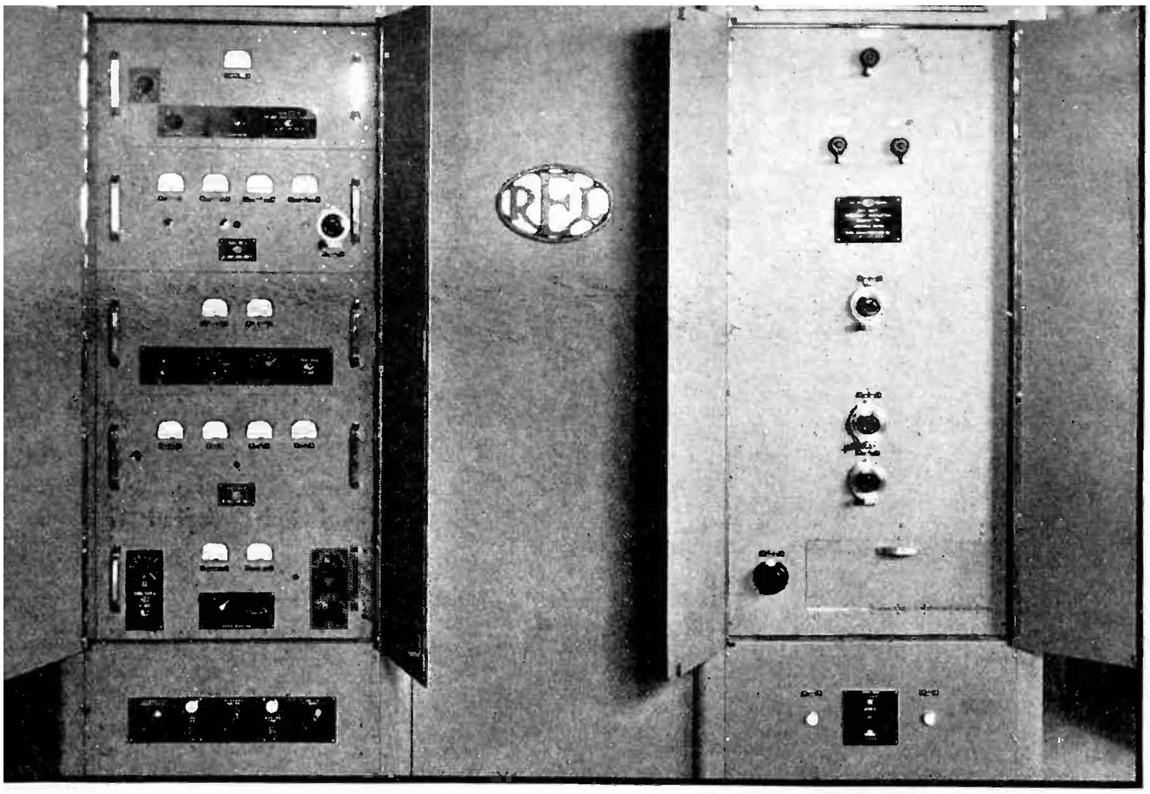
The power amplifiers for 1-kw service make use of a pair of RK-47 tubes in class C "telegraph" service which drive a pair of 450TL tubes in the output stage. The power supply for this transmitter is included in the cabinet with the amplifiers. The 2-, 3-kw outfits make use of a pair of RK-48's in the driver stage, and a pair of 1500T's in the final out-put. The 5-kw final uses 2000T's. The main difference for the various powers is in the power supply. The 50-kw amplifier employs a pair of 899 tubes (formerly called AW-200 tubes) which are of the conventional water-cooled variety, having a conventional anode shell but adapted to u-h-f service. These tubes form the final stage of the Alpine transmitter.

Several of the operating characteristics of these transmitters are of interest. All the small receiving tubes in the modulator unit are operated at 180 volts, whereas the maximum tube ratings are 250 volts or more. The 807 output stage of the modulator operates at 350 volts (maximum tube rating of 600 volts), Hence the tube economy is high, and failures are so rare that they can be readily circumvented by periodic checking. The total frequency multiplication in the modulator unit is of the order of 3000 times (from 200 kc to about 43 Mc with one intermediate frequency conversion downward). The final amplifiers, in the 1-, 2-, 3-, and 5-kw equipment, have plate efficiencies of the order of 60 to 70 per cent. The total frequency swing for 100 per cent modulation is about 150 kc, 75 kc each side of the center frequency.

