RADIO - TELEVISION

Practical Training

NATIONAL SCHOOLS

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Transmitters

LESSON NO. 1

• EARLY TRANSMITTERS •

In one of the first lessons which you studied and which is titled "Radio Communication", you learned in a general way what radio transmitters are expected to accomplish. You were also at that time introduced to the different sections which are incorporated in the typical transmitter and their respective duties.

All of these units, as well as many more, are now going to be explained to you in detail in the present series of lessons.

CLASSIFICATION OF TRANSMITTERS

We can classify radio transmitters into two general groups, namely, those which are used to send messages by means of the telegraphic code and those which are used for the transmission of voice and musical programs.

The code type transmitter was the first form of successful transmitter and is still being most extensively used in the handling of commercial traffic, by amateurs, etc. Code signals can be received successfully over greater distances than can voice or phone transmission but each type of transmission, of course, has its particular advantages.

Code transmitters are simpler than phone transmitters from the standpoint of both design and construction and therefore we shall study code transmitters first. Many of the components and principles, however, are the same in both types of transmitters so that what you learn by a study of one can

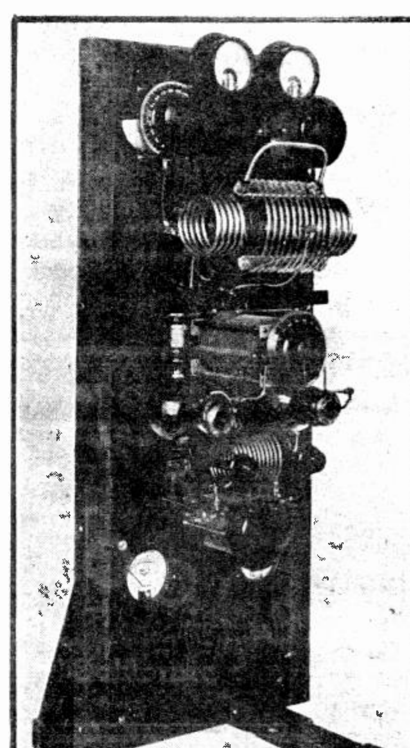

FIG. 1
A Typical Transmitter.

BE APPLIED EQUALLY WELL TO THE OTHER.

ALL MODERN TRANSMITTERS, WHETHER OF THE CODE OR PHONE TYPE, EMPLOY VACUUM TUBE OSCILLATORS BUT SINCE THE FIRST TRANSMITTERS DEPENDED UPON "SPARK OSCILLATORS", "ARC OSCILLATORS" ETC., IT WILL BE WELL FOR US TO CONSIDER THESE TYPES BRIEFLY BEFORE ENTERING THE STUDY OF THE MORE MODERN SYSTEMS. THIS WILL GIVE YOU A BETTER IDEA OF THE DEVELOPMENT AND ADVANCEMENT MADE IN THE FIELD OF TRANSMISSION.

THE SPARK TRANSMITTER

IN FIG. 2 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF A SIMPLE FORM OF COMMERCIAL TYPE SPARK TRANSMITTER.

HERE WE HAVE FIRST AN A.C. GENERATOR WHICH PRODUCES A VOLTAGE SOURCE HAVING A FREQUENCY OF APPROXIMATELY 500 CYCLES. THIS GENERATOR IS GENERALLY DRIVEN BY AN ELECTRIC MOTOR WHOSE ARMATURE SHAFT IS COUPLED TO THE ARMATURE SHAFT OF THE GENERATOR SO AS TO FORM A MOTOR-GENERATOR SET SIMILAR IN APPEARANCE TO THOSE ABOUT WHICH YOU STUDIED IN YOUR LESSONS PERTAINING TO BATTERY CHARGING EQUIPMENT.

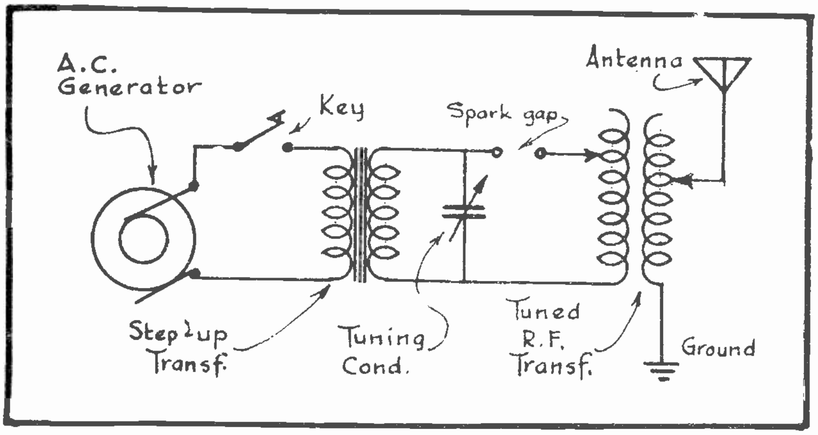

FIG. 2
A Simple Form of Spark Transmitter.

A TYPICAL KEY, AS USED WITH CODE TRANSMITTERS, IS ILLUSTRATED FOR YOU IN FIG. 3. THESE KEYS ARE GENERALLY KNOWN AS "TELEGRAPH KEYS" OR "WIRELESS KEYS" AND THEY CONSIST ESSENTIALLY OF A PAIR OF CONTACT POINTS WHICH ARE NORMALLY HELD IN AN OPEN POSITION BY SPRING TENSION. BY PRESSING DOWNWARD ON THE KNOB, WHICH IS MOUNTED ON THE END OF THE ARM, THE CONTACT POINTS ARE FORCED CLOSED IN ORDER TO COMPLETE THE CIRCUIT.

LATER ON YOU WILL BE GIVEN MORE COMPLETE INFORMATION REGARDING THE DIFFERENT TYPES OF KEYS AND THE TECHNIQUE OF USING THEM CORRECTLY. FOR THE PRESENT, LET US CONFINE OUR ATTENTION TO THE OPERATION OF THE CIRCUIT NOW UNDER CONSIDERATION.

RETURNING TO FIG. 2, WE FIND THAT WHEN THE KEY IS IN THE CLOSED POSITION, THE GENERATOR CIRCUIT THROUGH THE PRIMARY WINDING OF THE STEP-UP TRANSFORMER IS COMPLETE SO THAT A 500 CYCLE ALTERNATING CURRENT WILL FLOW THRU THIS WINDING.

BY INDUCTION, A MUCH HIGHER VOLTAGE WILL APPEAR ACROSS THE SECONDARY WINDING OF THE STEP-UP TRANSFORMER. IN THIS MANNER, A HIGH VOLTAGE IS APPLIED ACROSS THE TUNED OSCILLATOR CIRCUIT WHICH CONSISTS OF THE PRIMARY WINDING OF THE R.F. TRANSFORMER, THE TUNING CONDENSER AND THE SPARK GAP. THESE COMPONENTS OF THE TUNED R.F. CIRCUIT ARE ALL CONNECTED IN SERIES WITH EACHOTHER.

NOW THEN, NOTICE PARTICULARLY THAT THE SPARK GAP SERVES TO INTRODUCE AN OPEN CIRCUIT IN THE TUNED OSCILLATING CIRCUIT SO THAT NO OSCILLATING CURRENT WITH WHICH TO GENERATE RADIO FREQUENCY ENERGY FLOWS THROUGH THIS CIRCUIT AT THE TIME THE A.C. VOLTAGE BEGINS TO RISE TOWARDS ITS PEAK VALUE.

THE DISTANCE BETWEEN THE ELECTRODES OF THE SPARK GAP IS SO ADJUSTED THAT WHEN THE A.C. VOLTAGE REACHES A CRITICAL VALUE, THE CHARGE WHICH HAS BEEN BUILT UP ACROSS THE ELECTRODES OF THE SPARK GAP, AS WELL AS ACROSS THE TUNING CONDENSER PLATES, BECOMES SUFFICIENTLY GREAT TO OVERCOME THE RESISTANCE OF THE AIR GAP AND IT THEREFORE DISCHARGES ACROSS THE AIR GAP IN THE FORM OF A SPARK. WE THEN SAY THAT THE SPARK GAP "BREAKS DOWN".

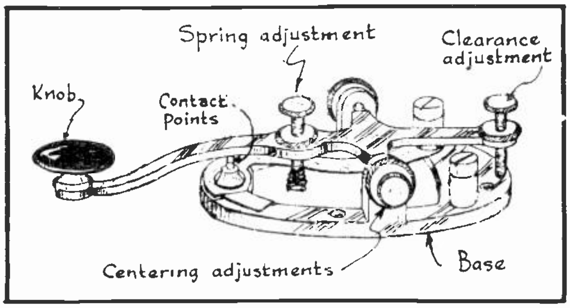

FIG. 3
A Telegraph Key.

THIS ACTION RESULTS IN A HIGH FREQUENCY OR OSCILLATING CURRENT BEING SET-UP IN THE TUNED HIGH FREQUENCY CIRCUIT OF THE TRANSMITTER. THIS CURRENT CONTINUES TO FLOW UNTIL THE VOLTAGE DROPS TO A VALUE LOW ENOUGH SO AS TO PERMIT THE RESISTANCE ACROSS THE SPARK GAP TO PREVENT ANY FURTHER FLOW OF CURRENT. THE VOLTAGE THEN COMMENCES TO BUILD UP AGAIN UNTIL ANOTHER SPARKING DISCHARGE OCCURS WITH ITS RESULTING FLOW OF RADIO FREQUENCY CURRENT THROUGH THE TUNED CIRCUIT AND AGAIN THIS RADIO FREQUENCY CURRENT DIES DOWN AS THE VOLTAGE DROPS IN VALUE. THIS CYCLE OF EVENTS CONTINUES IN THIS MANNER AS LONG AS THE KEY IS HELD CLOSED.

THE FREQUENCY OF OSCILLATION AS OCCURRING IN THIS CIRCUIT IS GOVERNED LARGELY BY THE TUNING CONSTANTS OF THIS SAME CIRCUIT AS DETERMINED BY THE CAPACITY OFFERED BY THE TUNING CONDENSER IN CONJUNCTION WITH THE INDUCTANCE VALUE OF THE R.F. TRANSFORMER'S PRIMARY WINDING. SO AS TO PROVIDE THE DESIRED TUNING RANGE, THE CONDENSER IS OF THE VARIABLE TYPE, WHILE THE PRIMARY WINDING OF THE R.F. TRANSFORMER IS GENERALLY SPACE-WOUND WITH LARGE DIAMETER BARE COPPER WIRE OR ELSE COPPER TUBING SO THAT THE COIL BECOMES SELF-SUPPORTING AND REQUIRES NO WINDING FORM. SPRING CLIPS ARE THEN USED AS ILLUSTRATED IN FIG. 4 SO THAT THE CONNECTIONS TO THE COIL CAN BE VARIED IN A CONVENIENT MANNER SO THAT AS MANY TURNS OF THE COIL AS NECESSARY CAN BE INCLUDED IN THE TUNED CIRCUIT IN ORDER TO OBTAIN THE DESIRED INDUCTANCE VALUE.

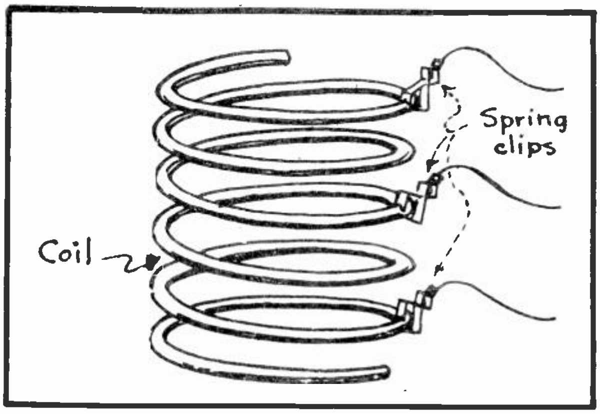

FIG. 4
A Variable-Inductance Coil.

SINCE THE SECONDARY WINDING OF THIS SAME R.F. TRANSFORMER IS INCLUDED IN THE ANTENNA CIRCUIT OF THE TRANSMITTER, WHILE AT THE SAME TIME BEING INDUCTIVELY COUPLED TO THE PRIMARY WINDING, IT IS CLEAR THAT THE ELECTRICAL OSCILLATIONS WHICH ORIGINATE IN THE TUNED CIRCUIT WILL BE TRANSFERRED BY INDUCTION TO THE SECONDARY WINDING. WITH THE OSCILLATING OR RADIO FREQUENCY CURRENT NOW FLOWING IN THE ANTENNA SYSTEM, IT WILL PRODUCE RADIO FREQUENCY WAVES WHICH ARE RADIATED OUT INTO SPACE.

SPARK GAPS

IN THE TRANSMITTER CIRCUIT OF FIG. 2 OF THIS LESSON, WE DEALT WITH A SIMPLE SPARK GAP CONSISTING OF TWO METAL BALLS SEPARATED BY AIR. A GAP AS THIS BECOMES QUITE HOT AFTER BEING IN CONTINUOUS OPERATION FOR SOME TIME AND THUS HAS A TENDENCY TO ARC. THIS ARCING EFFECT CAUSES THE AIR BETWEEN THE SPARK CONTACTS TO REMAIN A CONDUCTOR AND THIS WILL NOT PERMIT THE CONDENSER TO BE CHARGED TO ITS FULL CAPACITY. THAT IS, THE CONDENSER WILL DISCHARGE AT A POTENTIAL LOWER THAN DESIRED AND INSTEAD OF THE OSCILLATIONS IN THE CLOSED CIRCUIT BEING STOPPED AFTER THE AERIAL CIRCUIT HAS STARTED RADIATING ITS WAVES, WE FIND THAT THIS CONTINUAL ARCING ACROSS THE SPARK GAP ADDS EXTRA WAVES UPON THE ORIGINAL WAVE FORM, THEREBY PREVENTING TRANSMISSION OF "CLEAN CUT" WAVES.

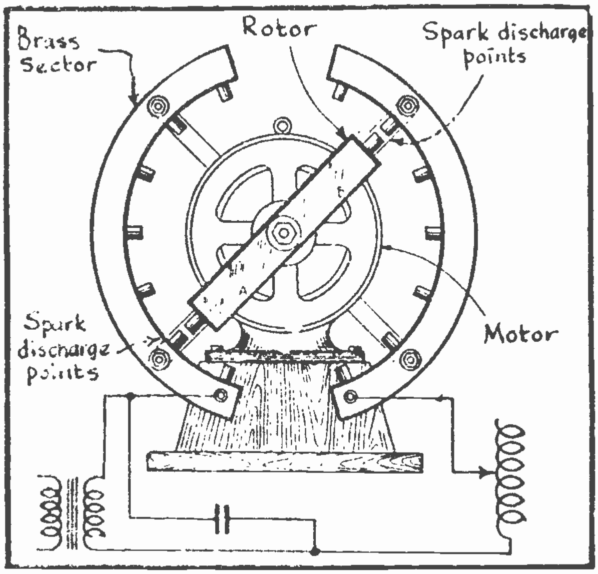

FIG.5
Non-Synchronous Discharger.

TO PREVENT THIS ILL EFFECT AND SO THAT MORE INTELLIGIBLE SIGNALS CAN BE TRANSMITTED, VARIOUS TYPES OF SPARK GAPS WERE DEVELOPED. IN FIG. 5 YOU WILL SEE A SPARK DISCHARGER, WHICH IS KNOWN AS A "NON-SYNCHRONOUS DISCHARGER." IN THIS CASE, A ROTOR ARM IS FIRMLY FASTENED AT THE CENTER TO THE ARMATURE SHAFT OF AN ELECTRIC MOTOR, SO THAT IT MUST ROTATE AS THE MOTOR'S ARMATURE SHAFT REVOLVES.

A SPARK DISCHARGE POINT IS FASTENED TO EACH END OF THIS ROTOR AND FOURTEEN OTHER SPARK DISCHARGE POINTS ARE FASTENED TO TWO STATIONARY BRASS SECTORS.

THE OSCILLATION CIRCUIT OF THE TRANSMITTER IS CONNECTED ACROSS THE DISCHARGER AS SHOWN AND WHEN THE ROTOR LINES UP WITH A PAIR OF STATIONARY ELECTRODES AS SHOWN IN FIG. 5, THEN THE SPARK CAN DISCHARGE ITSELF ACROSS THE TWO SPARK GAPS IN ORDER TO COMPLETE ITS CIRCUIT.

AS THE ROTOR REVOLVES, IT WILL CONTINUALLY BE CHANGING POSITIONS WITH RESPECT TO THE STATIONARY ELECTRODES, PERMITTING THE SPARK TO DISCHARGE THROUGH A DIFFERENT PAIR AS THE ROTOR REVOLVES. THIS PREVENTS OVER-HEATING OF THE CONTACT POINTS FOR ONE THING AND IN ADDITION, WE FIND THAT A MUSICAL PITCH IS PRODUCED AND THIS HELPS A GREAT DEAL IN "READING" THE CODE AT A RECEIVER, DUE TO ITS CLEARER AND MORE PRONOUNCED SIGNALS.

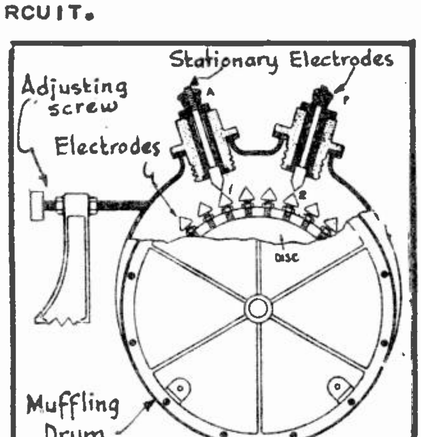

FIG. 6
Synchronous Rotary Discharger.

THE DRIVING MOTORS FOR SUCH DISCHARGERS GENERALLY RUN AT A SPEED OF FROM 1700 TO 3000 REVOLUTIONS PER MINUTE. THE REASON FOR CALLING THIS UNIT A "NON-SYNCHRONOUS" DISCHARGER is that the speed of the motor bears no relation to the frequency of the condenser charging current. In transmitters using a current of 60 cycles in their high voltage transformer, the rotor is generally driven at a speed which will deliver from about 200 to 300 spark discharges per second.

The most popular spark discharger is shown in Fig. 6 and this is known as a "Synchronous" rotary spark discharger. It consists of a metal disc, which is firmly keyed and locked to the shaft of the alternator. On the outer edge of this disc, you will find a number of pointed copper spark electrodes but the number of these disc electrodes will always be equal to the number of field poles, which are used in the alternator.

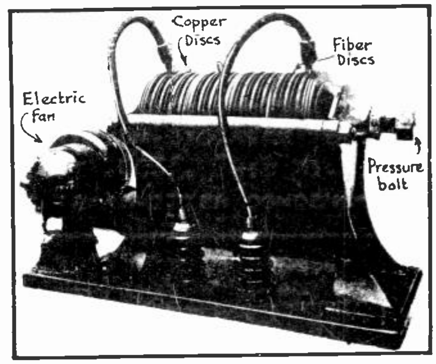

FIG. 7
Quenched Spark Discharger.

Because of the disc being driven directly by the alternator, as well as having spark electrodes of a number equal to the number of field poles within the alternator, we find that the discharge of the transmitter condenser will be accurately timed with the alternations of the charging current. It is for this reason that this type of spark discharger is reffered to as a "synchronous" discharger. That is, any two things, which are perfectly timed to eachother, are spoken of as being SYNCHRONIZED and this of course is the case with this type of discharger.

Two stationary electrodes are used, as shown in Fig. 6, and the oscillating circuit of the transmitter is connected across these two stationary electrodes. By regulating the adjusting screw, labeled in Fig. 6, the muffling drum can be shifted on its axis and in this way cause the stationary contacts to alter their position somewhat in relation to the driven disc. This adjustment permits the most favorable sparking point to be located and results in synchronous discharges, giving a clear, musical spark note.

Besides this adjustment for pitch, it is also necessary to have the spark gaps adjusted so as to give the shortest possible discharge gap without permitting the electrodes to touch. The minimum distance between the stationary and revolving points should be about .005". This will give a clear spark discharge and will not subject the transmitter condenser to

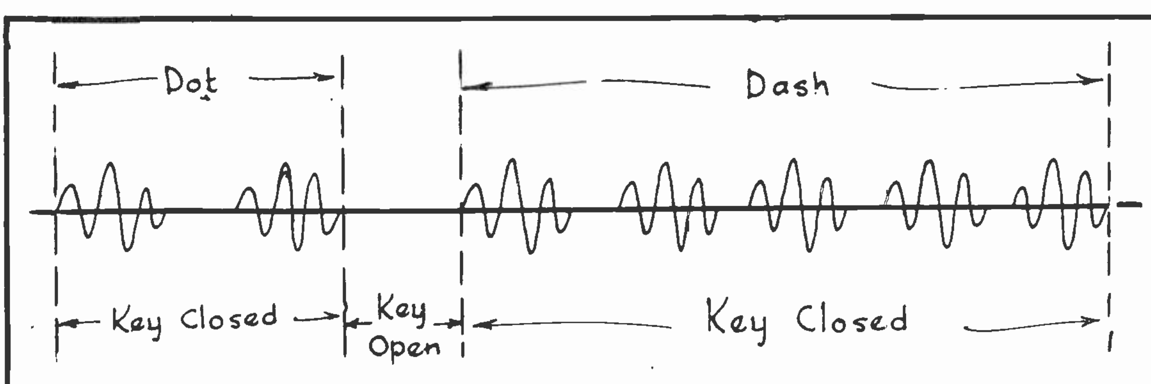

FIG. 8
Wave Radiation From Spark Transmitter.

AN ABNORMAL STRAIN.

SHOULD THE CIRCUIT OSCILLATION AT ANY ONE INSTANT BE SUCH AS TO FLOW INTO STATIONARY CONTACT "A", THEN THE SPARK WILL JUMP FROM THE CONTACT AT THE BOTTOM OF "A" OVER TO CONTACT #1 ON THE DISC. THENCE THROUGH THE DISC OVER TO ELECTRODE #2 AND ACROSS THE GAP TO STATIONARY CONTACT "B" AND IN THIS WAY RETURNING TO ITS ORIGIN. THE SYNCHRONOUS DISCHARGER IS CAPABLE OF HANDLING A LARGE AMOUNT OF POWER AND THEY HAVE BEEN SUCCESSFULLY OPERATED AT 500 KW.

IN SOME TRANSMITTERS, A "QUENCHED SPARK GAP" IS USED AND A PICTURE OF THIS TYPE GAP IS SHOWN IN FIG. 7. THIS DISCHARGER IS MAINLY USED IN THE LOWER POWER SPARK TRANSMITTERS, WHEREAS THE SYNCHRONOUS DISC DISCHARGER IS USED FOR THE SPARK TRANSMITTERS OF HIGHER POWER RATING.