Power and Price

Most of the present FCC authorizations for F-M service call for power of one or two kilowatts, with a few permits and one or two applications for 50 kw. The prices of transmitter, complete with power supply, tubes and crystal controls, but no site, building, antenna or installation are roughly \$8000 to \$10,000 for a 1-kw transmitter to \$65,000 to \$85,000 for a 50-kw equipment, with intermediate powers in rough proportion. For the low power equipment (below 1 kw) the principal item of cost is for the modulator, but at high power, the cost is taken up almost entirely with the high power tubes, circuits and power supplies. Corresponding prices for amplitude modulation equipment of 50-kw carrier power for the b-c band are roughly 25 to 35 per cent higher. Thus far no one has built a 50-kw a-m transmitter for the u-h-f bands, but its cost would certainly be very much more.

One of the interesting aspects of the power problem is the ease with which power may be increased or decreased when special conditions arise. One such condition is the forming of ice on antennas and feeders. In the high and exposed locations where F-M transmitters are usually located, the icing conditions may be very severe. Feeder systems which have been trimmed up to eliminate standing waves under normal conditions may show a considerable increase in the standing wave amplitude when ice begins to form. In that case the power of the transmitter may be reduced temporarily to whatever level is necessary to protect the feeder and antenna from the voltage peaks set up by the standing waves. Power reduction in a-m equipment involves reducing the modulator level simultaneously with the r-f level, but in



R.E.L. 2-kw transmitter, similar in appearance to the 1-kw and 5-kw outfits. The modulator at the left develops the carrier frequency at 10 watts, while two class-C stages at the right feed the antenna

f-m it is only necessary to reduce the plate voltage on the final r-f amplifier. Such reduction of power does temporarily reduce the quality of the transmissions at the fringes of the service area, but the effect on the bulk of the audience will go entirely unnoticed until conditions permit the power to be raised to its normal level. This simple adjustment of plate voltage is characteristic of the ease with which the class C amplifiers may be controlled, and is indicative also of the reliability and simplicity of class C operation. Broadcast operators in general (unless they happen to be hams with straight telegraph equipment of high power) are not familiar with the day-in day-out workability of the constant-level class C amplifier since this mode of operation has no use in a-m practice.

Raising the power is similarly simple. Tubes and power supplies will take plenty of load when not subjected to peaks of power, so that air-cooled tubes can be used, even at 40 Mc, for power levels up to 10 kw. But of even greater significance from the long-range point of view is the ease with which higher power stages can be added to existing equipment. Both manufacturers now offering commercial equipment have so designed their units that additional amplifiers may be added with a minimum of changes, and with practically no detriment to the appearance of the equipment. Thus many of the present f-m broadcasters have bought 2 or 3-kw transmitters, even though their construction permit calls only for 1 kw, in anticipation of operating the equipment at 1 kw output until conditions warrant higher power and the permit to use it is obtained. A 2 kw final amplifier makes an excellent driver for a 50 kw stage, if the latter should be added at a later date. Thus the present investment in equipment is not lost in the event that higher power becomes the rule on the F-M channels.

Monitoring equipment is available for use with each of the transmitters described above. A typical unit made by R.E.L. is a 10-tube receiver which tunes through the range from 40 to 44 Mc, and which has a pair of 6V6 beam power tubes in the audio output.

Receivers intended for the home, while not of direct concern to the broadcast engineer, are of general interest to all those of the radio fraternity who may desire to check the new system for themselves. Besides the R.E.L. monitor model which sells for $120 (speaker column $75), the General Electric and Stromberg-Carlson lines for 1940 contain receivers of several types. A G.E. 8-tube table model receiver for a price of about $60, contains circuits for F-M only, has an intermediate value of sensitivity, and adequate, but not elaborate audio equipment (five watts output). A similar "F-M only" receiver is available also in a console. The most elaborate receiver is a 13-tube outfit providing reception on both f-m and a-m with 20 watts audio output.

The Stromberg-Carlson line includes a table model for about $60 which includes F-M only, which is equipped with a high-frequency tweeter speaker. The low-frequency output is fed to the phonograph input jack of any standard broadcast receiver. This receiver comes close to being a "frequency-modulation attachment" despite the fact that it is a complete receiver. Two more elaborate models containing a-m as well as f-m circuits are also available in the Stromberg-Carlson line. One is a medium-priced console model, the other a more elaborate console with an acoustic labyrinth.

—D.G.F.

10-tube f-m monitor receiver furnished by R.E.L. for general service in conjunction with their transmitters. The r-f sensitivity is 10 microvolts