THIS QUENCHED SPARK DISCHARGER CONSISTS OF A NUMBER OF COPPER DISCS SEPARATED FROM EACHOTHER BY SOME SUCH INSULATING MATERIAL AS FIBRE, MICANITE ETC. THESE COPPER AND INSULATING DISCS ARE PLACED IN AN IRON RACK AND AND COMPRESSED BY MEANS OF A PRESSURE BOLT. THE THICKNESS OF THE WASHERS OR INSULATING DISCS IS SUCH THAT THE SPACE BETWEEN THE COPPER SPARKING SURFACES OF A SINGLE SET OF COPPER DISCS DOES NOT EXCEED .01 INCH.

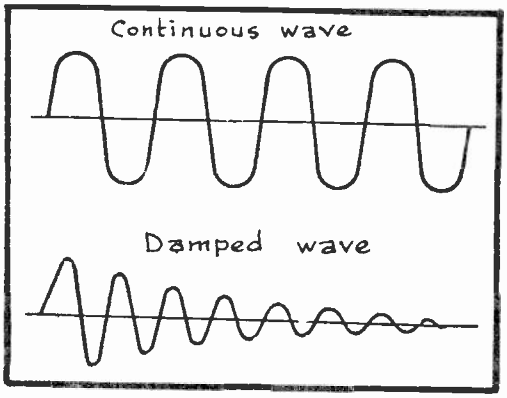

FIG.9
Continuous and damped waves.

THE INSULATING DISCS ARE ALSO SPECIALLY TREATED AND INSTALLED SO THAT THE DISCHARGE SURFACE IS AIRTIGHT AND THIS MAKES A NOISLESS DISCHARGE POSSIBLE, AT THE SAME TIME AIDING IN THE WORK OF QUENCHING OUT THE OSCILLATIONS IN THE OSCILLATING CIRCUIT.

A MOTOR-DRIVEN FAN OR BLOWER PROVIDES A DRAFT OF AIR OVER COOLING FLANGES OF THE SPARK DISCHARGER AND IN THIS WAY COOLS THE GAP.

WITH VERY LOOSE COUPLING BETWEEN THE COILS OF THE OSCILLATION OR R.F. TRANSFORMER, PRACTICALLY ANY TYPE OF SPARK GAP WILL PERMIT SATISFACTORY QUENCHING OF OSCILLATIONS, WHICH TEND TO CONTINUE IN THE OSCILLATOR CIRCUIT DURING THE RADIATION OF THE WAVE BUT THE QUENCHED SPARK DISCHARGER SHOWN IN FIG. 7 GIVES A SATISFACTORY QUENCHING RESULT, EVEN WHEN THE ANTENNA CIRCUIT IS CLOSELY COUPLED TO THE OSCILLATOR CIRCUIT AND THIS OF COURSE MAKES A GREATER ENERGY TRANSFER POSSIBLE WITH LESS POWER LOSS.

DUE TO THIS ADVANTAGE OF THE QUENCHED GAP, THE ANTENNA OSCILLATES AT BUT A SINGLE FUNDAMENTAL FREQUENCY AND WILL THEREFORE RADIATE A SINGLE WAVE, WITH NO ADDITIONAL WAVES SUPERIMPOSED UPON IT, BUT WHICH WOULD OTHERWISE OCCUR WITH THE SIMPLE FORM OF SPARK GAP.

THE RADIATED WAVE

NOW LET US CONSIDER THE NATURE OF THE SIGNAL WAVE WHICH IS RADIATED BY THE ORDINARY TYPE OF SPARK TRANSMITTER, SUCH AS SHOWN IN FIG. 2. A TYPICAL EXAMPLE OF SUCH WAVE RADIATIONS APPEAR IN FIG. 8.

STARTING AT THE LEFT OF THIS DRAWING, WE FIND THAT WHEN THE KEY IS HELD CLOSED FOR A SHORT DURATION OF TIME, A SERIES OF HIGHLY DAMPED WAVE GROUPS COMMENCE LEAVING THE ANTENNA. THE LONGER THAT THE KEY IS HELD CLOSED, THE GREATER WILL BE THE NUMBER OF THESE WAVE GROUPS WHICH LEAVE THE ANTENNA DURING ONE DEPRESSION OF THE KEY.

THE NUMBER OF PEAKS WHICH APPEAR IN EACH GROUP OF A WAVE TRAIN IS DETERMINED BY THE FREQUENCY OF OSCILLATION OCCURRING IN THE TRANSMITTER CIRCUIT, WHEREAS THE SEPARATION BETWEEN EACH OF THESE WAVE GROUPS IN ANY ONE WAVE TRAIN IS GOVERNED BY THE FREQUENCY OF THE A.C. INPUT. THAT IS, IF A 500 CYCLE A.C. GENERATOR IS WORKING INTO THE PRIMARY WINDING OF THE TRANSMITTERS' STEP-UP TRANSFORMER, THEN TWICE THIS AMOUNT OR 1000 WAVE GROUPS PER SECOND WILL BE RADIATED BY THE ANTENNA.

THE FREQUENCY OF EACH OF THE HIGHLY DAMPED WAVE GROUPS IS OF RADIO FREQUENCY AND ARE THEREFORE INAUDIBLE AND THE NUMBER OF WAVE GROUPS RADIATED PER SECOND DETERMINE THE AUDIBLE FREQUENCY. EACH WAVE TRAIN VIBRATES THE HEADPHONE DIAPHRAGM AT THE RECEIVER ONCE SO THAT THE LISTENER HEARS A MUSCIAL NOTE. THAT IS TO SAY, IF 1000 WAVE GROUPS PER SECOND ARE BEING RADIATED, THEN THE SOUND PRODUCED IN THE RECEIVER HEADPHONES WILL BE EQUIVALENT TO A 1000 CYCLE MUSICAL NOTE.

WHEN THE KEY IS IN THE OPEN POSITION, NO WAVES ARE RADIATED AND THEREFORE NO SOUNDS ARE HEARD AT THE RECEIVER. WITH THE KEY CLOSED FOR A VERY SHORT INTERVAL OF TIME, THE "DOT" OF THE TELEGRAPHIC CODE IS FORMED AND IS HEARD IN THE RECEIVER HEADPHONES AS THE SHORT ABRUPT SOUND "DIT". BY CLOSING THE KEY FOR A LONGER PERIOD OF TIME (ABOUT THREE TIMES AS LONG AS THAT USED TO FORM THE "DOT") WE PRODUCE THE "DASH" OF THE CODE WHICH IS HEARD IN THE HEADPHONES AS THE MORE DRAWN-OUT SOUND "DAH". A PROPER COMBINATION OF DOTS AND DASHES ARE USED TO FORM THE LETTERS OF THE ALPHABET — THESE ARE COMBINED TO SPELL WORDS AND THUS THE DESIRED MESSAGE IS RADIATED INTO SPACE.

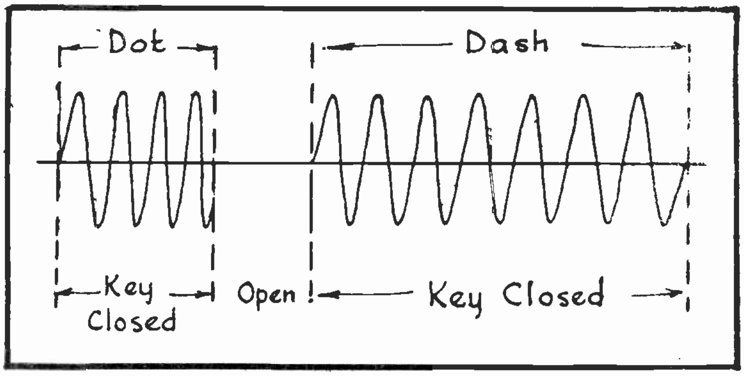

FIG. 10
C. W. Code Transmission.

SPARK TRANSMITTERS RADIATE A VERY HIGHLY DAMPED FORM OF WAVE AND SPREAD OUT OVER SUCH A WIDE FREQUENCY BAND SO THAT THEY CAN BE HEARD ALL OVER THE DIAL AT THE RECEIVING END. FURTHERMORE, THEY ARE VERY INEFFICIENT AS REGARDS THE INPUT POWER REQUIRED AND THE ACTUAL OUTPUT OR RADIATION POWER OBTAINED. CONSEQUENTLY, SPARK TRANSMITTERS HAVE BEEN REPLACED WITH THE MORE DESIRABLE TYPE OF TRANSMITTER WHICH RADIATES A CONTINUOUS WAVE.

CONTINUOUS WAVES

CONTINOUS WAVES, YOU WILL RECALL FROM EARLIER STUDIES, MAINTAIN A CONSTANT AMPLITUDE AS ILLUSTRATED IN THE UPPER PORTION OF FIG. 9, WHILE THE DAMPED WAVES START WITH A MAXIMUM AMPLITUDE WHICH RAPIDLY DIMINISHES TO A ZERO VALUE AS SHOWN IN THE LOWER PART OF FIG. 9. IT IS THE COMMON PRACTICE

TO REFER TO CONTINUOUS WAVES SIMPLY AS C.W. WAVES.

CONTINUOUS WAVES CAN BE USED FOR THE TRANSMISSION OF MUSICAL BROADCAST PROGRAMS OR VOICE, AS WELL AS FOR CODE COMMUNICATION. ONE METHOD OF USING THESE C.W. WAVES FOR CODE TRANSMISSION IS ILLUSTRATED IN FIG. 10.

IN THIS CASE, THE KEY IS OPERATED SO AS TO START AND STOP THE WAVE PROPOGATION TO FORM THE "DOTS" AND "DASHES" OF THE CODE. ALTHOUGH RADIATION CEASES WHENEVER THE KEY IS OPEN YET THERE IS NO DAMPING EFFECT IN THE WAVE FORM.

THESE OSCILLATIONS ARE OF RADIO FREQUENCY AND THEREFORE FAR ABOVE AUDIBILITY. FOR THIS REASON, THEY CANNOT UNDER ORDINARY CONDITIONS BE HEARD AT THE RECEIVER. HOWEVER, TO MAKE THEM AUDIBLE, IT IS GENERALLY THE PRACTICE TO USE A SPECIAL OSCILLATOR AT THE RECEIVER AND WHICH IS KNOWN AS A BEAT OSCILLATOR.

THIS BEAT OSCILLATOR GENERATES RADIO FREQUENCY ENERGY AT CONTROLLED FREQUENCIES, THE SAME AS DOES THE OSCILLATOR OF A SUPERHETERODYNE RECEIVER. AS THE C.W. SIGNALS ARE PICKED UP AND AMPLIFIED BY THE RECEIVER, THE R.F. ENERGY GENERATED BY THE BEAT OSCILLATOR IS MADE TO HETERODYNE WITH THE INCOMING SIGNAL FREQUENCY TO PRODUCE THE INTERMEDIATE FREQUENCY, ONLY THAT IN THE CASE OF THE RECEPTION OF C.W. CODE SIGNALS, THE BEAT FREQUENCY IS IN THE AUDIBLE RANGE. THIS SUBJECT WILL BE EXPLAINED MORE THOROUGHLY IN A LATER LESSON.

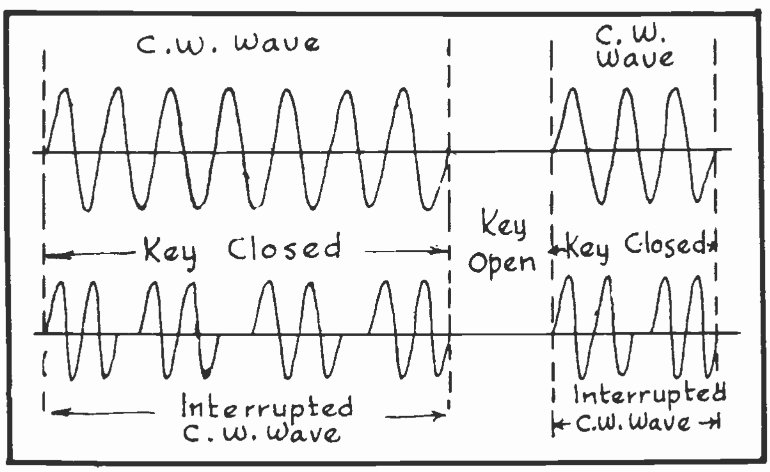

FIG. 11
The Interrupted C.W. Wave.

A STILL DIFFERENT TYPE OF CONTINUOUS WAVE IS THAT KNOWN AS THE INTERRUPTED CONTINUOUS WAVE AND WHICH IS ABREVIATED AS "I.C.W." IN THIS CASE, THE WAVE IS STILL OF THE CONTINUOUS TYPE BUT IS INTERRUPTED AT DEFINITE INTERVALS AS SHOWN IN THE LOWER PORTION OF FIG. 11. IN OTHER WORDS, DURING THE TIME THE KEY IS HELD CLOSED, A SERIES OF WAVES ARE RADIATED SOMEWHAT SIMILAR TO THE WAVE RADIATION FROM THE SPARK TRANSMITTER, ONLY THAT THE INDIVIDUAL WAVE GROUPS OF THE INTERRUPTED C.W. RADIATION ARE NOT DAMPED BUT OF CONSTANT AMPLITUDE.

WHILE THE KEY IS HELD CLOSED, THE CONTINUOUS WAVE IS INTERRUPTED AT A RATE CORRESPONDING TO AN AUDIBLE FREQUENCY, SAY FOR INSTANCE 500 TO 1000 TIMES PER SECOND. THE SIGNAL PRODUCED AT THE RECEIVER HEADPHONES, WHILE THE TRANSMITTER KEY IS HELD CLOSED, IS THEREFORE AUDIBLE. THEN BY CONTROLLING THE LENGTH OF TIME AT WHICH THE TRANSMITTER KEY IS HELD CLOSED, THE DOTS AND DASHES OF THE CODE ARE FORMED.

NOW THAT YOU ARE FAMILIAR WITH THE DIFFERENT WAVE FORMS AS RADIATED BY THE CODE TYPE TRANSMITTERS, LET US NEXT SEE HOW CONTINUOUS WAVES WERE PRODUCED BY THE EARLY TRANSMITTERS.

HIGH FREQUENCY GENERATORS

ONE OF THE METHODS WHICH HAS BEEN EMPLOYED FOR PRODUCING A CONTINUOUS OR INTERRUPTED CONTINUOUS WAVE FROM EARLY TRANSMITTERS WAS TO USE WHAT ARE KNOWN AS HIGH FREQUENCY GENERATORS.

A FUNDAMENTAL TYPE OF ALTERNATOR USED FOR THIS PURPOSE IS KNOWN AS THE "INDUCTOR TYPE". HERE THE ROTATING PART OF THE GENERATOR OR "INDUCTOR" CARRIES NO WINDINGS--INSTEAD, THE SURFACE OF THE IRON ROTOR IS SLOTTED SO AS TO FORM TEETH. AS THE ROTOR IS CAUSED TO REVOLVE, THE PASSAGE OF THE INDUCTOR TEETH ACROSS MAGNETIC POLES GENERATES AN ALTERNATING CURRENT. THIS PRINCIPLE WAS EMPLOYED IN THE ALEXANDERSON HIGH FREQUENCY ALTERNATORS WHICH WERE USED QUITE EXTENSIVELY BEFORE VACUUM TUBE TRANSMITTERS CAME INTO PROMINENCE.

ALEXANDERSON ALTERNATORS WERE CONSTRUCTED TO GENERATE FREQUENCIES AS HIGH AS 200 KC.

STILL OTHER TYPES OF HIGH FREQUENCY ALTERNATORS WHICH WERE USED WERE CONSTRUCTED MORE ALONG THE LINE OF THE COMMERCIAL ALTERNATORS. THAT IS, THEY CONSISTED OF A STATIONARY WINDING OR "STATOR" AND A REVOLVING WINDING OR ROTOR. HOWEVER, THE TWO WINDINGS ARE MADE PARTS OF TUNED OSCILLATORY CIRCUITS. DIFFERENT FREQUENCIES ARE GENERATED IN THE TWO WINDINGS AND THESE FREQUENCIES REACT WITH EACHOTHER TO PRODUCE BEAT FREQUENCIES OF TWICE, THREE TIMES AND FOUR TIMES THE ORIGINAL FREQUENCY. THE HIGHER FREQUENCIES CAN THEN BE USED FOR RADIATION PURPOSES.

IN FIG. 12 YOU WILL SEE A TYPICAL METHOD OF HOW A HIGH FREQUENCY GENERATOR CAN BE CONNECTED TO THE TRANSMITTER FOR CODE TRANSMISSION. HERE YOU WILL SEE THAT THE OUTPUT OF THE HIGH-FREQUENCY GENERATOR IS APPLIED ACROSS A CIRCUIT WHICH IS TUNED TO THE OUTPUT FREQUENCY OF THE GENERATOR. THIS CIRCUIT IS COUPLED TO THE TUNED ANTENNA CIRCUIT SO THAT A CONTINUOUS WAVE OF CORRESPONDING FREQUENCY CAN BE RADIATED. THE TRANSMITTER KEY IS CONNECTED IN THE FIELD CIRCUIT OF THE ALTERNATOR WHERE THE CURRENT VALUE IS RATHER SMALL.

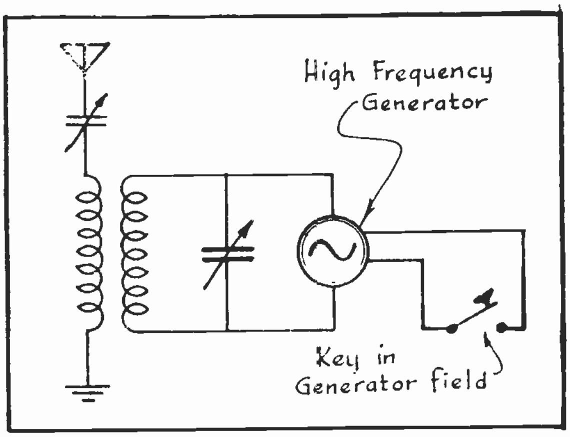

FIG. 12
Transmitter Circuit With High-Frequency Generator.

THE ARC TRANSMITTER

A SIMPLE ARC TRANSMITTER CIRCUIT IS ILLUSTRATED FOR YOU IN FIG. 13. THE SOURCE OF ELECTRICAL ENERGY IN THIS SYSTEM IS A DIRECT CURRENT GENERATOR WHICH FURNISHES AN E.M.F. OF 200 TO 1200 VOLTS, DEPENDING UPON ITS SIZE.

THE DIRECT CURRENT AS FURNISHED BY THE GENERATOR FLOWS FROM THE POSITIVE TERMINAL THROUGH THE CHOKE, WHOSE PURPOSE IS TO MAINTAIN THE CURRENT OF UNIFORM VALUE. THE CURRENT THEN FLOWS THROUGH THE ARC JUST AS IN AN ORDINARY ARC LAMP AND RETURNS TO THE NEGATIVE GENERATOR TERMINAL. A TUNED CIRCUIT CONSISTING OF AN INDUCTANCE L_1 AND THE CONDENSER C_1 ARE ALSO CONNECTED ACROSS THE ELECTRODES OF THE ARC.

DUE TO THE PRESENCE OF THE CHOKE IN THE GENERATOR CIRCUIT, THE TOTAL CURRENT FURNISHED TO BOTH THE ARC AND THE TUNED CIRCUIT REMAINS CONSTANT IN VALUE. AT THE TIME THE CIRCUIT COMMENCES TO OPERATE, CONDENSER C_1 IS NOT CHARGED AND THEREFORE A LARGE PORTION OF THE GENERATOR CURRENT FLOWS INTO THE CONDENSER PLATES, CHARGING THEM. THEREFORE, LESS CURRENT WILL NOW FLOW THROUGH THE ARC BECAUSE THE GENERATOR CURRENT TENDS TO MAINTAIN A CONSTANT VALUE.

THIS DECREASE IN CURRENT THROUGH THE ARC CAUSES THE VOLTAGE ACROSS IT, AS WELL AS ACROSS THE TUNED CIRCUIT, TO RISE UNTIL THE CONDENSER C_1 IS FULLY CHARGED.

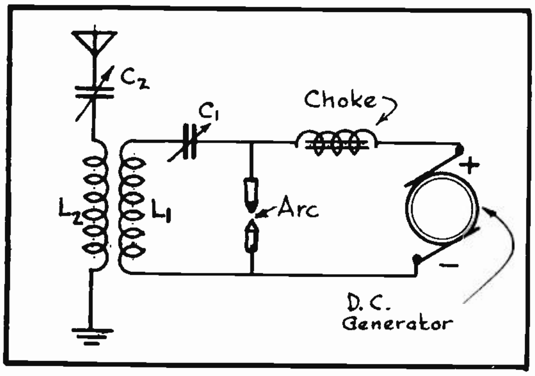

FIG. 13
Simple Arc Transmitter.

AS SOON AS THE CONDENSER C_1 IS FULLY CHARGED, THE CURRENT THROUGH THE ARC INCREASES TO ITS NORMAL VALUE AND THEREFORE THE VOLTAGE ACROSS THE ARC WILL DROP. HOWEVER, SINCE CONDENSER C_1 IS STILL FULLY CHARGED, ITS VOLTAGE VALUE WILL BE HIGHER THAN THAT OF THE ARC AND IT THEREFORE DISCHARGES ACROSS THE ARC. A CHARGE THEN COMMENCES TO BUILD UP AGAIN ON CONDENSER C_1 PREPARATORY FOR ANOTHER DISCHARGE AND THIS CYCLE OF EVENTS REPEATS ITSELF AS LONG AS THE D.C. VOLTAGE IS APPLIED.

SINCE THE DISCHARGE OCCURS THROUGH A TUNED OSCILLATORY CIRCUIT CONSISTING OF C_1 AND L_1, THE OSCILLATIONS PRODUCED OCCUR AT A FREQUENCY DETERMINED BY THE INDUCTIVE VALUE OF L_1 IN CONJUNCTION WITH THE CAPACITIVE VALUE OF C_1.

THESE OSCILLATIONS ARE THEN TRANSFERRED TO THE TUNED ANTENNA CIRCUIT BY MEANS OF ELECTROMAGNETIC INDUCTION AND ARE THUS RADIATED INTO SPACE.

TO KEY TRANSMITTERS OF THIS TYPE, THE METHOD ILLUSTRATED IN FIG. 14 CAN BE EMPLOYED. HERE YOU WILL SEE THAT THE KEY IS CONNECTED IN SERIES WITH THE SOLENOID WINDING OF THE BACK-SHUNT RELAY AND A LOW VOLTAGE D.C. SUPPLY. AT THE TIME THE KEY IS HELD CLOSED, THE RESULTING CURRENT FLOW THROUGH THE SOLENOID WINDING OF THE RELAY WILL ATTRACT THE CONTACT BLADE TOWARDS THE LEFT SO THAT IT WILL TOUCH CONTACT #1. THIS WILL SERVE TO CONNECT THE ARC CIRCUIT TO THE TUNED ANTENNA CIRCUIT SO

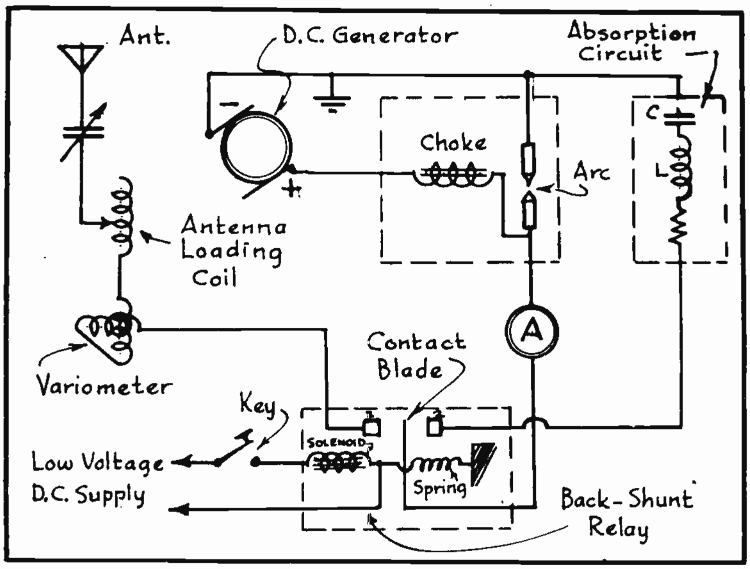

FIG. 14
The Arc Transmitter.

THAT ITS OSCILLATIONS MAY RADIATE A CONTINUOUS WAVE FROM THE ANTENNA.

WHEN THE KEY IS RELEASED, THE SOLENOID LOSES ITS ATTRACTION SO THAT THE CONTACT BLADE OF THE RELAY IS OVERCOME BY THE SPRING TENSION AND THEREFORE CLOSES THE CIRCUIT THROUGH CONTACT #2. THIS WILL DISCONNECT THE ANTENNA CIRCUIT FROM THE SYSTEM AND AT THE SAME TIME WILL CONNECT THE ABSORPTION CIRCUIT ACROSS THE ARC. THE ABSORPTION CIRCUIT IS ALSO A RESONANCE CIRCUIT AND PERMITS CONTINUED OSCILLATION TO OCCUR IN THE TRANSMITTER BUT PREVENTS RADIATION. THUS BY PROPERLY OPERATING THE KEY, THE DESIRED INTERRUPTIONS CAN BE PRODUCED IN THE TRANSMITTED CONTINUOUS WAVE TO FORM THE LETTERS OF THE CODE.

ALTHOUGH ALL MODERN TRANSMITTERS EMPLOY VACUUM TUBE CIRCUITS RATHER THAN THE SYSTEMS DESCRIBED IN THIS LESSON, YET THIS LESSON SHOULD HAVE SERVED ITS PURPOSE OF FAMILIARIZING YOU WITH THESE EARLIER CIRCUITS SUFFICIENTLY SO THAT YOU WILL AT LEAST HAVE SOME IDEA AS TO THEIR CONSTRUCTION AND OPERATION IN THE EVENT THAT YOU SHOULD AT SOME TIME OR OTHER HEAR ABOUT THEM.

THERE IS NO NEED TO DESCRIBE THESE EARLIER TRANSMITTERS IN FURTHER DETAIL AND SO IN THE NEXT LESSON, WE WILL START RIGHT IN WITH THE MODERN VACUUM TUBE TRANSMITTER CIRCUITS. YOU WILL FIND THE STUDIES TO FOLLOW TO BE UP TO DATE AND COMPLETE IN EVERY RESPECT.

Answered July 18 1941

Examination Questions

LESSON NO. T-1

It is well for a man to respect his own vocation whatever it is, and to think himself bound to uphold it, and to claim for it the respect it deserves.

1. – DRAW A DIAGRAM OF A SIMPLE SPARK TRANSMITTER AND EXPLAIN HOW IT OPERATES.

2. – DESCRIBE A "QUENCHED SPARK GAP" AND EXPLAIN THE REASON FOR USING IT.

3. – MAKE A SIMPLE DRAWING OF A SYNCHRONOUS DISCHARGER AND EX PLAIN HOW IT OPERATES.

4. – WHAT IS THE DIFFERENCE BETWEEN AN INTERRUPTED CONTINUOUS WAVE AND THE TYPE OF WAVE RADIATED BY A SIMPLE SPARK TRAN SMITTER WHEN SENDING CODE SIGNALS?

5. – BY WHAT METHODS MAY CONTINUOUS WAVES BE GENERATED?

6. – DRAW A DIAGRAM OF A SIMPLE ARC TRANSMITTER CIRCUIT AND EX PLAIN HOW IT OPERATES.

7. – FOR WHAT TYPE OF RADIO COMMUNICATION ARE CONTINOUS WAVES ADAPTED?

8. – WHAT IS THE DIFFERENCE BETWEEN A "SYNCHRONOUS DISCHARGER" AND A "NON-SYNCHRONOUS DISCHARGER" AS USED IN A SPARK TRANS MITTER?

9. – HOW DOES A TELEGRAPH KEY ENABLE THE "DOTS" AND DASHES" OF THE CODE TO BE FORMED WHEN OPERATING A TRANSMITTER WHICH RADIATES AN INTERRUPTED CONTINUOUS WAVE?

10. – WHY IS A BEAT NOTE OSCILLATOR USED IN CONJUNCTION WITH A RECEIVER WHEN LISTENING TO C.W. CODE SIGNALS?

NOTICE:– BE SURE TO NUMBER ALL OF YOUR EXAMINATION PAPERS FOR THE ADVANCED LESSON GROUPS TO CORRESPOND WITH THE LESSON NUMBER APPEARING AT THE TOP OF THE EXAMINATION PAGE IN EACH OF THESE LESSONS. FOR EXAMPLE, THE NUMBER OF THIS LESSON IS T-1. THIS IS IMPORTANT.

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RADIO - TELEVISION

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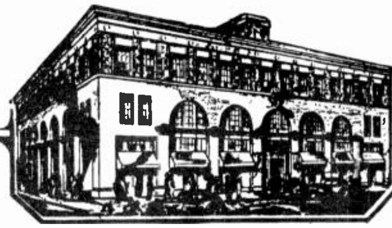
Los Angeles, California



Transmitters

LESSON NO. 2

• VACUUM TUBE OSCILLATORS •

YOU HAVE ALREADY BEEN TOLD THAT MODERN TRANSMITTERS EMPLOY VACUUM TUBE OSCILLATORS IN ORDER TO GENERATE THE RADIO FREQUENCY ENERGY WHICH IS TO BE USED FOR RADIATING CONTINUOUS WAVES AND IN THIS LESSON, YOU ARE GOING TO BE SHOWN HOW SUCH OSCILLATORS FUNCTION AND THE METHODS OF USING THEM IN TRANSMITTER CIRCUITS.

PRODUCING OSCILLATIONS

OUR FIRST STEP WILL BE TO SEE HOW ELECTRICAL OSCILLATIONS CAN BE PRODUCED IN A VACUUM TUBE CIRCUIT AND IN FIGURE 2 YOU ARE SHOWN THE FUNDAMENTAL CIRCUIT OF AN INDUCTIVE FEED-BACK TYPE OSCILLATOR. HERE, YOU WILL NOTICE, THAT WE HAVE A SMALL PLATE COIL CONNECTED IN SERIES WITH THE PLATE CIRCUIT OF THE TUBE AND AT THE SAME TIME CLOSELY COUPLED TO THE GRID COIL OF THE SAME TUBE SO THAT THERE IS MUTUAL INDUCTANCE BETWEEN THESE TWO COILS.

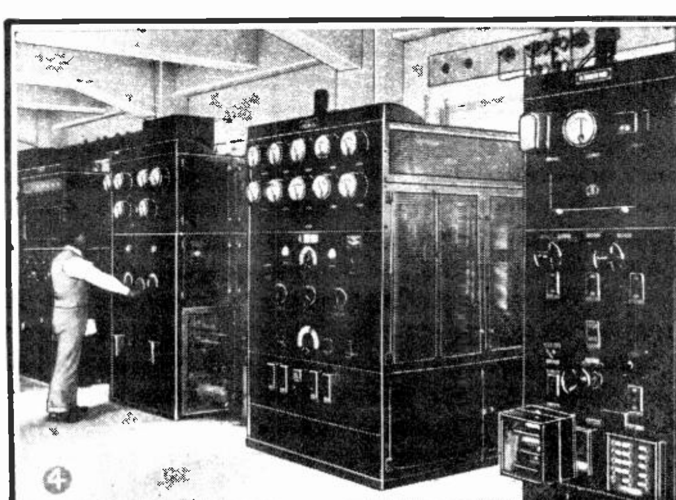


FIG. 1
Engineer at Work Adjusting a Transmitter.

WHEN IT IS DESIRED TO SET THIS SYSTEM IN OPERATION, THE FIRST STEP TAKEN IS TO CLOSE THE FILAMENT CIRCUIT SO THAT THE CURRENT FURNISHED BY THE "A" SUPPLY CAN HEAT UP THE FILAMENT. THE RESULTING ELECTRON EMISSION WILL PERMIT PLATE CURRENT TO FLOW THROUGH THE CIRCUIT.

THIS PLATE CURRENT MUST ALL FLOW THROUGH THE PLATE COIL AND IN DOING SO, A MAGNETIC FIELD IS ESTABLISHED AROUND IT. HOWEVER, IT IS IMPORTANT TO NOTE THAT

BEFORE THIS PLATE CURRENT REACHES ITS PEAK VALUE, A CERTAIN LENGTH OF TIME IS REQUIRED AND DURING WHICH PERIOD THE RESULTING MAGNETIC FIELD PRODUCED BY THE PLATE COIL IS UNDERGOING AN EXPANDING IMPULSE.

SINCE THE PLATE AND GRID COILS ARE INDUCTIVELY COUPLED, THE EXPANDING FIELD OF THE PLATE COIL WILL CUT THROUGH THE TURNS OF THE GRID COIL AND IN SO DOING INDUCE AN E.M.F. IN THE GRID COIL. IF CONDITIONS ARE SUCH THAT THE UPPER END OF THE GRID WINDING AT THIS PARTICULAR INSTANT BECOMES POSITIVE WHILE ITS LOWER END BECOMES NEGATIVE, THEN THE GRID OF THE TUBE WILL HAVE A POSITIVE CHARGE IMPRESSED UPON IT. THIS IN TURN WILL CAUSE THE FLOW OF PLATE CURRENT TO INCREASE.

THIS INCREASING PLATE CURRENT CAUSES A STILL GREATER EXPANSION OF THE MAGNETIC FIELD AROUND THE PLATE COIL, WHICH RESULTS IN A STILL GREATER INDUCTION IN THE GRID COIL AND THE APPLICATION OF A STILL HIGHER POSITIVE POTENTIAL UPON THE GRID OF THE TUBE. THIS CAUSES A FURTHER INCREASE IN THE PLATE CURRENT AND THE APPLICATION OF STILL HIGHER POSITIVE POTENTIALS UPON THE GRID. THIS BUILDING-UP PROCESS CONTINUES IN THIS WAY UP TO A CERTAIN POINT AND WHICH IS DEPENDENT UPON THE CHARACTERISTICS OF THE TUBE AS WELL AS THE RESISTANCE OF THE CIRCUIT.

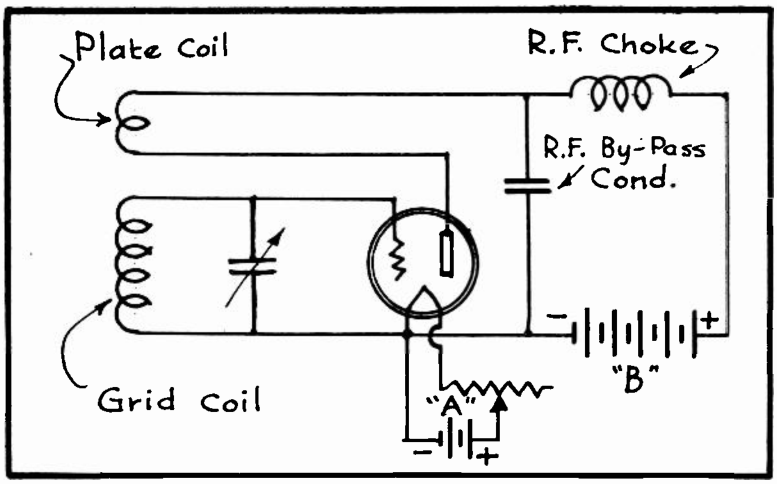


FIG. 2

A Fundamental Oscillator Circuit.

FINALLY, THE PLATE CURRENT WILL STOP INCREASING AND HEREFORE THE MAGNETIC FIELD OF THE PLATE COIL NO LONGER CONTINUES TO EXPAND. AT THIS TIME, NO VOLTAGE CAN BE INDUCED IN THE GRID WINDING AND THE VOLTAGE AT THE GRID THUS DROPS TO ZERO. THIS BRINGS ABOUT A REDUCTION IN THE PLATE CURRENT AND A COLLAPSE OF THE MAGNETIC FIELD. SINCE THE LINES OF FORCE ARE NOW MOVING IN A DIRECTION OPPOSITE TO THEIR FORMER DIRECTION OF TRAVEL, THE POLARITY OF THE GRID COIL WILL AT THIS TIME BE REVERSED, THAT IS, ITS UPPER END WILL NOW BE NEGATIVE AND ITS LOWER END POSITIVE. THIS MEANS THAT A NEGATIVE VOLTAGE WILL NOW BE APPLIED TO THE GRID AND THEREBY REDUCE THE FLOW OF PLATE CURRENT STILL MORE.

THE PLATE CURRENT WILL CONTINUE TO DECREASE IN THIS MANNER, DROPPING BELOW ITS NORMAL VALUE UNTIL A POINT IS FINALLY REACHED AT WHICH NO FURTHER DECREASE TAKES PLACE AND THE GRID POTENTIAL REMAINS CONSTANT FOR AN INSTANT. THE CURRENT THEN COMMENCES TO INCREASE AGAIN AND THE CYCLE AS JUST DESCRIBED WILL REPEAT ITSELF, CONTINUING IN THIS MANNER INDEFINITELY AS LONG THE OPERATING VOLTAGES ARE APPLIED TO THE TUBE.

ALTHOUGH THE "B" SUPPLY FURNISHES A DIRECT CURRENT, YET WHEN THE TUBE IS IN A STATE OF OSCILLATION, THE PLATE CURRENT RISES AND FALLS WITH RE-

SPECT TO THE NORMAL PLATE CURRENT (THE NORMAL PLATE CURRENT IS THAT PLATE CURRENT VALUE WHICH FLOWS WHEN NO "SIGNAL" VOLTAGE IS APPLIED TO THE GRID). THIS NORMAL PLATE CURRENT VALUE THEREFORE IS EQUIVALENT TO THE ZERO LINE OR LEVEL IN THE WAVE FORM OF A TRUE ALTERNATING CURRENT. IT IS CUSTOMARY TO REFER TO THE RISES AND FALLS IN PLATE CURRENT AS THE A.C. COMPONENT OF THE PLATE CURRENT AND IT IS OBVIOUS THAT IF A CURRENT OF THIS TYPE PASSES THROUGH THE PRIMARY WINDING OF A TRANSFORMER, A.C. VOLTAGES WILL THROUGH INDUCTION APPEAR ACROSS THE SECONDARY TERMINALS. THE A.C. COMPONENT OF AN OSCILLATOR'S PLATE CURRENT CAN THEREFORE PRODUCE THE SAME RESULTS AS A CONVENTIONAL ALTERNATING CURRENT.

IN FIG. 3 YOU ARE SHOWN A GROUP OF CURVES WHICH ILLUSTRATE CLEARLY HOW AN ALTERNATING E.M.F. WHEN APPLIED TO THE GRID OF THE OSCILLATOR TUBE CAN PRODUCE AN A.C. COMPONENT OF STILL GREATER MAGNITUDE IN THE PLATE CIRCUIT AND IT IS IMPORTANT TO REMEMBER THAT THE A.C. GRID VOLTAGE AS APPLIED TO THE GRID OF THE OSCILLATOR TUBE IS OBTAINED FROM THE TRANSFER OF PLATE ENERGY TO THE GRID CIRCUIT.

IT IS REALLY THE ABILITY OF A VACUUM TUBE TO AMPLIFY WHICH ENABLES IT TO FUNCTION AS AN OSCILLATOR. IN OTHER WORDS, SINCE THE POWER REQUIRED BY THE INPUT OF AN AMPLIFIER IS MUCH LESS THAN THE AMPLIFIED OUTPUT, THE AMPLIFIER TUBE CAN BE MADE TO SUPPLY ITS OWN INPUT. IT IS ALSO TRUE THAT AT THE TIME THE CIRCUIT GOES INTO OSCILLATION, THE R.F. ENERGY AS FURNISHED BY THE PLATE CIRCUIT TO THE GRID CIRCUIT IS GREAT ENOUGH SO AS TO REDUCE THE GRID CIRCUIT LOSSES TO ZERO.

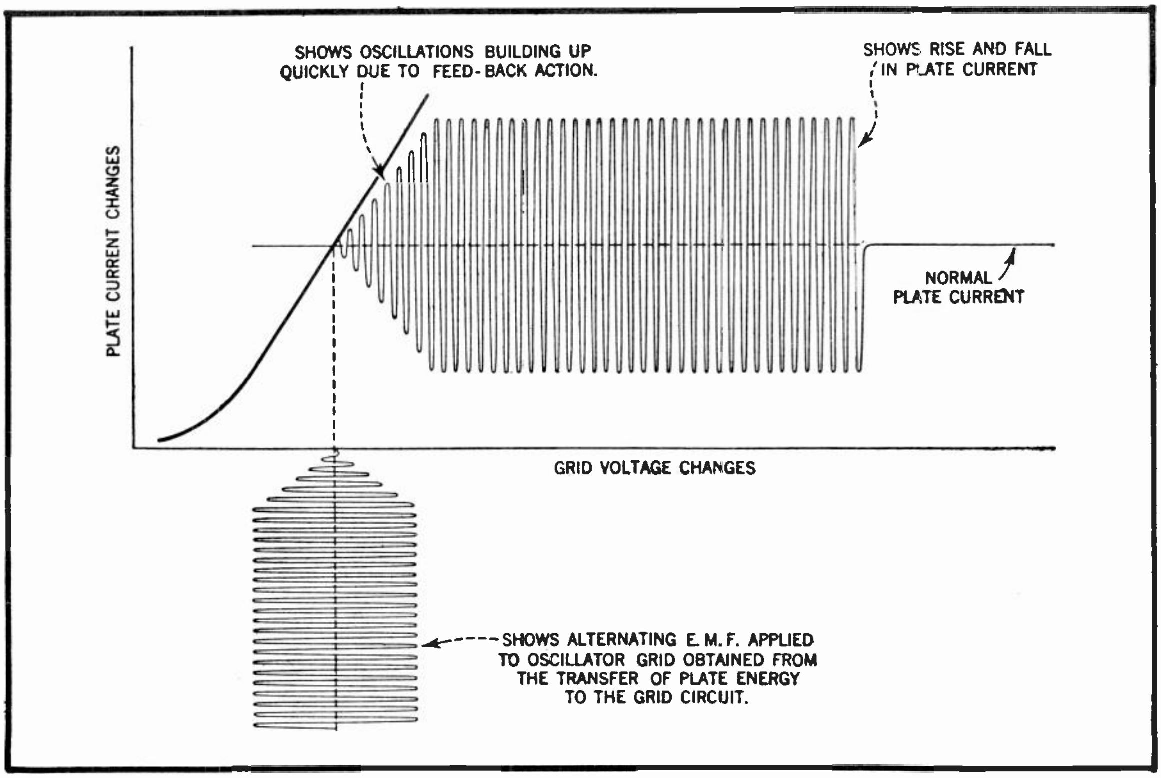


FIG. 3

Curves Showing How High-Frequency A.C. is Generated by the Oscillator Circuit.

OBSERVE IN FIG. 3 THAT THE OSCILLATIONS BUILD UP QUITE RAPIDLY UNTIL THE FINAL AMPLITUDE IS REACHED AND THAT WHEN ONCE IN OPERATION, THE WAVE FORM IS CONTINUOUS AND OF CONSTANT AMPLITUDE AND IT IS THIS FEATURE WHICH PERMITS THE VACUUM TUBE OSCILLATOR TO PRODUCE A CONTINUOUS WAVE. THE FREQUENCY OF OSCILLATION, OR THE FREQUENCY AT WHICH THE PLATE CURRENT RISES AND FALLS IS GOVERNED BY THE CAPACITIVE AND INDUCTIVE VALUES AS USED IN THE TUNED CIRCUIT (THE GRID CIRCUIT IN THE CASE OF FIG.2).

IN PRACTICE, SEVERAL FUNDAMENTAL OSCILLATOR CIRCUITS ARE EMPLOYED AND THESE SHALL NOW BE EXPLAINED IN THEIR PROPER ORDER.

THE HARTLEY OSCILLATOR

IN FIG. 4 YOU ARE SHOWN WHAT IS KNOWN AS A "SHUNT-FEED" HARTLEY OSCILLATOR. BY STUDYING THIS DIAGRAM CAREFULLY, YOU WILL OBSERVE THAT WE HAVE FIRST A COIL OR INDUCTANCE L AND A VARIABLE CONDENSER C WHICH TOGETHER FORM THE TUNING CIRCUIT. THE UPPER END OF COIL L IS CONNECTED TO THE GRID OF THE TUBE AND THE LOWER END OF THIS SAME COIL IS CONNECTED TO THE PLATE OF THE TUBE THRU THE COUPLING CONDENSER C_2. THE FILAMENT CIRCUIT AND B— ARE CONNECTED TO COIL L AT A POINT BETWEEN ITS END CONNECTIONS AND THIS RESULTS IN THE UPPER SECTION OF COIL L BEING INCLUDED IN THE GRID CIRCUIT AND THE LOWER SECTION OF L BEING INCLUDED IN THE PLATE CIRCUIT OF THE SAME TUBE. THEN SINCE THESE TWO SECTIONS ARE PARTS OF THE SAME WINDING, WE HAVE THE GRID AND PLATE CIRCUITS OF THIS TUBE SO COUPLED THAT OSCILLATIONS CAN BE PRODUCED AS ALREADY EXPLAINED RELATIVE TO FIG. 2.

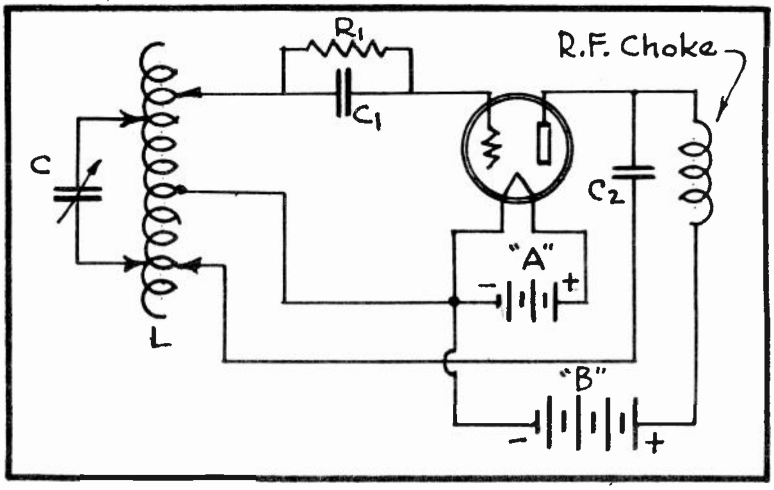


FIG. 4
Shunt-Feed Hartley Oscillator

THE CONNECTIONS AT COIL L WHICH ARE INDICATED BY MEANS OF THE ARROW HEADS INDICATE THAT THESE CONNECTIONS ARE SUBJECT TO CHANGE AT THE TIME THE OSCILLATOR IS BEING ADJUSTED FOR OPERATION. IT IS CUSTOMARY TO WIND COIL L WITH COPPER TUBING SO THAT A SPACE-WOUND, SELF-SUPPORTING COIL IS OBTAINED AND TO USE CLIP CONNECTIONS AT THOSE POINTS WHICH ARE INDICATED BY THE ARROW HEADS IN FIG. 4.

THE R.F. CHOKE PROVIDES A HIGH IMPEDANCE TO RADIO FREQUENCY CURRENTS IN THE "B" CIRCUIT OF THIS TUBE AND THEREBY FORCES THE R.F. ENERGY THRU CONDENSER C_2 INTO THE LOWER SECTION OF COIL L.

THE PURPOSE OF THE CONDENSER C_1 AND THE LEAK RESISTOR R_1 AS USED IN THIS CIRCUIT IS TO KEEP THE AVERAGE POTENTIAL OF THE GRID NEGATIVE WITH RESPECT TO THE FILAMENT. CONDENSER C_1 OFFERS PRACTICALLY NO OPPOSITION TO THE HIGH FREQUENCY CURRENTS SO THAT R.F. VOLTAGES CAN BE APPLIED THRU IT

AND IMPRESSED UPON THE GRID OF THE TUBE. EACH TIME THAT THE INSTANTANEOUS GRID POTENTIAL IS POSITIVE, ELECTRONS ARE ATTRACTED TO THE GRID AND PERMITTED TO FLOW THROUGH THE GRID CIRCUIT BY BEING SHUNTED AROUND C_1 THRU RESISTOR R_1. SINCE THIS GRID CURRENT FLOW THROUGH R_1 IS ALWAYS IN THE SAME DIRECTION, THE RESULTING VOLT DROP ACROSS R_1 CAN BE USED AS A BIAS VOLTAGE FOR THE TUBE — THE GRID BEING NEGATIVE WITH RESPECT TO THE FILAMENT.

THE SERIES-FEED HARTLEY OSCILLATOR

THE "SERIES-FEED" HARTLEY OSCILLATOR IS ILLUSTRATED IN FIG. 5. THIS CIRCUIT IN GENERAL IS QUITE SIMILAR TO THE HARTLEY CIRCUIT OF FIG. 4 BUT IT DIFFERS IN THAT IN THE SERIES-FEED SYSTEM, THE LOWER SECTION OF COIL L IS USED TO COMPLETE THE CONNECTION BETWEEN B- AND A-. IN OTHER WORDS, IN THE SERIES-FEED SYSTEM, THE LOWER SECTION OF COIL L IS IN SERIES WITH THE "B" CIRCUIT. THIS BEING TRUE, WE HAVE HERE ANOTHER CASE WHERE THE GRID AND PLATE CIRCUITS ARE CLOSELY COUPLED SO THAT OSCILLATION CAN BE PRODUCED. THE PURPOSE OF CONDENSER C_2 IS TO PROVIDE A SHUNTING PATH AROUND THE "B" SUPPLY SO THAT NONE OF THE RADIO FREQUENCY ENERGY WILL BE COMPELLED TO FLOW THROUGH THE "B" SUPPLY.

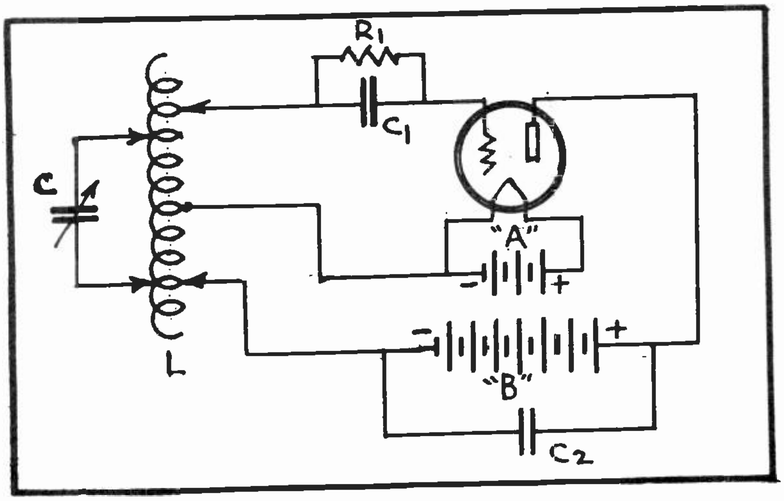


FIG. 5
Series-Feed Hartley Oscillator.

THE COLPITTS CIRCUIT

IN THE OSCILLATORS AS SO FAR DESCRIBED, FEED-BACK WAS ACCOMPLISHED THROUGH INDUCTIVE COUPLING BETWEEN THE PLATE AND GRID CIRCUITS OF THE OSCILLATOR TUBE. IN ADDITION TO THIS METHOD, IT IS ALSO POSSIBLE TO OBTAIN THIS FEED-BACK BY UTILIZING CAPACITY COUPLING BETWEEN THE PLATE AND GRID CIRCUITS OF THE TUBE. A CIRCUIT OF THIS TYPE IS SHOWN YOU IN FIG. 6 AND IT IS KNOWN AS THE COLPITTS SYSTEM.

BY STUDYING FIG. 6 CAREFULLY, YOU WILL OBSERVE THAT THE TWO SERIES CONNECTED CONDENSERS C_1 AND C_2 ARE TOGETHER CONNECTED ACROSS COIL L. IT IS ALSO TRUE THAT CONDENSERS C_2 AND C_3 ARE EFFECTIVELY CONNECTED IN SERIES AND TOGETHER SHUNTED ACROSS THE "B" SUPPLY. THE GRID CONDENSER C_4 AND LEAK RESISTOR R_1 FUNCTION IN THE SAME MANNER AS ALREADY EXPLAINED RELATIVE TO THE PRECEDING CIRCUITS.

WITH THESE POINTS IN MIND, LET US NOW SEE HOW THIS SYSTEM OPERATES:

AT THE TIME THE FILAMENT CIRCUIT IS COMPLETED, ELECTRON EMISSION TAKES PLACE AND PLATE CURRENT COMMENCES TO FLOW. THE R.F. CHOKE IN THE PLATE CIRCUIT OPPOSES ANY FLOW OF RADIO FREQUENCY CURRENT THROUGH IT AND FORCES THE R.F. ENERGY THROUGH CONDENSERS C_3 AND C_2 WHICH ARE CONNECTED IN

SHUNT WITH THE "B" CIRCUIT AND THEREFORE VOLTAGE DROPS OF CORRESPONDING VARIATION APPEAR ACROSS THE PLATES OF CONDENSER C_2. THE METHOD OF CONNECTION BETWEEN C_1–C_2 AND L ARE SUCH THAT IF A VOLTAGE DROP OR DIFFERENCE OF POTENTIAL IS ESTABLISHED ACROSS THE PLATES OF C_2, A VOLTAGE DROP OR DIFFERENCE OF POTENTIAL MUST ALSO APPEAR ACROSS CONDENSER C_1 AND WHICH WILL RESULT IN A VOLTAGE DIFFERENCE BETWEEN THE FILAMENT AND GRID ACROSS WHICH IT IS CONNECTED. THIS CHANGE IN THE VOLTAGE DIFFERENCE BETWEEN THE FILAMENT AND GRID WILL PRODUCE A CORRESPONDING CHANGE IN THE PLATE CURRENT AND WHICH IN TURN WILL BRING ABOUT A FURTHER CHANGE IN GRID POTENTIAL DUE TO THE CORRESPONDING VOLTAGE CHANGES WHICH APPEAR ACROSS C_2 AND C_1 ON ACCOUNT OF THE FEED-BACK. SINCE THE A.C. COMPONENT OF THE PLATE CIRCUIT IS BEING UTILIZED FOR FEED-BACK, ALTERNATING-POTENTIAL VARIATIONS ARE BEING APPLIED TO THE GRID AND THE PHASE RELATION IN THE CIRCUITS IS SUCH THAT SELF-SUSTAINED OSCILLATIONS RESULT.

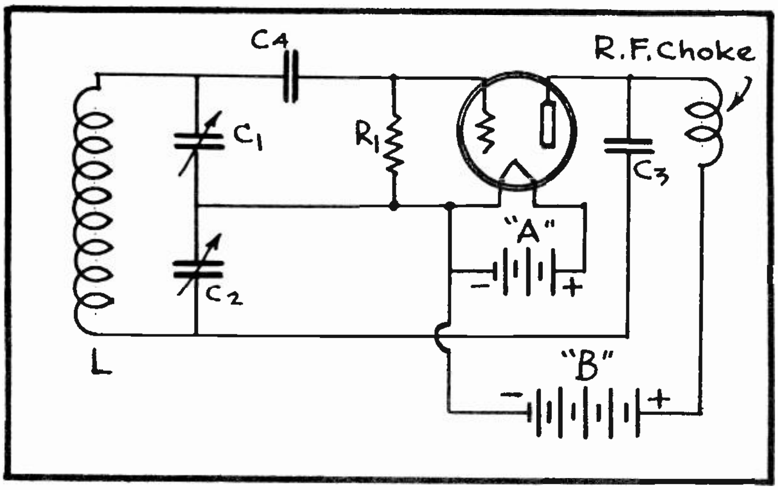


FIG. 6
The Colpitts Oscillator.

THE FEED-BACK EFFECT IS INFLUENCED BY THE CAPACITY OF CONDENSERS C_1 AND C_2 AND THE FREQUENCY OF OSCILLATION IS DETERMINED BY THE INDUCTANCE VALUE OF COIL L IN CONJUNCTION WITH THE CAPACITIVE VALUES OF CONDENSERS C_1 AND C_2.

THE TUNED-PLATE, TUNED-GRID OSCILLATOR

IN FIG.7 YOU ARE SHOWN A TUNED- PLATE, TUNED-GRID OSCILLATOR AND WHICH ALSO MAKES USE OF A CAPACITIVE FEED-BACK SYSTEM. IN THIS CASE, ONE TUNED CIRCUIT CONSISTING OF L_1 AND C_1 IS CONNECTED ACROSS THE GRID CIRCUIT AND ANOTHER TUNED CIRCUIT CONSISTING OF L_2 AND C_2 IS CONNECTED IN THE PLATE CIRCUIT.

WHEN THESE TWO CIRCUITS ARE TUNED TO RESONANCE WITH EACHOTHER, R.F. ENERGY OF THIS SAME FREQUENCY IS REJECTED BY THE TUNED PLATE CIRCUIT AND SOME IF IT IS FORCED THROUGH THE TUBE'S GRID-PLATE CAPACITY AND THUS APPLIED TO THE GRID. VOLTAGE CHANGES THUS IMPRESSED UPON THE TUBE'S GRID AT RADIO FREQUENCIES WILL CAUSE CORRESPONDING VARIATIONS IN PLATE CURRENT AND SINCE THE OUTPUT POWER OF THE TUBE IS MUCH GREATER THAN THE INPUT POWER REQUIRED TO PRODUCE IT, CONTINUOUS OSCILLATIONS CAN BE GENERATED THE SAME AS ALREADY EXPLAINED RELATIVE TO THE SYSTEMS PREVIOUSLY DESCRIBED.

THE R.F. CHOKE AND CONDENSER C_4 ARE USED IN THE CIRCUIT OF FIG.7 SO THAT THERE WILL BE NO TENDENCY FOR R.F. ENERGY TO PASS THROUGH THE "B" SUPPLY. THE GRID CONDENSER C_3 AND THE LEAK RESISTOR R_1 FUNCTION IN THE SAME MANNER AS ALREADY EXPLAINED FOR THESE SAME UNITS EARLIER IN THIS LESSON.

THE MEISSNER CIRCUIT

IN THE MEISSNER CIRCUIT WHICH IS ILLUSTRATED IN FIG.8 WE HAVE THREE

COILS INDUCTIVELY COUPLED. COIL L_1 IS INCLUDED IN THE GRID CIRCUIT AND INDUCTIVELY COUPLED TO THE ANTENNA COIL, WHILE COIL L_2 IS INCLUDED IN THE PLATE CIRCUIT AND ALSO INDUCTIVELY COUPLED TO THE ANTENNA COIL. NEITHER L_1 NOR L_2 IS TUNED — THE FREQUENCY OF OSCILLATION IN THIS CIRCUIT BEING CONTROLLED BY TUNING THE ANTENNA CIRCUIT.

IN THIS CIRCUIT RADIO FREQUENCY ENERGY IN THE PLATE CIRCUIT IS INDUCED FROM COIL L_2 INTO THE ANTENNA COIL WITH WHICH IT IS COUPLED AND THE ANTENNA COIL IN TURN INDUCES VOLTAGES OF CORRESPONDING FREQUENCY INTO THE GRID COIL L_1 WITH WHICH IT IS COUPLED. IN THIS MANNER REGENERATION AND OSCILLATION IS PRODUCED.

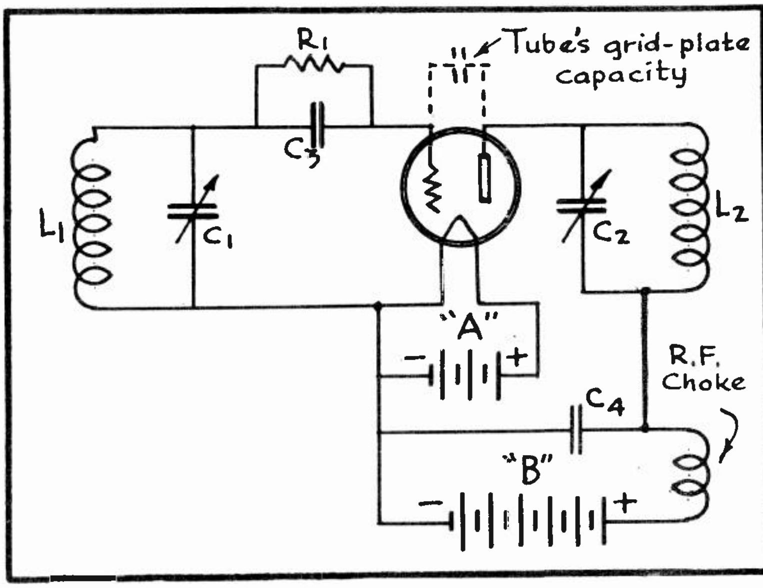


FIG. 7

Tuned-Plate, Tuned-Grid Oscillator.

THE "TNT" CIRCUIT

THE CIRCUITS AS SO FAR DESCRIBED ARE THE FUNDAMENTAL OSCILLATOR CIRCUITS BUT IN PRACTICE YOU WILL FIND THAT IN ADDITION TO THESE, A NUMBER OF MODIFICATIONS OF THESE FUNDAMENTAL CIRCUITS ARE EMPLOYED. IN FIG. 9, FOR INSTANCE, WE HAVE WHAT IS KNOWN AS THE "T.N.T." CIRCUIT.

BY STUDYING FIG. 9 CAREFULLY, YOU WILL OBSERVE THAT THE TUNING CIRCUIT IS HERE INCLUDED IN THE PLATE CIRCUIT OF THE TUBE AND CONSISTS OF THE COIL L_1 AND THE CONDENSER C_1. THE GRID COIL L_2 IS SO CONSTRUCTED THAT ITS INDUCTANCE TOGETHER WITH ITS DISTRIBUTED CAPACITY AND THE ADDITIONAL CAPACITY INTRODUCED BY THE GRID CIRCUIT WIRING PERMITS IT TO RESONATE BROADLY AT THE OPERATING FREQUENCY. THE GRID-PLATE CAPACITY OF THE TUBE PROVIDES THE NECESSARY FEED-BACK THE SAME AS IN THE TUNED-GRID, TUNED-PLATE OSCILLATOR — THE ONLY DIFFERENCE BEING THAT THE GRID COIL IS NOT TUNED BY A CONDENSER.

THE ELECTRON-COUPLED OSCILLATOR

FIG. 10 SHOWS YOU HOW A SCREEN GRID TUBE OF THE HEATER TYPE IS USED IN AN ELECTRON-COUPLED OSCILLATOR CIRCUIT. THE SCREEN GRID, CATHODE AND CONTROL GRID ARE CONNECTED IN A HARTLEY CIRCUIT SO AS TO GENERATE THE OSCILLATIONS. THE AMPLIFIED R.F. ENERGY IS TAKEN FROM THE TUNING CIRCUIT WHICH IS CONNECTED IN SERIES WITH THE PLATE. IN OTHER WORDS, THIS ARRANGEMENT SERVES AS AN OSCILLATOR AS WELL AS AN R.F. AMPLIFIER SO THAT THE R.F. ENERGY IN ADDITION TO BEING GENERATED CAN ALSO BE AMPLIFIED BY THE SAME TUBE.

ALTHOUGH BATTERIES ARE SHOWN AS SUPPLYING THE "B" VOLTAGES, AND ALSO THE "A" VOLTAGE IN THESE DIFFERENT OSCILLATOR CIRCUITS, YET YOU MUST BEAR IN MIND THAT THE OSCILLATOR CIRCUIT ARRANGEMENT REMAINS THE SAME REGARD-

LESS OF THE TYPE OF POWER SUPPLY BEING USED. THE DIFFERENT POWER SUPPLIES AS USED WITH TRANSMITTERS AND ALSO COMPLETE TRANSMITTER CIRCUIT DIAGRAMS TOGETHER WITH THEIR PROPER POWER SUPPLIES WILL ALL BE BROUGHT TO YOUR ATTENTION AT THE PROPER TIME IN THE COURSE.

TWO-TUBE OSCILLATORS

SOMETIMES, IT IS DESIRED TO OBTAIN A GREATER POWER OUTPUT FROM AN OSCILLATOR THAN CAN BE SUPPLIED FROM A SINGLE TUBE OF THE TYPE AVAILABLE. IN SUCH CASES, IT IS THEREFORE THE PRACTICE TO USE TWO TUBES TO FUNCTION SIMULTANEOUSLY AS OSCILLATORS AND IN THIS WAY FURNISH APPROXIMATELY TWICE THE POWER OUTPUT OF A SINGLE TUBE. ONE METHOD IS TO CONNECT THE TWO OSCILLATOR TUBES IN PARALLEL, THAT IS, USING THE SAME FUNDAMENTAL OSCILLATOR CIRCUIT AS WITH A SINGLE TUBE BUT TO CONNECT TOGETHER THE GRIDS, THE PLATES AND THE FILAMENTS OF TWO SIMILAR TUBES.

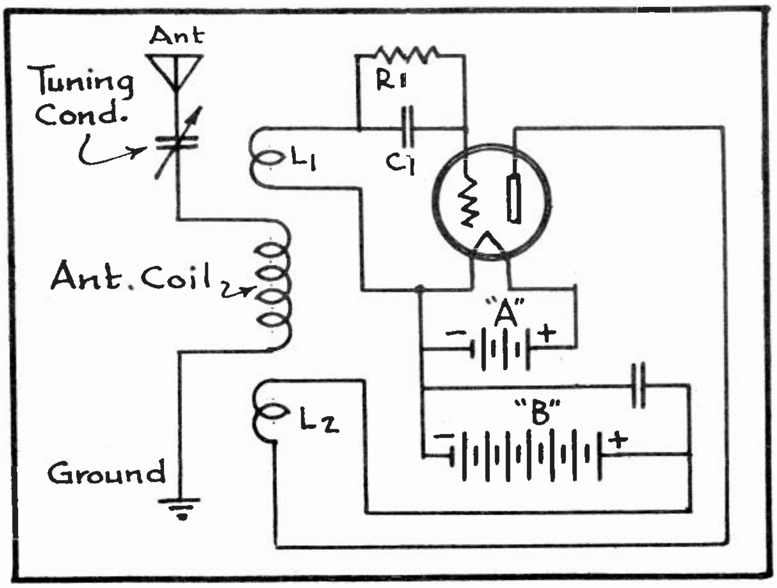


FIG. 8
The Meissner Circuit.

A PARALLEL OSCILLATOR CONNECTION, HOWEVER, IS NOT ALTOGETHER DESIRABLE IN THAT THIS ARRANGEMENT ALSO PLACES THE GRID-PLATE CAPACITIES OF THE TWO TUBES IN PARALLEL AND IN THIS WAY INCREASES THE FEED-BACK. WHEN TWO TUBES ARE TOGETHER INVOLVED IN THIS WAY THE FEED-BACK IS NOT EASILY CONTROLLED.

IF TWO OSCILLATOR TUBES ARE WANTED, THEN IT IS BETTER TO CONNECT THEM IN A PUSH-PULL ARRANGEMENT. THE PUSH-PULL CIRCUIT IN THIS CASE WILL HAVE THE SAME CHARACTERISTICS AS A PUSH-PULL TUBE CONNECTION IN AUDIO AMPLIFIERS. IN OTHER WORDS, THE PUSH-PULL OSCILLATOR CONNECTION ALSO PROVIDES US WITH ABOUT TWICE THE POWER OUTPUT OF A SINGLE TUBE AND IN ADDITION PLACES THE GRID-PLATE CAPACITIES OF THE TWO TUBES EFFECTIVELY IN SERIES.

IN THIS MANNER, WE ARE THEREFORE ABLE TO REALIZE A GREATER POWER OUTPUT AND AT THE SAME TIME REDUCE THE GRID-PLATE CAPACITY SO THAT FEED-BACK CAN BE READILY CONTROLLED. IT IS FOR THESE REASONS THAT THE PUSH-PULL CONNECTION IS MOST USED WHERE DUAL OSCILLATOR TUBES ARE EMPLOYED.

THE PUSH-PULL OSCILLATOR

A SIMPLE FORM OF PUSH-PULL OSCILLATOR IS SHOWN YOU IN FIG. 11 AND WHICH YOU WILL NO DOUBT READILY RECOGNIZE AS BEING BASED ON THE T.N.T. CIRCUIT.

COIL L_1 OF THE PLATE TUNED CIRCUIT IS CENTER-TAPPED AND CONNECTED TO B+, WHILE ITS EXTREMETIES ARE EACH CONNECTED TO ONE OF THE OSCILLATOR TUBE PLATES. THE R.F. CHOKE L_2 WHICH IS CONNECTED ACROSS THE GRIDS OF THE TWO TUBES IS ALSO CENTER-TAPPED, THE CENTER TAP BEING CONNECTED TO B- AND THE ELECTRICAL CENTER OF THE FILAMENT CIRCUIT THROUGH THE BLOCKING CONDENSER C_2 AND THE LEAK RESISTOR R_1. THE PURPOSE OF THE CONDENSER C_3 IS TO SERVE AS A HIGH FREQUENCY BY-PASS AROUND THE B SUPPLY.

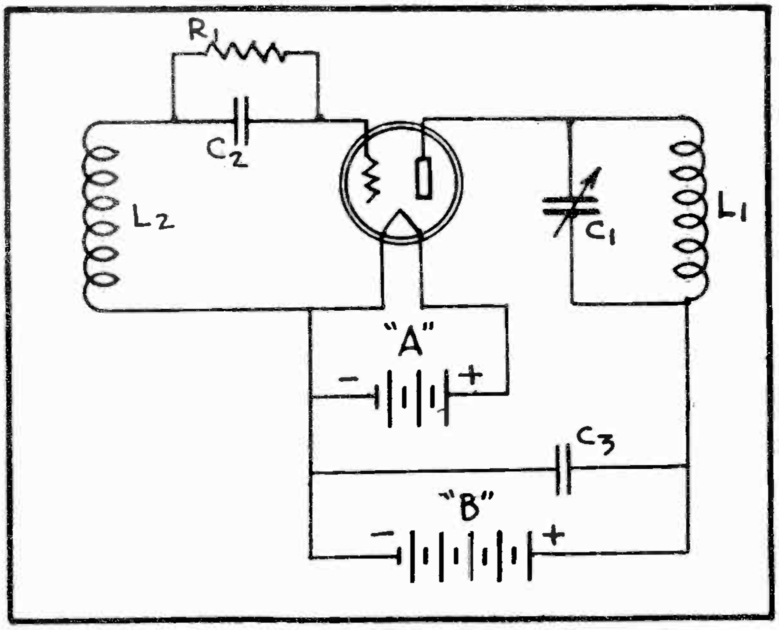


FIG. 9
The "T.N.T." Circuit.

FROM WHAT YOU HAVE ALREADY LEARNED IN THIS LESSON CONCERNING AN OSCILLATOR CIRCUIT OF THIS TYPE WHEN USING A SINGLE TUBE IN CONJUNCTION WITH WHAT YOU ALREADY KNOW ABOUT PUSH-PULL OPERATION, YOU SHOULD HAVE NO DIFFICULTY WHATEVER IN ACQUIRING AN INTELLIGENT UNDERSTANDING OF THE CIRCUIT PRESENTED IN FIG. 11.

THE TUNED-PLATE, TUNED-GRID, PUSH-PULL OSCILLATOR

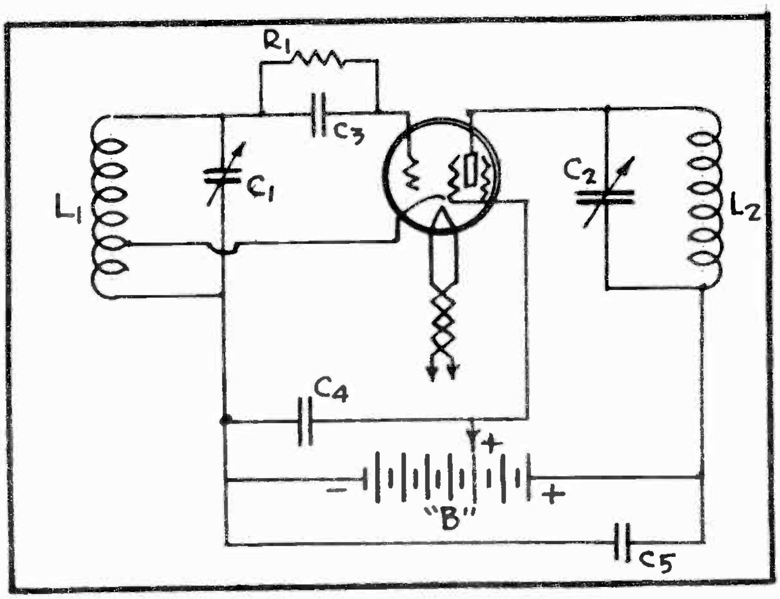


FIG. 10
The Electron-Coupled Oscillator.

IN FIG. 12 YOU WILL SEE HOW TWO TUBES CAN BE OPERATED IN A PUSH-PULL ARRANGEMENT BY USING THE TUNED-PLATE, TUNED-GRID OSCILLATOR PRINCIPLE. HERE, THE GRID COIL L_1 IS CENTER TAPPED AND TUNED BY CONDENSER C_1 — THE CENTER TAP IS CONNECTED TO B- AND THE ELECTRICAL CENTER OF THE FILAMENT CIRCUIT THROUGH THE BLOCKING CONDENSER C_3 AND THE LEAK RESISTOR R_1. THE PLATE COIL L_2 IS ALSO CENTER TAPPED AND TUNED BY CONDENSER C_2 — THE CENTER TAP BEING CONNECTED TO B+. THE OTHER CONNECTIONS

AND CIRCUIT COMPONENTS ARE SELF-EXPLANATORY BY THIS TIME.

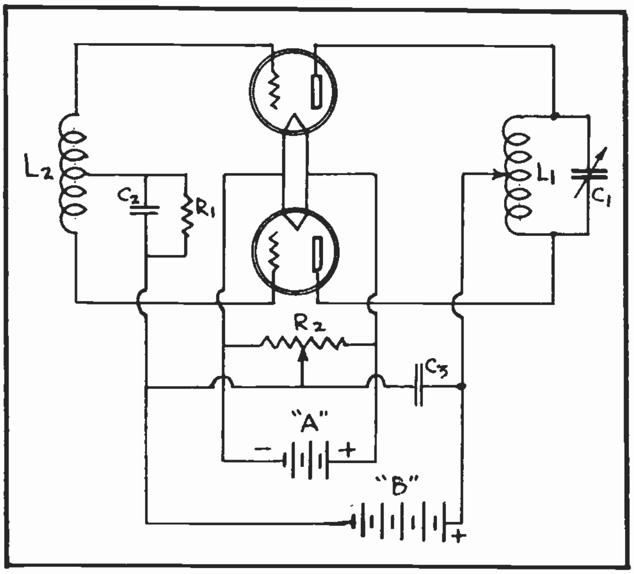


FIG. 11
The Push-Pull Oscillator.

WHEN PUSH-PULL OSCILLATOR TUBES ARE USED, THE T.N.T. AND TUNED-PLATE, TUNED-GRID ARRANGEMENTS ARE MOST GENERALLY EMPLOYED, HOWEVER, THE HARTLEY AND COLPITTS SYSTEM CAN ALSO BE APPLIED IN A PUSH-PULL CIRCUIT.

THE PUSH-PULL HARTLEY CIRCUIT

FOR YOUR INFORMATION YOU ARE SHOWN IN FIG. 13 A HARTLEY OSCILLATOR CIRCUIT IN WHICH TWO TUBES ARE USED IN PUSH-PULL. HERE THE BASIC PUSH-PULL ARRANGEMENT IS USED AND IN ADDITION THE COUPLING CONDENSERS C_2 AND C_3 ARE CONNECTED BETWEEN THE GRIDS OF THE TUBES AND OPPOSITE ENDS OF THE PLATE COIL L_1. THESE CONDENSERS ARE USED TO PERMIT FEED-BACK AND THEIR POINT OF CONNECTION TO L_1 IS VARIABLE SO THAT MORE OR LESS OF COIL L_1 CAN BE INCLUDED IN THE FEED-BACK CIRCUIT FOR BOTH TUBES. DUE TO THE MANY CONNECTIONS WHICH ARE NECESSARY AT COIL L_1 WHEN USING THIS CIRCUIT, THE COIL IN THIS CASE BECOMES QUITE CUMBERSOME AND AWKWARD TO HANDLE.

OTHER THAN THE FEED-BACK CONNECTIONS AT THE COIL L_1 THE CIRCUIT IN GENERAL DIFFERS VERY LITTLE FROM THE OTHER PUSH-PULL CIRCUITS SHOWN YOU IN THIS LESSON.

THE PUSH-PULL COLPITTS CIRCUIT

THE PUSH-PULL COLPITTS CIRCUIT IS SHOWN YOU IN FIG. 14. HERE THE CONDENSERS C_1 AND C_2 WHICH TOGETHER TUNE THE CIRCUIT MUST BE EITHER INDIVIDUAL CONDENSERS OR ELSE A SPLIT STATOR CONDENSER. THE VARIABLE GRID CONDENSERS C_3 AND C_4 ARE USED TO FURNISH A CONTROL OF GRID EXITATION.

THE REMAINING FEATURES OF THIS CIRCUIT FOLLOW THE

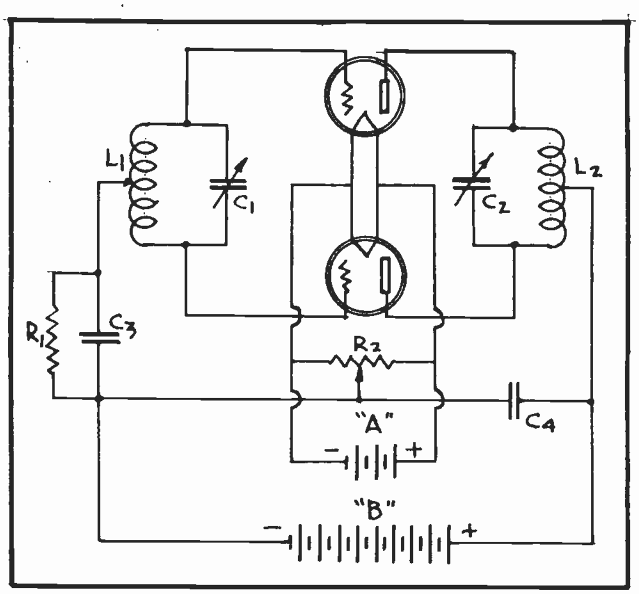


FIG. 12
The Tuned-Plate, Tuned Grid Push-Pull Oscillator.

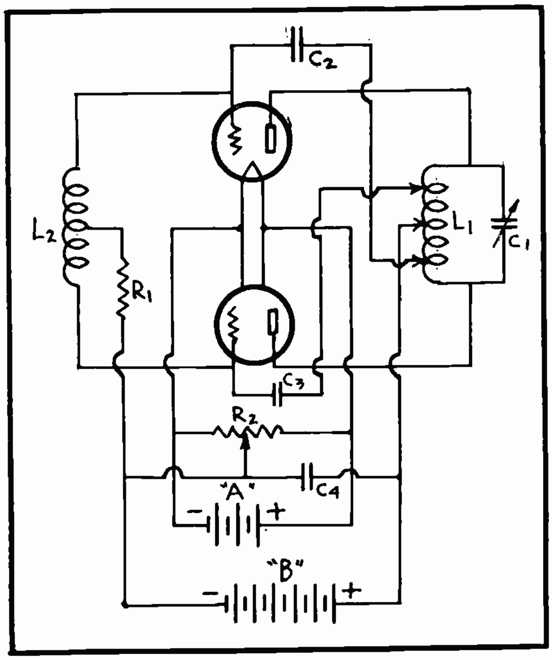


FIG. 13
The Push-Pull Hartley Circuit.

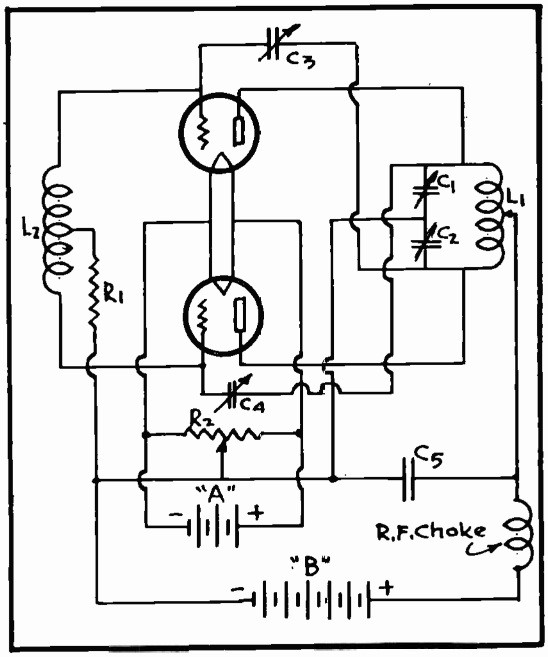


FIG. 14
The Push-Pull Colpitts Circuit.

SAME DESIGN PRINCIPLES AS THE OTHERS SO FAR DESCRIBED IN THIS LESSON AND THERE IS THEREFORE NO NEED FOR REPEATING THIS INFORMATION AT THE PRESENT TIME.

IN THIS LESSON YOU HAVE HAD THE OPPORTUNITY OF BECOMING ACQUAINTED WITH THE BASIC OSCILLATOR CIRCUITS AS USED IN TRANSMITTERS FOR BOTH CODE AND PHONE TRANSMISSION. IN THE FOLLOWING LESSON YOU ARE GOING TO CONTINUE YOUR TRANSMITTER STUDIES BY APPLYING THESE FUNDAMENTAL OSCILLATOR CIRCUITS TO LOW-POWER CODE TRANSMITTERS AND WHERE YOU WILL ALSO BE GIVEN COMPLETE CONSTRUCTIONAL DATA AS WELL AS THE ELECTRICAL VALUES OF THE PARTS USED AND CORRECT PROCEDURE FOR OPERATING SUCH TRANSMITTERS. YOU WILL THEN ADVANCE IN LOGICAL STEPS THROUGH YOUR CODE STUDIES, THE APPLICATION OF R.F. AMPLIFICATION TO TRANSMITTERS, MODULATION SYSTEMS ETC. SO THAT BY THE TIME YOU COMPLETE THIS SERIES OF LESSONS TREATING WITH TRANSMITTERS, YOU WILL HAVE A MOST THOROUGH KNOWLEDGE OF THIS DIVISION OF THE RADIO FIELD.

Answered 7/18/41

LESSON NO. T-2

Study and understudy. After you have really mastered your job and know more about it than anyone else, study the job of the man ahead. Be an understudy. Be prepared for opportunity

1. — DRAW A DIAGRAM OF A FUNDAMENTAL VACUUM TUBE OSCILLATOR CIRCUIT AND EXPLAIN HOW OSCILLATION IS PRODUCED.

2. — DRAW A DIAGRAM OF A SHUNT-FEED HARTLEY OSCILLATOR AND EXPLAIN HOW IT OPERATES.

3. — DRAW A DIAGRAM OF THE COLPITTS OSCILLATOR AND EXPLAIN HOW IT OPERATES.

4. — DRAW A DIAGRAM OF A TUNED-PLATE, TUNED-GRID OSCILLATOR AND EXPLAIN HOW IT OPERATES.

5. — DRAW A DIAGRAM OF THE T.N.T. OSCILLATOR CIRCUIT AND EXPLAIN HOW IT OPERATES.

6. — WHAT ADVANTAGES ARE OBTAINED BY EMPLOYING TWO TUBES IN A PUSH-PULL OSCILLATOR CIRCUIT AND WHY IS THIS ARRANGEMENT PREFERABLE TO PARALLEL CONNECTED OSCILLATOR TUBES?

7. — DRAW A DIAGRAM OF A TUNED-PLATE, TUNED-GRID PUSH-PULL OSCILLATOR AND EXPLAIN HOW IT OPERATES.

8. — WHAT IS THE DIFFERENCE BETWEEN THE SERIES-FEED HARTLEY OSCILLATOR AND THE SHUNT-FEED HARTLEY OSCILLATOR?

9. — WHY IN OSCILLATOR CIRCUITS IS IT CUSTOMARY TO CONNECT A BY-PASS CONDENSER ACROSS THE B POWER SUPPLY CIRCUIT?

10.— DRAW A DIAGRAM OF THE MEISSNER OSCILLATOR CIRCUIT AND EXPLAIN HOW IT OPERATES.

RADIO - TELEVISION

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Transmitters

LESSON NO. 3

LOW-POWER TRANSMITTERS

With what you have learned in the previous lesson about vacuum tube oscillators, you are now in a position to study about low-power transmitters in their complete form and the correct method of operating them. It is no more but logical that we start this study with the simpler circuits involving an oscillator stage only and then gradually advance through the more complex systems in which a greater number of tubes are employed.

You will also find that for the present, only code-transmitters are being considered in that these transmitters make use of more simple circuit designs than do the phone transmitters which are described in later lessons.

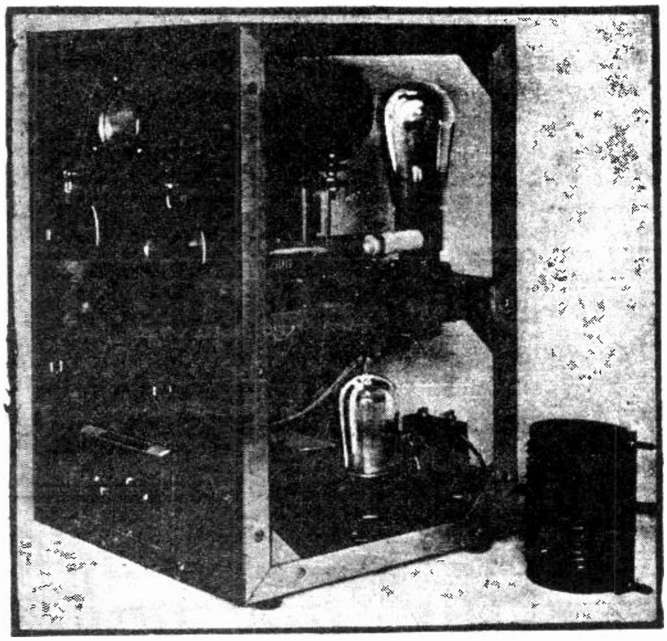

FIG. 1
An Attractive Low-Power Transmitter.

We want you to understand clearly, that the constructional data as furnished in these lessons is offered solely for instructional purposes and that it is unlawful to operate any of this transmitting equipment without first having passed the required examination and received a license from the Federal Communications Commission (formerly known as the Federal Radio Commission) to

OPERATE AN AMATEUR STATION.

LATER IN THIS COURSE, YOU WILL RECEIVE MORE SPECIFIC DATA AS TO THE REQUIREMENTS FOR QUALIFYING FOR SUCH A LICENSE.

A ONE-TUBE TRANSMITTER

IN FIG.2 YOU ARE SHOWN THE CONSTRUCTIONAL FEATURES AND GENERAL LAYOUT OF A LOW-COST, LOW-POWER TRANSMITTER. THIS TRANSMITTER, YOU WILL OBSERVE, REQUIRES BUT A SINGLE TUBE, OPERATING AS AN OSCILLATOR. IN THE PARTICULAR ILLUSTRATION HERE SHOWN A TYPE -45 TUBE IS BEING USED. THIS TUBE WILL FUNCTION SPLENDIDLY WHEN FILAMENT AND "B" VOLTAGES ARE SUPPLIED BY THE POWER PACK WHICH IS DESCRIBED LATER IN THIS LESSON.

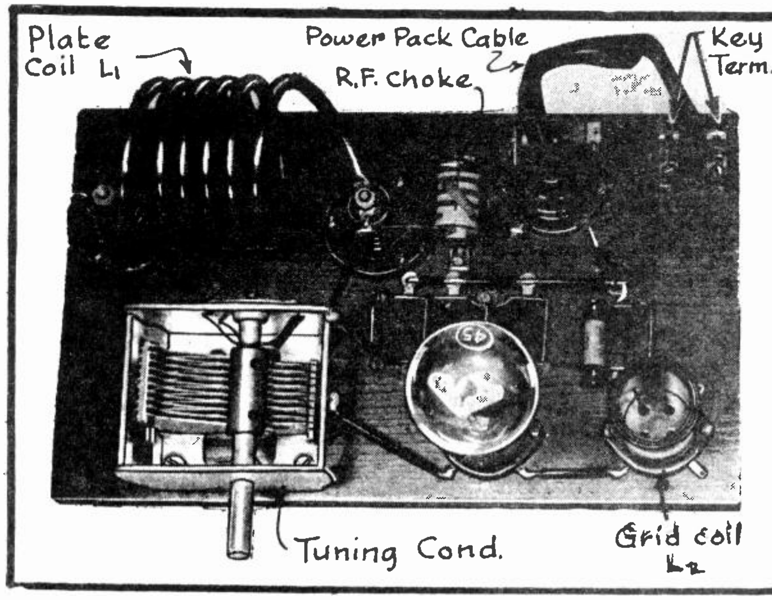

FIG.2
The One Tube Transmitter.

FOR BATTERY OPERATION, A TYPE 30 TUBE CAN BE USED WITH 90 VOLTS ON THE PLATE OR ELSE A TYPE -71A OR AN -01A WITH 180 VOLTS ON THE PLATE. FOR A STILL GREATER POWER OUTPUT AND WHEN A SUITABLE A.C. POWER PACK IS AVAILABLE, THEN A TYPE -10 TUBE CAN BE USED WITH 500 VOLTS APPLIED TO THE PLATE.

THE CIRCUIT DIAGRAM OF THIS PARTICULAR TRANSMITTER APPEARS IN FIG.3 AND IS HERE SHOWN USING A TYPE-45 TUBE. BY INSPECTING THIS DIAGRAM CLOSELY, YOU WILL READILY REALIZE HOW IT RESEMBLES THE BASIC OSCILLATOR CIRCUITS WHICH WERE SHOWN YOU IN THE PREVIOUS LESSON.

THE TUNING CIRCUIT OF THIS TRANSMITTER CONSISTS OF THE PLATE COIL L_1 ACROSS WHICH A CONVENTIONAL RECEIVER TYPE VARIABLE CONDENSER OF .00035 MFD. RATING IS CONNECTED.

COIL L_1 IS WOUND OF 1/4" DIAMETER SOFT COPPER TUBING, A PIPE OR DRY CELL APPROXIMATELY 2 3/8" IN DIAMETER BEING USED AS THE WINDING FORM. AFTER THE WINDING HAS BEEN COMPLETED, THE FORM IS REMOVED AND THE ENDS OF THE COIL ARE FLATTENED AND DRILLED SO AS TO FIT OVER THE MACHINE SCREWS IN THE STAND-OFF INSULATORS AS SHOWN IN FIG. 2.

ALL PARTS OF THIS TRANSMITTER ARE MOUNTED ON A WOODEN BOARD AND CAN BE LOCATED QUITE EASILY DIRECT FROM FIG. 2. THE STAND-OFF INSULATORS FOR SUPPORTING COIL L_1 ARE MOUNTED DIRECTLY BEHIND THE TUNING CONDEN

SER AND THE DISTANCE BETWEEN THE TWO INSULATORS IS 5" AS MEASURED BETWEEN CENTERS.

So that this transmitter can be operated in either the 20; 40 or 80 meter bands in which amateurs may conduct code communication, three different coils are used for L_1. The specifications for this set of three plate coils are as follows:

80 Meter band	14 turns
40 Meter band	6 turns
20 Meter band	4 turns

The grid coil L_2 is also wound as a set of three to cover the 20; 40 and 80 meter bands — each being wound on a standard four-prong plug-in coil form of 1¼" diameter. The specifications for the grid coil follow:

80 Meter band, 50 turns
40 Meter band, 15 turns
20 Meter band, 6 turns

All of these grid coils are wound with #30 B&S double cotton covered magnetic wire. Grid coil L_2 is inserted in the four-hole socket which is mounted directly to the right of the tube in Fig. 2.

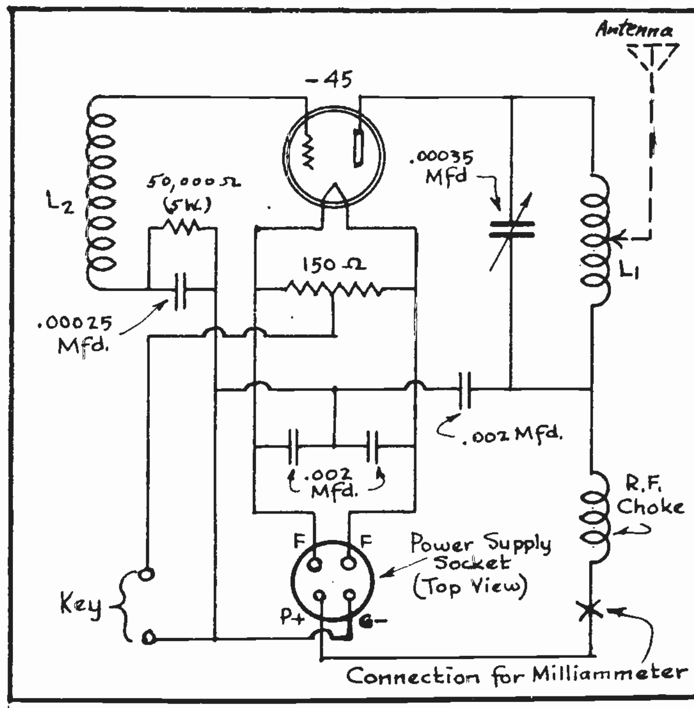

FIG. 3
Circuit Diagram of the Transmitter.

Notice in Fig. 3 that a 150 ohm center-tapped filament resistor is connected across the filament circuit and that its center tap serves as the B- connection. You will also observe in this same diagram that the terminals for the key are so placed that the key will be connected in series with the negative side of the "B" circuit and in this way provide a means whereby the plate circuit can be completed or interrupted to form the dots and dashes of the code.

The various by-pass condensers which are used may be of the type suitable for receivers but should have a mica dielectric. The purpose of the two series connected .002 mfd. condensers which are connected across the filament circuit is to provide a high frequency path from the filament to B- so that the high frequency currents won't have to pass thru the filament resistor or key.

A standard short-wave R.F. choke may be used in this circuit but

IT IS IMPORTANT THAT IT BE CAPABLE OF PASSING 100 MILLIAMPERES.

THE CIRCUITS ARE ALL WIRED WITH HEAVY BUS BAR AND THE LEADS ARE MADE AS SHORT AS POSSIBLE SO THAT THE RESISTANCE OF THE VARIOUS CIRCUITS WILL BE REDUCED TO A MINIMUM.

THE POWER PACK

THIS TRANSMITTER IS CONNECTED TO ITS POWER PACK BY MEANS OF A FOUR-WIRE CABLE AND THROUGH A PLUG AND SOCKET CONNECTION — THE SOCKET BEING MOUNTED ON THE TRANSMITTER AND THE CABLE WITH PLUG TO THE POWER PACK. THE CORRESPONDING POWER PACK IS SHOWN IN FIG. 4 AND ITS CIRCUIT DIAGRAM IN FIG. 5.

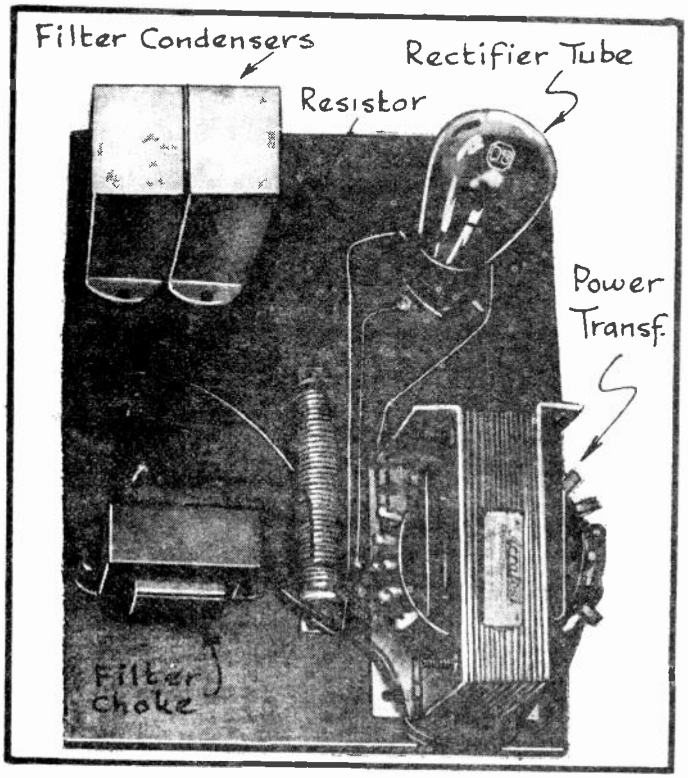

FIG. 4
The Power Pack.

YOU WILL IMMEDIATELY REALIZE THAT THIS POWER PACK FOLLOWS THE SAME CONVENTIONAL DESIGN AS USED IN A.C. RECEIVERS AND THERE IS THEREFORE NO PARTICULAR NEED FOR OFFERING ANY ADDITIONAL EXPLANATIONS REGARDING IT.

THE ANTENNA

IN A LATER LESSON YOU WILL BE GIVEN COMPLETE INSTRUCTIONS REGARDING TRANSMITTER ANTENNA SYSTEMS BUT IN ORDER THAT THE TRANSMITTER WHICH IS NOW BEING DESCRIBED WILL NOT BE INCOMPLETE, THE ANTENNA DATA RELATED THERETO SHALL NOW BE GIVEN.

THE ANTENNA WHICH IS TO BE USED WITH THIS TRANSMITTER IS OF THE MOST SIMPLE TYPE AND SO THAT THE TRANSMITTER MAY BE OPERATED ON EITHER THE 20; 40 OR 80 METER BANDS, ITS DIMENSIONS SHOULD CORRESPOND WITH THE DIAGRAM WHICH HAS BEEN PREPARED FOR YOU IN FIG. 6. HERE YOU WILL OBSERVE THAT THE TOTAL LENGTH OF THE ANTENNA FROM INSULATOR TO INSULATOR AMOUNTS TO 133 FT. AND THE WIRE USED FOR THIS PURPOSE IS A #14 B&S SOLID, ENAMELED WIRE.

THE "FEEDER" WHICH CORRESPONDS TO THE LEAD-IN ON A RECEIVING TYPE ANTENNA IS TAKEN OFF FROM A POINT 18 FT — 7 INCHES FROM THE CENTER OF THE ELEVATED WIRE OR FLAT-TOP. A HEAVY RUBBER-COVERED COPPER WIRE MAY BE USED AS THE FEEDER AND ITS LENGTH IS NOT CRITICAL. IT SHOULD, HOWEVER, RUN AT RIGHT ANGLES TO THE FLAT TOP FOR AT LEAST THE FIRST 30% OF ITS LENGTH.

NO GROUNDING SYSTEM IS USED IN CONJUNCTION WITH THIS TRANSMITTER

AND ITS ANTENNA.

SO MUCH FOR THE CONSTRUCTIONAL FEATURES OF THE TRANSMITTER. YOUR NEXT STEP WILL BE TO LEARN HOW THIS TRANSMITTER IS TO BE TUNED AND ADJUSTED SO THAT IT WILL OPERATE CORRECTLY AND IN THE PROPER FREQUENCY BAND. FOR THIS WORK, MOST AMATEUR OPERATORS USE A UNIT WHICH IS KNOWN AS A MONITOR AND SO THIS WILL BE DESCRIBED TO YOU NEXT, AFTER WHICH YOU WILL BE SHOWN HOW IT IS USED IN ORDER TO ADJUST THE TRANSMITTER.

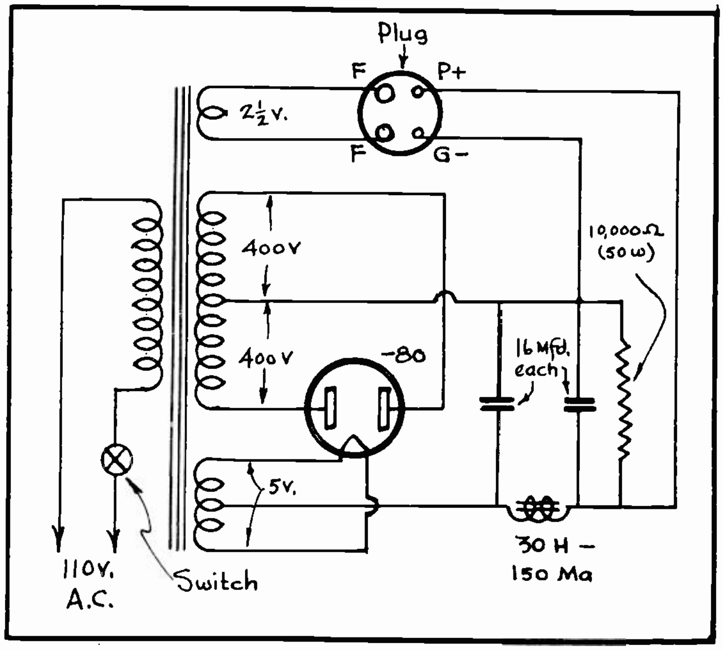

FIG. 5

Diagram of the Power Pack.

THE MONITOR

AN EXTERNAL VIEW OF A TYPICAL MONITOR IS SHOWN YOU IN FIG. 7, WHILE THE INTERNAL CONSTRUCTION OF THIS SAME UNIT IS SHOWN IN FIG. 8.

THE MONITOR IS IN REALLITY A SMALL ONE-TUBE, TOTALLY SHIELDED REGENERATIVE RECEIVER. THE PARTICULAR MONITOR HERE SHOWN USES A TYPE 30 TUBE AND THE TWO SERIES CONNECTED DRY CELLS FOR THE "A" BATTERY, AS WELL AS THE SMALL SIZE 45 VOLT "B" BATTERY, ARE ALL CONTAINED DIRECTLY IN THE SHIELD CAN TOGETHER WITH THE COIL, TUNING CONDENSER AND THE OTHER MISCELLANEOUS PARTS.

THE CIRCUIT DIAGRAM OF THIS MONITOR IS PRESENTED TO YOU IN FIG. 9 AND BY STUDYING THIS DIAGRAM YOU WILL SEE HOW SIMPLE IN CONSTRUCTION IT REALLY IS.

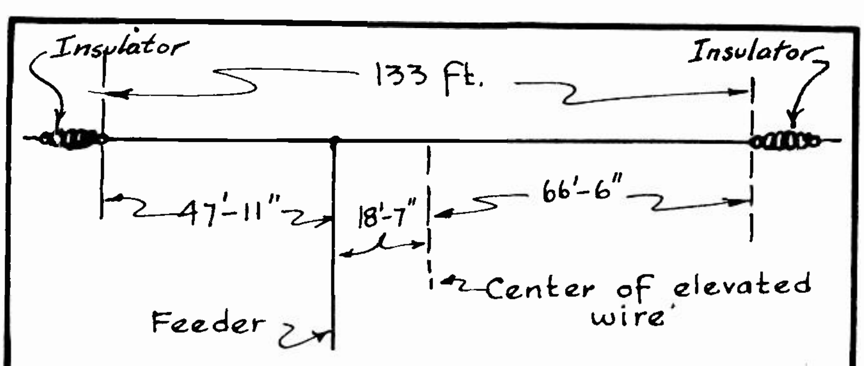

FIG. 6

The Antenna Dimensions.

SO THAT THIS MONITOR MAY ALSO COVER THE 20-40 AND 80 METER BANDS IN WHICH THIS TRANSMITTER IS TO BE OPERATED, IT IS ALSO PROVIDED WITH THREE SETS OF COILS — ONE FOR EACH BAND.

THE PLATE

AND GRID COIL FOR EACH COIL SET ARE BOTH WOUND TOGETHER ON A CONVENTIONAL PLUG-IN TYPE COIL FORM — THE WINDINGS BEING ARRANGED AS ILLUSTRATED IN FIG. 10. BOTH WINDINGS FOR ALL THREE WAVE BANDS ARE WOUND WITH #30 B&S DOUBLE COTTON- COVERED WIRE AND THE WINDING SPECIFICATIONS FOLLOW:

FIG. 7
Front View of the Monitor.

WAVE BAND	GRID COIL	PLATE COIL
80 METER	43 TURNS	20 TURNS
40 METER	15 TURNS	10 TURNS
20 METER	7 TURNS	7 TURNS

IN ALL CASES, NO SPACING IS TO BE ALLOWED BETWEEN THE GRID AND PLATE WINDINGS.

THE MONITOR POSSESSES TWO IMPORTANT CHARACTERISTICS, NAMELY, (1) IT OFFERS A MEANS OF LISTENING TO THE STATION TRANSMITTER'S SIGNAL AT LOW VOLUME AND OF THE SAME TONE AND CHARACTERISTIC AS WILL THESE SAME SIGNALS BE HEARD AT A DISTANT RECEIVING STATION. (2) THE MONITOR ALSO FUNCTIONS AS A MINIATURE TRANSMITTER SO THAT ITS SIGNAL CAN BE PICKED UP BY THE STATION RECEIVER.

CALIBRATING THE MONITOR

THE NEXT STEP IS TO CALIBRATE THE MONITOR AND THIS IS ACCOMPLISHED IN THE MANNER AS WILL NOW BE DESCRIBED.

FIRST, A GOOD SHORT-WAVE RECEIVER SHOULD BE AVAILABLE. AFTER THE RECEIVER HAS BEEN OPERATED FOR SOME TIME, ONE WILL BE FAMILIAR WITH THE LOCATION OF THE DIFFERENT AMATEUR BANDS WITH RESPECT TO THE RECEIVER'S DIAL SETTINGS. HAVING LOCATED ONE OF THESE AMATEUR BANDS IN THIS WAY, THE NEXT STEP IS TO TUNE IN SEVERAL COMMERCIAL AND GOVERNMENT STATIONS WHICH OPERATE CLOSEST TO BOTH ENDS OF THE PARTICULAR AMATEUR BAND IN QUESTION. THE FREQUENCY OF THESE STATIONS CAN BE DETERMINED BY CONSULTING A RADIO CALL BOOK IN WHICH ALL COMMERCIAL STATIONS ARE LISTED TOGETHER WITH THEIR FREQUENCY ASSIGNMENTS.

THESE STATIONS ARE GENERALLY REFERRED TO AS "MARKER STATIONS" BY AMATEURS. WITH ONE OF THESE MARKER STATIONS LOCATED, THE MONITOR IS PLACED NEAR THE RECEIVER AND PUT INTO OPERATION, USING THE PROPER COIL FOR THE BAND IN QUESTION. THE MONITOR IS THEN TUNED SO THAT ITS SIGNAL IS AUD-

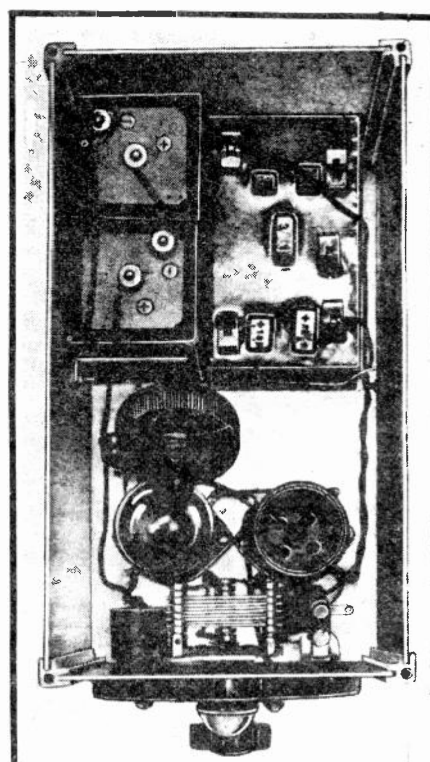

FIG. 8
Internal View of the Monitor.

IBLE AT THE RECEIVER AND AT A FREQUENCY REASONABLY CLOSE TO THAT AT WHICH THE FIRST MARKER STATION WAS TUNED IN. THIS DONE, THE MARKER STATION IS TUNED IN ACCURATELY ON THE RECEIVER AND THE MONITOR DIAL IS THEN ROTATED CAREFULLY SO THAT THE MONITOR SIGNAL FREQUENCY WILL BE ADJUSTED TO ZERO BEAT WITH THE SIGNAL COMING FROM THE MARKER STATION. THE DIAL SETTING OF THE MONITOR IS THEN CAREFULLY NOTED AND THEN PLOTTED ON GRAPH PAPER WHICH IS RULED OFF IN TERMS OF DIAL SETTINGS AND KILOCYCLES AS SHOWN IN FIG. 11.

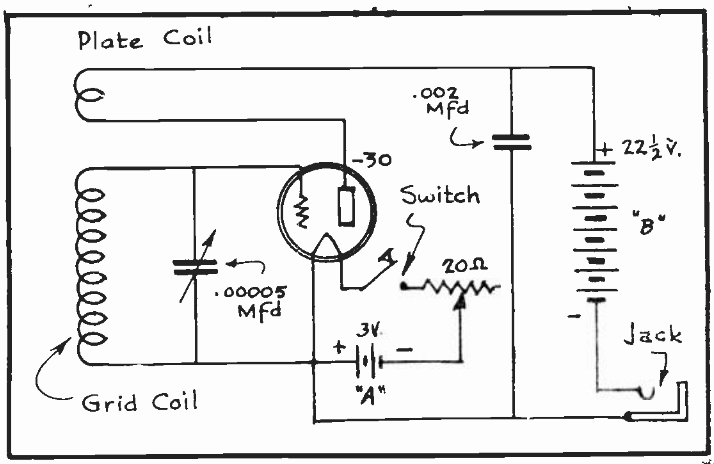

FIG. 9
Circuit Diagram of the Monitor.

THIS SAME PROCEDURE SHOULD BE REPEATED FOR EACH AVAILABLE MARKER STATION AND WHEN ALL THE CORRESPONDING MONITOR DIAL SETTINGS HAVE THUS BEEN PLOTTED ON THE GRAPH, A CONTINUOUS LINE IS DRAWN THROUGH THESE POINTS AND THIS RESULTS IN THE CALIBRATION CURVE FOR THE MONITOR. FROM THIS CURVE THE CORRESPONDING FREQUENCY FOR EACH DIAL SETTING OF THE MONITOR CAN BE DETERMINED WITH A REASONABLE AMOUNT OF ACCURACY. ONE SUCH CURVE MUST BE PLOTTED FOR EACH OF THE MONITOR COILS WHICH ARE USED. A SIMILAR SET OF CALIBRATION CURVES CAN AT THE SAME TIME BE PLOTTED FOR THE RECEIVER.

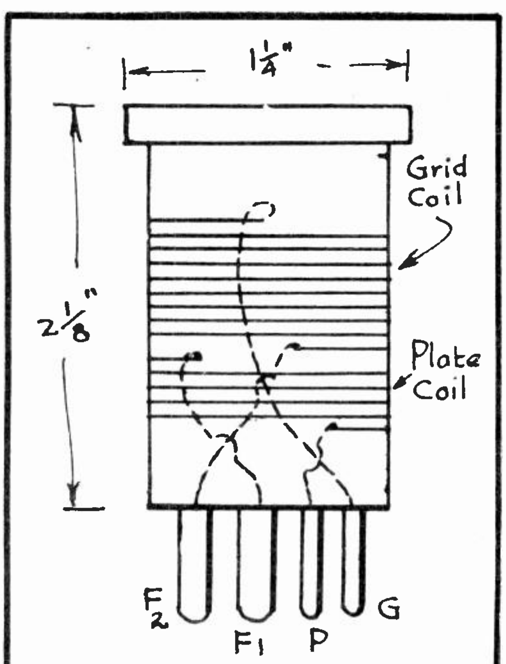

FIG. 10
The Monitor Coil.

IT IS TO BE UNDERSTOOD THAT THE MONITOR SIGNAL IS PICKED UP BY THE RECEIVER THROUGH RADIATION WHEN THE MONITOR IS PLACED REASONABLY CLOSE TO THE RECEIVER AND THAT NO WIRED CONNECTIONS ARE USED BETWEEN THESE TWO UNITS. SHOULD THE SHIELDING OF THE MONITOR BE TOO NEAR PERFECT, THEN SOMETIMES HOLES ARE DRILLED THROUGH THE SHIELDING SO THAT THE PROPER SIGNAL PICK-UP CAN BE OBTAINED.

TUNING THE TRANSMITTER

WHEN TUNING THE TRANSMITTER PREPARATORY TO GOING ON THE AIR, THE FIRST STEP IS TO INSTALL THE PROPER SET OF COILS FOR THE BAND TO BE USED AND THE TRANSMITTER IS FOR THE TIME BEING DISCONNECTED FROM THE ANTENNA FEEDER. NOW TUNE IN THE BAND WITH THE RECEIVER AND LOCATE A POINT WELL WITHIN THE BAND WHICH IS COMPARATIVELY CLEAR. THE MON

ITOR IS NOW ADJUSTED FOR THIS SAME FREQUENCY BY REFERENCE TO ITS CALIBRATION CURVE.

A MILLIAMMETER HAVING A RANGE FROM 0 TO 100 MA. IS CONNECTED IN SERIES WITH THE TRANSMITTER'S PLATE LEAD AT THE POINT MARKED WITH AN "X" IN FIG. 3. THE OPERATING MONITOR IS PLACED WITHIN A REASONABLE DISTANCE FROM THE TRANSMITTER AND ITS DIAL SETTING LEFT AT THE SAME POSITION WHICH HAS JUST PREVIOUSLY BEEN DETERMINED. THE NEXT STEP IS TO TURN THE TRANSMITTER DIAL UNTIL THE NEEDLE OF THE MILLIAMMETER DROPS TO A MINIMUM POSITION.

SOMEWHERE IN THAT PORTION OF THE DIAL WHERE A MINIMUM READING IS OBTAINED, A WHISTLE SHOULD BE HEARD IN THE EARPHONES WHICH ARE CONNECTED TO THE MONITOR. THE NUMBER OF TURNS USED ON THE GRID COIL SHOULD BE SUCH THAT THE MILLIAMMETER WILL READ MINIMUM AT THE LOW FREQUENCY END OF THE DIAL — IF IT DOESN'T, TURNS CAN BE ADDED TO OR TAKEN OFF THIS COIL.

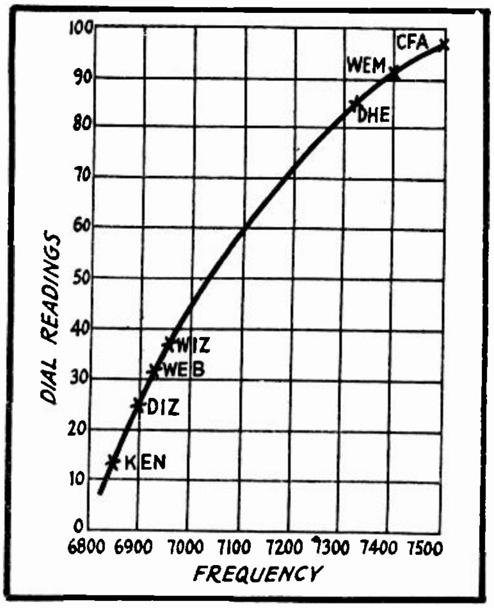

FIG. 11
A Calibration Curve.

WITH THE GRID COILS PROPERLY ADJUSTED, RETUNE THE TRANSMITTER FOR ZERO BEAT WITH THE MONITOR AND CLIP THE ANTENNA UNTO THE PLATE COIL, AT A POINT CORRESPONDING TO ONE TURN FOR THE 20, TWO TURNS FOR THE 40 AND FIVE TURNS FOR THE 80 METER COIL AS COUNTED FROM THE "COLD" OR PLATE BLOCKING CONDENSER END OF THIS COIL. ANY FINAL ADJUSTMENT IN TUNING CAN THEN BE MADE SO THAT THE TRANSMITTER FREQUENCY WILL BE THE SAME AS THAT FOR WHICH THE MONITOR IS TUNED. THE ANTENNA CAN BE CLIPPED ONTO THE PLATE AS NEAR THE HOT END AS POSSIBLE BUT WHICH STILL PERMITS SENDING A GOOD CLEAN NOTE.

FOR THE PARTICULAR ANTENNA SPECIFICATIONS WHICH WERE GIVEN FOR THIS TRANSMITTER, THE TRANSMITTER WILL OPERATE AT PEAK EFFICIENCY AT 3575 KC. IN THE 80 METER BAND AND ALSO AT THE HARMONIC 7150 KC. IN THE 40 METER BAND AND AT 14,300 KC. IN THE 20 METER BAND.

AFTER THE TRANSMITTER IS OPERATING PROPERLY AT THE CORRECT FREQUENCY, THE MONITOR CAN BE USED WITH THE HEADPHONES SO THAT THE OPERATOR CAN AT ALL TIMES "LISTEN-IN" AND CHECK UP ON THE QUALITY OF HIS TRANSMISSION.

A PUSH-PULL TRANSMITTER

THE SAME BASIC DESIGN AS JUST DESCRIBED RELATIVE TO THE ONE-TUBE TRANSMITTER CAN ALSO BE APPLIED TO A LOW-POWER PUSH-PULL TRANSMITTER. THE CONSTRUCTIONAL FEATURES OF THIS PUSH-PULL TRANSMITTER ARE SHOWN IN FIG. 12, WHERE YOU WILL SEE THE TRANSMITTER ITSELF, AS WELL AS THE POWER PACK.

THE CIRCUIT DIAGRAM OF THE PUSH-PULL TRANSMITTER APPEARS IN FIG.

13. AND BY STUDYING BOTH FIGS 12 AND 13 YOU WILL NOTICE THAT A PAIR OF TYPE-45 RECEIVER TUBES ARE EMPLOYED.

FROM WHAT YOU HAVE ALREADY LEARNED ABOUT TRANSMITTERS OF SIMILAR TYPE, THIS CIRCUIT IS SELF-EXPLANATORY. THE PLATE COIL TOGETHER WITH THE .0005 MFD. VARIABLE CONDENSER CONSTITUTES THE TUNING CIRCUIT AND THE SPECIFICATIONS FOR WINDING THIS COIL FOR THE 80; 40 AND 20 METER ARMATEUR BANDS FOLLOWS:

ALL THREE COILS ARE WOUND OF 1/4" DIAMETER SOFT COPPER TUBING AND ARE 2 3/8" IN DIAMETER. THE NUMBER OF TURNS USED ARE 12 FOR THE 80 METER BAND, 6 FOR THE 40 METER BAND AND 4 FOR THE 20 METER BAND. THE CENTER TAP CONNECTION TO THESE COILS CAN BE MADE BY MEANS OF A CLIP.

THE GRID COILS ARE ALL WOUND ON BAKELITE TUBING OF 1" DIAMETER AND WITHOUT ANY SPACING BETWEEN TURNS. EACH OF THESE GRID COILS IS FITTED WITH THREE PRONGS WHICH FIT INTO CORRESPONDING JACK-HOLES WHICH ARE MOUNTED IN A STRIP OF BAKELITE AND PLACED ON THE BASEBOARD OF THE TRANSMITTER. THIS GRID COIL CONSTRUCTION IS CLEARLY ILLUSTRATED IN FIG. 14.

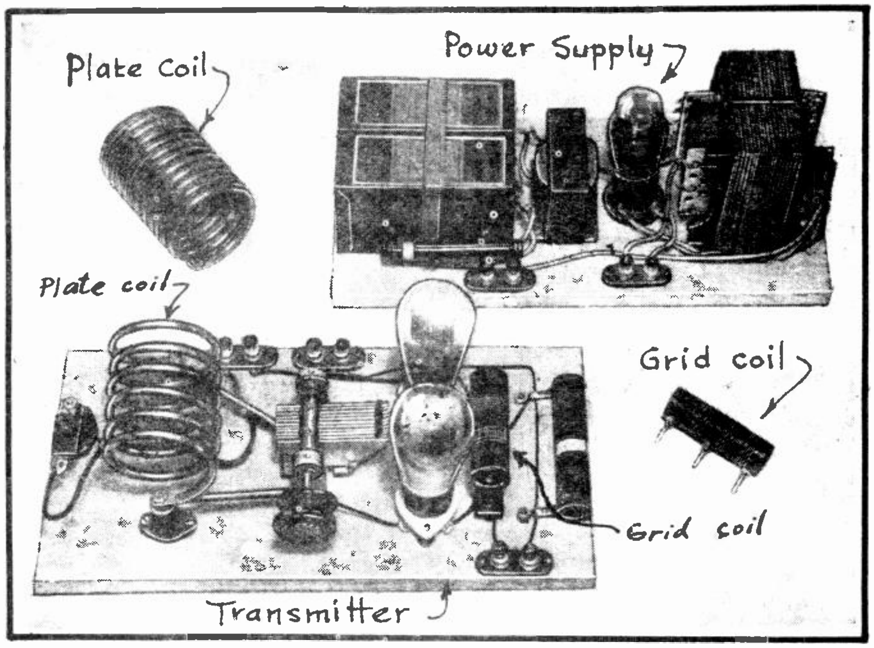

FIG. 12

The Push-Pull Transmitter and Power Supply.

EACH OF THESE GRID COILS IS WOUND IN TWO SECTIONS WITH A SPACE OF 9/16" BETWEEN SECTIONS. THE DATA FOR THESE COILS TO COVER THE THREE BANDS USED ARE AS FOLLOWS:

BAND	NO. OF TURNS	SIZE OF WIRE
80 METER	78	36 D.S.C.
40 METER	42	26 D.S.C.
20 METER	16	26 D.S.C.

THE SAME ANTENNA SYSTEM IS USED WITH THIS PUSH-PULL TRANSMITTER AS HAS BEEN RECOMMENDED FOR THE ONE-TUBE TRANSMITTER EARLIER IN THIS LESSON, ONLY THAT THE FEEDER IS CONNECTED TO THE PLATE COIL THROUGH A .001 MFD. MICA-DIELECTRIC FIXED CONDENSER.

THE POWER PACK FOR THIS TRANSMITTER IS DESIGNED TO FURNISH A "B"

VOLTAGE OF 400 VOLTS AND A TYPE -83 TUBE IS USED AS THE RECTIFIER. THE DIAGRAM FOR THIS POWER PACK APPEARS IN FIG. 15.

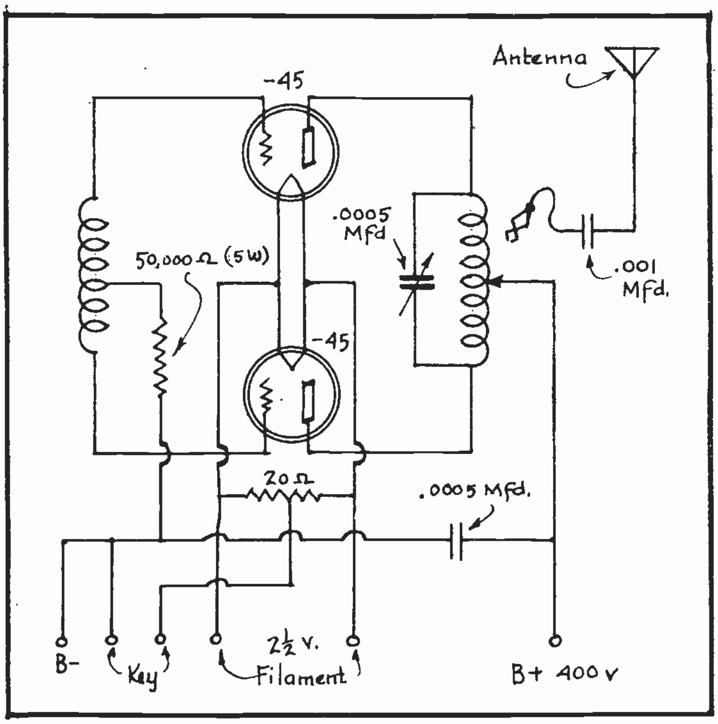

FIG. 13
Circuit of the Push-Pull Transmitter.

TO PREPARE THIS TRANSMITTER FOR OPERATION, THE SAME GENERAL PROCEDURE IS FOLLOWED AS HAS ALREADY BEEN EXPLAINED RELATIVE TO THE ONE-TUBE TRANSMITTER EARLIER IN THIS LESSON.

ANOTHER PUSH-PULL TRANSMITTER

IN FIG. 16 YOU ARE SHOWN THE COMPLETE CIRCUIT DIAGRAM OF A TRANSMITTER WHICH EMPLOYS A PAIR OF TYPE -10 TUBES IN A PUSH-PULL, TUNED-PLATE, TUNED-GRID CIRCUIT. THIS TRANSMITTER CAN ALSO BE CONSTRUCTED ON A WOODEN BASEBOARD THE SAME AS THE OTHERS ALREADY DESCRIBED IN THIS LESSON.

THE POWER PACK FOR THIS TRANSMITTER USES A PAIR OF TYPE -81 TUBES AS RECTIFIERS AND DUE TO THE HIGH VOLTAGE BEING HANDLED, GREAT CARE SHOULD BE TAKEN IN SELECTING FILTER CONDENSERS FOR THIS POWER PACK. THE FIRST FILTER CONDENSER AT THE INPUT END OF THE FILTER, FOR EXAMPLE, SHOULD BE RATED AT 1000 VOLTS D.C. OR HIGHER, AS SHOULD ALSO THE CENTER FILTER CONDENSER. A RATING OF APPROXIMATELY 750 VOLTS D.C. IS REQUIRED FOR THE FILTER CONDENSER WHICH IS PLACED AT THE OUTPUT END OF THE FILTER. THE FILTER CHOKES SHOULD EACH BE CAPABLE OF CARRYING 150 MILLIAMPERES AS SHOULD ALSO THE SHORT-WAVE R.F. CHOKE (R.F.C.). THE POWER TRANSFORMER IS TO BE EQUIPPED WITH A PRIMARY WINDING DESIGNED FOR THE LINE VOLTAGE BEING USED, TWO 7½ VOLT SECONDARIES, AND A 1100 VOLT CENTER-TAPPED SECONDARY.

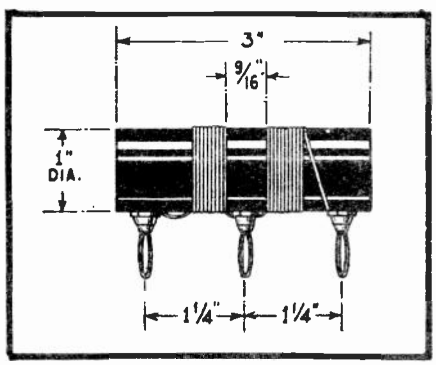

FIG. 14
Details of the Grid Coil.

COILS L_1 AND L_2 OF THE TRANSMITTER CIRCUIT ARE IDENTICAL FOR EACH WAVE BAND AND THE SAME WINDING SPECIFICATIONS CAN BE USED AS ALREADY SPECIFIED FOR THE PLATE COIL L_1 AS USED IN THE TRANSMITTER WHOSE CIRCUIT DIAGRAM APPEARS IN FIG. 3 OF THIS LESSON. THE CENTER TAP CONNECTION AT EACH OF THESE

COILS CAN BE MADE BY MEANS OF GOOD CLIPS HAVING STRONG SPRINGS.

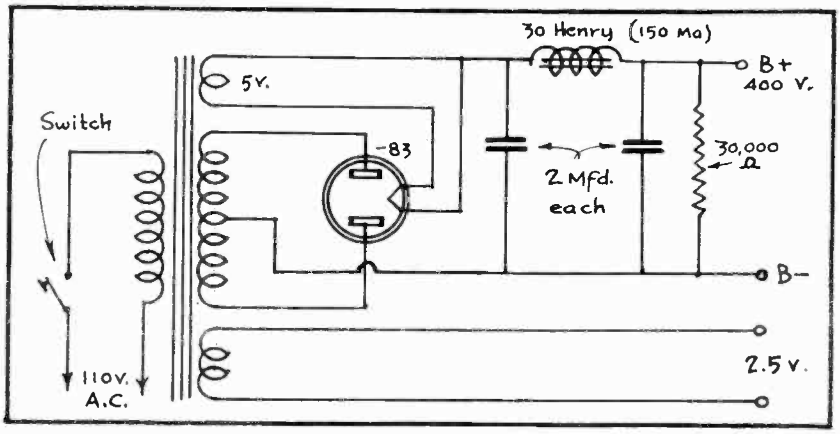

FIG. 15

Power Pack For the Push-Pull Transmitter.

THE ANTENNA SYSTEM WHICH IS ILLUSTRATED TOGETHER WITH THE TRANSMITTER CIRCUIT IN FIG. 16 IS KNOWN AS A ZEPPELIN ANTENNA AND ITS DIMENSIONS SHOULD BE AS FOLLOWS: LENGTH OF FLAT TOP BETWEEN INSULATORS = 133 FT.; LENGTH OF FEEDERS = 45 FT. THE TWO FEEDER WIRES SHOULD BE SEPARATED ABOUT 10 INCHES WITH GOOD LIGHTWEIGHT SPREADERS WHICH HAVE BEEN PREVIOUSLY BOILED IN PARAFFINE. THE TWO ANTENNA COILS "L" SHOULD EACH BE WOUND WITH THE SAME SIZE COPPER TUBING AS USED FOR COILS L_1 AND L_2. APPROXIMATELY 5 TURNS WOUND IN A $2\frac{1}{2}$" DIAMETER COIL WILL BE SATISFACTORY FOR EACH OF THE ANTENNA COILS. ONE OF THESE ARE MOUNTED AT EACH END OF L_1 AND PROVISIONS MADE SO THAT THE COUPLING AT THESE POINTS CAN BE VARIED.

TO ADJUST THIS TRANSMITTER FOR OPERATION, ALL THAT IS NECESSARY IS TO ADJUST THE TWO TUNING CONDENSERS C_1 AND C_2 FOR THE PROPER FREQUENCY

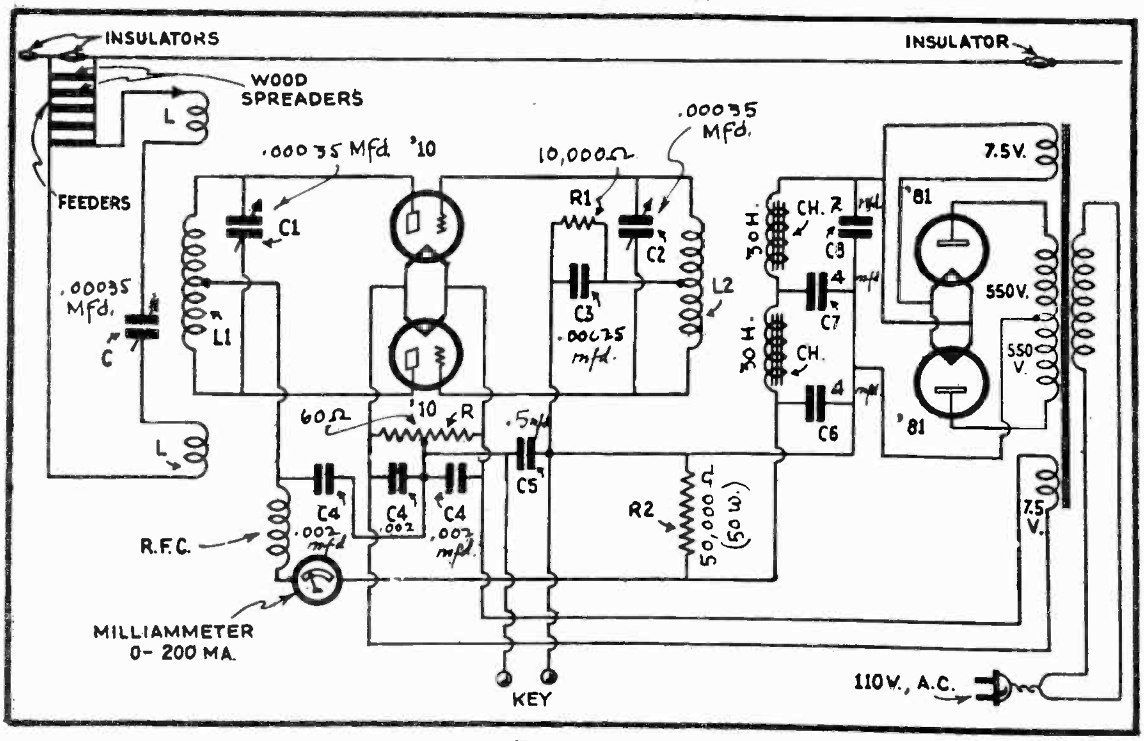

FIG. 16

A Push-Pull Tune-Plate, Tuned-Grid Transmitter.

AS CHECKED WITH THE MONITOR — THE MILLIAMMETER WILL AT THIS TIME SHOW A LOW READING OF AROUND 40 TO 60 MILLIAMPERES. THEN WITH THE ANTENNA CONNECTED UP, THE ANTENNA CONDENSER IS ADJUSTED UNTIL THE READING ON THE MILLIAMMETER IS MAXIMUM.

IN THE NEXT LESSON YOU ARE GOING TO RECEIVE CODE INSTRUCTION AND SUGGESTIONS REGARDING THE CORRECT MANNER OF OPERATING THE TRANSMITTER KEY. YOU WILL THEN PROGRESS IN LOGICAL STEPS, LEARNING ABOUT CRYSTAL-CONTROLLED OSCILLATORS, AMPLIFYING SYSTEMS FOR TRANSMITTERS, MORE ELABORATE METHODS OF ADJUSTING TRANSMITTERS ETC.

Examination Questions

LESSON NO. T-3

1. — DRAW A CIRCUIT DIAGRAM OF A COMPLETE LOW-POWER TRANSMITTER TOGETHER WITH ITS POWER-PACK.

2. — EXPLAIN THE OPERATION OF THE SYSTEM WHICH YOU HAVE DRAWN IN ANSWER TO THE PRECEDING QUESTION.

3. — DRAW A CIRCUIT DIAGRAM OF A MONITOR AND EXPLAIN ITS OPERATING PRINCIPLES.

4. — EXPLAIN HOW YOU WOULD PROCEED IN ORDER TO CALIBRATE A MONITOR WHICH HAS JUST BEEN CONSTRUCTED?

5. — EXPLAIN HOW YOU WOULD ADJUST THE TRANSMITTER ILLUSTRATED IN FIGS. 2 AND 3 OF THIS LESSON PREPARATORY TO GOING ON THE AIR.

6. — HOW ARE THE TUNED WINDINGS OF THESE LOW-POWER TRANSMITTERS GENERALLY CONSTRUCTED?

7. — DRAW A COMPLETE CIRCUIT DIAGRAM OF A TRANSMITTER USING PUSH-PULL OSCILLATOR TUBES AND A TUNED-PLATE, TUNED-GRID CIRCUIT.

8. — EXPLAIN HOW YOU WOULD ADJUST FOR OPERATION THE TRANSMITTER WHOSE CIRCUIT DIAGRAM YOU HAVE DRAWN IN ANSWER TO QUESTION #7 OF THIS EXAMINATION.

9. — WHAT ARE SOME OF THE MOST IMPORTANT THINGS TO CONSIDER IN SELECTING THE PARTS WHICH ARE TO BE USED IN A TRANSMITTER?

10. — IN WHAT PART OF A LOW-POWER TRANSMITTER CIRCUIT IS IT CUSTOMARY TO CONNECT THE KEY?

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Transmitters

LESSON NO. 4

MASTERING THE CODE

PART I

IN THE PRECEDING LESSON, YOU WERE TOLD ABOUT THE CONSTRUCTIONAL FEATURES AND METHOD OF SETTING UP SOME SIMPLE TRANSMITTERS PREPARATORY TO OPERATION. SINCE THESE TRANSMITTERS ARE ALL DESIGNED TO RADIATE THEIR MESSAGES BY MEANS OF THE TELEGRAPHIC CODE, IT IS NATURALLY NECESSARY THAT THE OPERATOR OF SUCH A TRANSMITTER BE THOROUGHLY FAMILIAR WITH THIS CODE. THIS THEN WILL BE YOUR NEXT STEP.

FURTHERMORE, SHOULD IT BE YOUR DESIRE TO QUALIFY EITHER AS AN AMATEUR OPERATOR, AS A COMMERCIAL OPERATOR, OR AS AN UNLIMITED BROADCAST OPERATOR, THEN YOU WILL BE REQUIRED TO PASS A CODE EXAMINATION IN THE PRESENCE OF AN EXAMINER WHO IS AUTHORIZED BY THE FEDERAL COMMUNICATIONS COMMISSION.

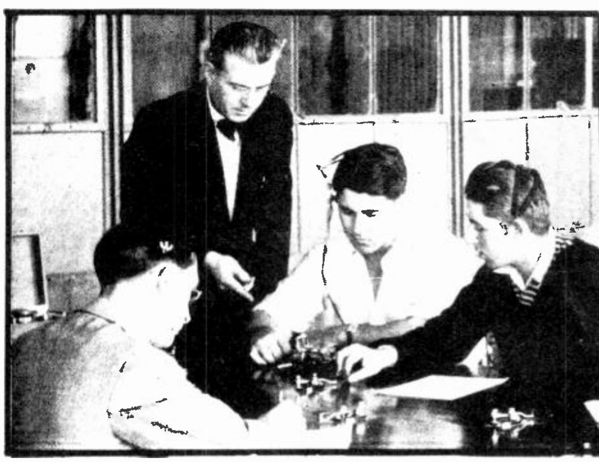

FIG. I
A Group of National Students Learning the Code.

IT IS ADVISABLE THAT YOU QUALIFY FOR AN AMATEUR'S LICENSE FIRST SINCE THIS DOES NOT CALL FOR SUCH A HIGH CODE SPEED OR AS COMPLETE TECHNICAL KNOWLEDGE AS DO THE REQUIREMENTS FOR LICENSE HOLDERS OF HIGHER RANK. IN ADDITION, THE EXPERIENCE WHICH YOU WILL ACQUIRE AS AN AMATEUR OPERATOR WILL BE OF A TREMENDOUS HELP IN PREPARING YOU TOWARDS BECOMING A COMMERCIAL OPERATOR LATER ON.

APPLICANTS FOR AN AMATEUR'S LICENSE ARE EXPECTED TO TRANSMIT AND RECEIVE AT LEAST 10 WORDS PER MINUTE IN THE CONTINENTAL CODE — FIVE CHARACTERS TO THE WORD. THIS, THEREFORE, SHOULD BE YOUR FIRST GOAL TOWARDS MASTERING THE CODE.

THE COMPLETE INTERNATIONAL MORSE CODE (CONTINENTAL CODE), AS WELL AS THE CONVENTIONAL SIGNALS, ARE ALL LISTED FOR YOU IN TABLE I IN A HANDY REFERENCE FORM. STUDY THIS TABLE CAREFULLY SO AS TO HAVE A GOOD IDEA OF ITS CONTENTS BUT FOR THE PRESENT DON'T ATTEMPT TO MEMORIZE THE CODE, ESPECIALLY IN THE FORM IN WHICH IT IS PRESENTED HERE. THIS TABLE IS TO SERVE CHIEFLY AS A REFERENCE FOR FUTURE USE.

TABLE I

INTERNATIONAL MORSE CODE AND CONVENTIONAL SIGNALS

To be used for all general public service radio communication

1. A dash is equal to three dots.
2. The space between parts of the same letter is equal to one dot.
3. The space between two letters is equal to three dots.
4. The space between two words is equal to five dots.

A	• —
B	— • • •
C	— • — •
D	— • •
E	•
F	• • — •
G	— — •
H	• • • •
I	• •
J	• — — —
K	— • —
L	• — • •
M	— —
N	— •
O	— — —
P	• — — •
Q	— — • —
R	• — •
S	• • •
T	—
U	• • —
V	• • • —
W	• — —
X	— • • —
Y	— • — —
Z	— — • •
Ä (German)	• — • —
Á or Å (Spanish-Scandinavian)	• — — • —
CH (German-Spanish)	— — — —
É (French)	• • — • •
Ñ (Spanish)	— — • — —
Ö (German)	— — — •
Ü (German)	• • — —
1	• — — — —
2	• • — — —
3	• • • — —
4	• • • • —
5	• • • • •
6	— • • • •
7	— — • • •
8	— — — • •
9	— — — — •
0	— — — — —

Period	• • • • • •
Semicolon	— • — • — •
Comma	• — • — • —
Colon	— — — • • •
Interrogation	• • — — • •
Exclamation point	— — • • — —
Apostrophe	• — — — — •
Hyphen	— • • • • —
Bar indicating fraction	— • • — •
Parenthesis	— • — — • —
Inverted commas	• — • • — •
Underline	• • — — • —
Double dash	— • • • —
Distress Call	• • • — — — • • •
Separation signal	• — • • —
General inquiry call	— • — • — — • —
From (de)	— • • •
Invitation to transmit (go ahead)	— • —
Warning—high power	— — • • — —
Question (please repeat after ......)—interrupting long messages	• • — — • •
Wait	• — • • •
Break (Bk.) (double dash)	— • • • —
Understand	• • • — •
Error	• • • • • • • •
Received (O. K.)	• — •
Position report (to precede position messages)	— • — •
End of each message (cross)	• — • — •
Transmission finished (end of work) (conclusion of correspondence)	• • • — • —

BY GLANCING THROUGH TABLE I, YOU WILL NOTE THAT THE LETTERS OF THE ALPHABET, NUMBERS, PUNCTUATION, AND MISCELLANEOUS CONVENTIONAL SIGNALS ALL CONSIST OF DOTS AND DASHES ARRANGED IN A DEFINITE MANNER. IT IS NOT ADVISABLE TO THINK OF THESE LETTERS OR CODE GROUPS IN TERMS OF DOTS AND DASHES BUT RATHER IN TERMS OF THEIR EQUIVALENT SOUNDS. FOR EXAMPLE, YOU SHOULD THINK OF A DOT AS THE SOUND "DIT" AND OF A DASH AS THE SOUND "DAH". THUS THE LETTER A SHOULD REGISTER IN YOUR MIND AS THE SOUNDS "DIT DAH" RATHER THAN DOT DASH, THE LETTER B AS "DAH DIT DIT DIT" INSTEAD OF DASH DOT DOT DOT ETC.

THE LOGICAL METHOD OF LEARNING THE CODE IS TO LEARN THE ALPHABET FIRST, FOR THE TIME BEING FORGETTING ALL ABOUT THE NUMBERS, PUNCTUATION ETC. FURTHERMORE, IT IS ALSO ADVISABLE THAT YOU START LEARNING THE CODE BY ACTUAL USE OF THE KEY RIGHT FROM THE START. IN THIS WAY, YOU WILL AT THE VERY BEGINNING BECOME ACCUSTOMED TO THINKING OF THE ALPHABETICAL LETTERS IN TERMS OF THEIR EQUIVALENT SOUNDS AND WHICH IS OF UTMOST IMPORTANCE.

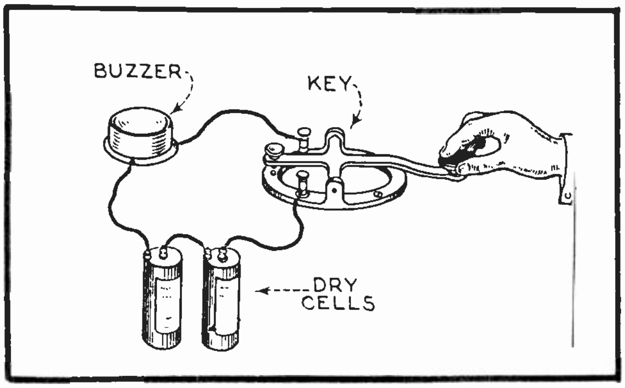

FIG. 2
The Buzzer Practice Set.

BEFORE DESCRIBING TO YOU THE ROUTINE TO FOLLOW IN ORDER TO MASTER THE CODE IN THE EASIEST AND QUICKEST POSSIBLE MANNER, SOME SUGGESTIONS WILL FIRST BE GIVEN SO THAT YOU CAN CONSTRUCT SUITABLE CODE-PRACTICE EQUIPMENT.

A BUZZER-TYPE CODE PRACTICE SET

IN FIG. 2 YOU ARE SHOWN THE CONSTRUCTIONAL FEATURES OF A BUZZER-TYPE CODE PRACTICE SET. THIS ASSEMBLY, YOU WILL OBSERVE, CONSISTS OF A REGULAR TELEGRAPH KEY (AS USED WITH RADIO TRANSMITTERS) CONNECTED IN SERIES WITH TWO #6 SERIES-CONNECTED DRY CELLS AND AN ORDINARY BUZZER AS USED FOR CALL SYSTEMS.

EACH TIME THE KEY IS DEPRESSED, THE BUZZER WILL EMIT ITS CHARACTERISTIC SOUND AND THUS BY PROPER MANIPULATION OF THE KEY, THE BUZZER SOUNDS CAN BE PRODUCED AS THE DIT DAH'S OF THE CODE.

THE AUDIO-OSCILLATOR CODE PRACTICE SET

THE AUDIO OSCILLATOR CODE PRACTICE SET WHOSE DIAGRAM APPEARS IN FIG. 3 IS BY FAR PREFERABLE TO THE BUZZER PRACTICE SET. THIS ARRANGEMENT IS NOTHING MORE THAN A SIMPLE AUDIO OSCILLATOR, CONSISTING ESSENTIALLY OF A TYPE -30 TUBE, AN OLD A.F. TRANSFORMER, A 20 OHM RHEOSTAT, AN "A" SUPPLY OF TWO SERIES-CONNECTED #6 DRY CELLS AND A $22\frac{1}{2}$ VOLT "B" BATTERY. A SET OF HEADPHONES AND A KEY ARE CONNECTED IN SERIES WITH THE PLATE CIRCUIT AS HERE SHOWN SO THAT EACH TIME THAT THE KEY IS DEPRESSED, A SIGNAL WILL BE HEARD IN THE HEADPHONES WHICH GREATLY RESEMBLES THAT AS HEARD FROM A RECEIVER WHEN A SIGNAL IS TUNED IN.

SOMETIMES, THE "B" BATTERY CAN BE ELIMINATED AND THE PLATE CIRCUIT

CONNECTED DIRECTLY TO THE "A" PLUS TERMINAL. THE SIGNAL WILL UNDER THESE CONDITIONS NATURALLY BE WEAKER BUT FREQUENTLY STILL STRONG ENOUGH FOR THIS USE. IF YOU WISH, YOU CAN TRY THIS LATTER CONNECTION BEFORE INVESTING IN A 22½ VOLT "B" BATTERY.

THE PRACTICE SET AS ILLUSTRATED IN FIG.3 IS QUITE INEXPENSIVE, NEVERTHELESS IT WILL SERVE ITS PURPOSE MOST ADMIRABLY. THE VARIOUS PARTS CAN ALL BE MOUNTED ON A WOODEN BASE-BOARD, FAHNESTOCK CLIPS BEING USED FOR THE EXTERNAL CONNECTIONS TO THE HEADPHONES ETC.

ALTHOUGH MORE ELABORATE CODE-PRACTICE SETS CAN BE CONSTRUCTED THAN THOSE HERE DESCRIBED, YET THE FEW ADDITIONAL FEATURES OBTAINED THEREFROM HARDLY WARRANTS A GREATER EXPENSE SINCE AFTER ALL, THIS ARRANGEMENT IS ONLY GOING TO BE USED FOR A LIMITED TIME. IT IS ADVISABLE TO PURCHASE A REASONABLY GOOD KEY FOR THE CODE PRACTICE SET SO THAT IT WILL ALSO BE SUITABLE FOR THE TRANSMITTER LATER ON. THE REMAINING PARTS WILL ALSO BE USEFUL AGAIN LATER ON, EITHER IN THE SHORT-WAVE RECEIVER OF THE STATION OR IN THE MONITOR ETC.

SO MUCH FOR THE CONSTRUCTIONAL FEATURES OF THE CODE-PRACTICE SET. NOW LET US PROCEED WITH THE HANDLING OF THE KEY.

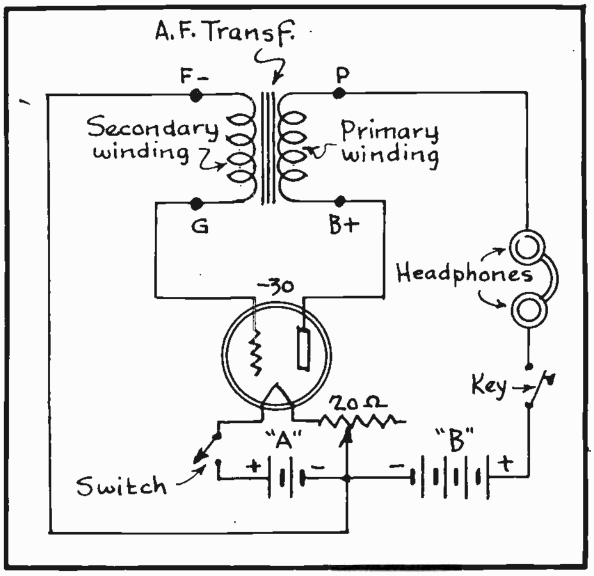

FIG. 3
The Audio-Oscillator Code Practice Set.

MOUNTING THE KEY

THE CONVENTIONAL KEYS ARE PROVIDED WITH A BASE OFFERING PROVISIONS FOR FASTENING THE KEY DOWN FIRMLY UPON THE TOP OF A TABLE WITH WOOD SCREWS. THIS IS IMPORTANT SO THAT THE KEY WILL NOT JUMP AROUND WHILE IT IS BEING OPERATED. IF NO TABLE IS AVAILABLE UPON WHICH THE KEY CAN BE MOUNTED, THEN THE NEXT BEST THING IS TO FASTEN THE KEY UPON A LARGE FLAT BOARD WHICH CAN BE PLACED ON TOP OF A TABLE AND STILL NOT PERMIT THE KEY TO SHIFT ITS POSITION WHILE IT IS BEING OPERATED.

THE CORRECT POSITION FOR THE KEY IS APPROXIMATELY EIGHTEEN INCHES FROM THE EDGE OF TABLE WHICH FACES THE OPERATOR AND APPROXIMATELY IN LINE WITH THE OPERATOR'S RIGHT SHOULDER. THIS POSITION OF THE KEY WILL PERMIT THE OPERATOR'S ELBOW TO REST ON THE TABLE AND WHICH IS IMPORTANT TOWARDS GOOD KEY MANIPULATION.

ADJUSTING THE KEY

THE BEGINNER IS URGED TO USE A CONVENTIONAL KEY IN PREFERENCE TO

THE HIGH-SPEED "VIBROPLEX" AND "DOUBLE-ACTION" KEYS WHICH ARE INTENDED PRIMARILY FOR THE EXPERIENCED OPERATOR. THE CONSTRUCTIONAL DETAILS OF THE CONVENTIONAL OR STANDARD KEY ARE CLEARLY ILLUSTRATED IN FIG. 4 AND HERE YOU WILL NOTICE THAT THREE SETS OF ADJUSTMENTS ARE PROVIDED. THESE ADJUSTMENTS ARE AS FOLLOWS: (1) A SCREW AND LOCKING NUT FOR ADJUSTING THE SPRING TENSION. (2) A SCREW AND LOCKING NUT FOR ADJUSTING THE CLEARANCE BETWEEN THE CONTACT POINTS OF THE KEY WHEN IN ITS NORMAL POSITION. (3) THE TWO SCREWS AND LOCKS, THE ADJUSTMENT OF WHICH PERMITS CENTERING THE ARM CONTACT OVER THE STATIONARY CONTACT, AS WELL AS SIDE-PLAY OF THE ARM.

WITH THE CONTACT POINTS PROPERLY LINED UP, THE SPRING TENSION SHOULD BE ADJUSTED. THE CORRECT TENSION VARIES WITH DIFFERENT OPERATORS, BUT FOR THE BEGINNER A FAIRLY HEAVY SPRING ADJUSTMENT IS MOST DESIRED. THE CLEARANCE ADJUSTMENT SHOULD BE SO REGULATED THAT A VERTICAL MOVEMENT OF THE KNOB EQUIVALENT TO APPROXIMATELY 1/16" IS NECESSARY IN ORDER TO CLOSE THE CONTACT POINTS OR A CLEARANCE BETWEEN THE POINTS OF ABOUT 1/32" OR SLIGHTLY MORE. THE ADJUSTMENTS AS HERE GIVEN ARE ONLY AVERAGE AND CAN BE VARIED TO BEST SUIT THE INDIVIDUAL OPERATOR SO AS TO PERMIT HIM TO SEND THE CLEAREST SIGNALS POSSIBLE.

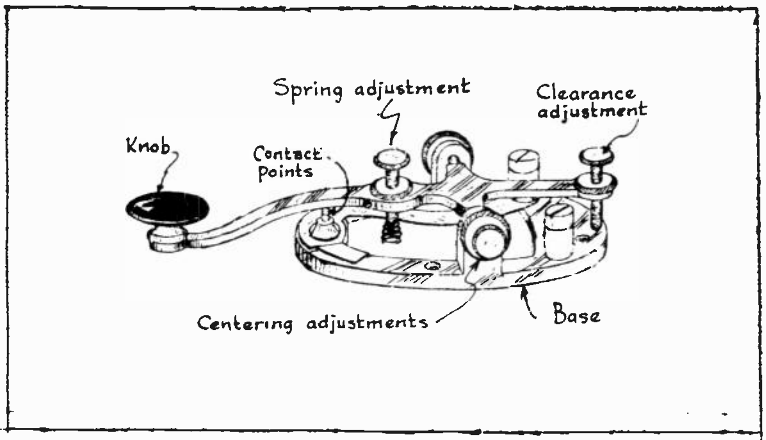

FIG. 4
Details of the Key.

MANIPULATING THE KEY

THE CORRECT METHOD OF GRASPING THE KEY IS ILLUSTRATED FOR YOU IN FIG. 5. NOTE THAT THE KEY IS NOT HELD TIGHTLY AND THAT THE HAND IS PERMITTED TO REST LIGHTLY ON THE KEY. THE THUMB SHOULD BE HELD AGAINST THE LEFT SIDE OF THE KEY, WHEREAS THE FIRST AND SECOND FINGERS SHOULD BE BENT SLIGHTLY AND SHOULD HOLD THE MIDDLE AND RIGHT SIDES OF THE KNOB RESPECTIVELY. OBSERVE IN FIG. 5 THAT THESE THREE FINGERS ARE PARTLY ON TOP OF THE KNOB WHILE THE REMAINING TWO FINGERS ARE ENTIRELY FREE OF THE KEY.

WHEN OPERATING THE KEY, THE ELBOW SHOULD BE RESTED ON THE TABLE AND A WRIST MOTION USED TO WORK THE KEY. DO NOT USE FINGER MOTION NOR THE WHOLE ARM. THE WRIST SHOULD AT ALL TIMES BE HELD ABOVE THE TABLE AND THE FINGERS WHICH GRASP THE KEY SHOULD NEVER LEAVE THE KEY WHILE SENDING.

SINCE THE CODE IS MADE UP OF DIFFERENT COMBINATIONS OF DOTS AND DASHES, IT IS IMPORTANT THAT THE INDIVIDUAL DOTS AND DASHES BE OF THE CORRECT LENGTH AND THAT THE PROPER TIME INTERVAL OR SPACING BE ALLOWED BETWEEN PARTS OF THE SAME LETTER, BETWEEN LETTERS OF THE SAME WORD ETC. IF THIS IS NOT DONE, THEN UTTER CONFUSION WOULD RESULT ON THE PART OF THE PERSON WHO IS RECEIVING YOUR SIGNALS.

HERE ARE THE RULES WHICH YOU MUST FOLLOW:

(1) A DASH IS EQUAL IN LENGTH TO THREE DOTS.

(2) THE SPACE BETWEEN PARTS OF THE SAME LETTER IS EQUAL TO ONE DOT.

(3) THE SPACE BETWEEN TWO LETTERS IS EQUAL TO THREE DOTS.

(4) THE SPACE BETWEEN TWO WORDS IS EQUAL TO FIVE DOTS.

MEMORIZING GROUPS

NOW FOR THE ACTUAL MEMORIZING OF THE CODE. AS HAS BEEN STATED BEFORE, WE START WITH THE ALPHABET BUT IT ISN'T ADVISABLE TO LEARN THE LETTERS IN THE SAME ORDER IN WHICH THEY APPEAR IN THE ALPHABET. SUCH A PROCEDURE WOULD COMPLICATE THINGS CONSIDERABLY AND MAKE YOUR LEARNING OF THE CODE QUITE DIFFICULT.

A BETTER PLAN IS TO DIVIDE THE ALPHABET INTO GROUPS, SO THAT YOU START WITH THE SIMPLER LETTERS AND THEN GRADUALLY ADVANCE THROUGH THE MORE DIFFICULT ONES. BY GLANCING THROUGH THE ALPHABET IN TABLE I, YOU WILL FIND THAT THE LETTERS T-M AND O ARE ALL DASH LETTERS, WHEREAS THE LETTERS E-I-S AND H ARE ALL DOT LETTERS. THEREFORE, IT IS NO MORE BUT LOGICAL TO MEMORIZE THESE SIMPLER LETTERS FIRST. THE VARIOUS CODE GROUPS ARE ALL ARRANGED FOR YOU IN TABLE II IN THEIR ORDER OF SIMPLICITY AND WHICH IS THE SAME ORDER IN WHICH YOU SHOULD MEMORIZE THEM.

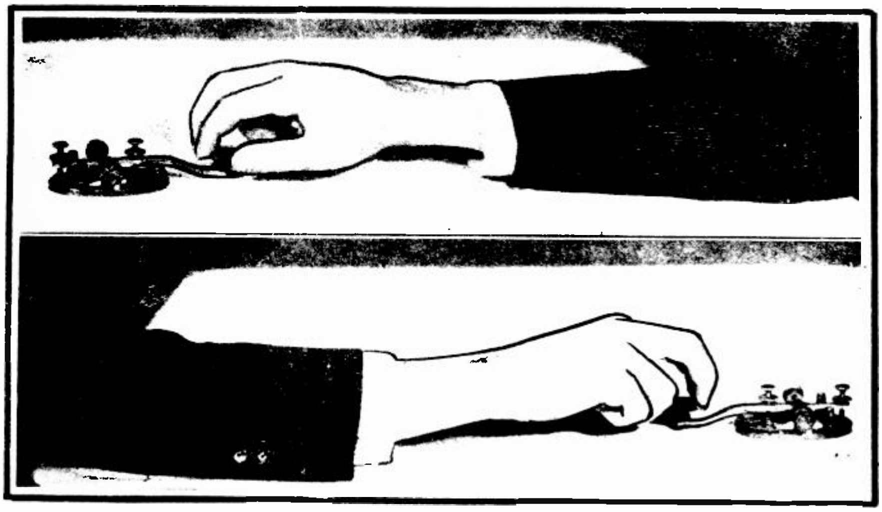

FIG. 5
Two Views Showing the Correct Position of Hand, Wrist and Elbow When Sending.

START WITH MEMORIZING GROUP #1 FIRST, PRACTICE THE SENDING OF THE LETTERS T, M AND O DILIGENTLY UNTIL YOU ARE ABLE TO SEND ANY ONE OF THESE SMOOTHLY AND WITHOUT ANY EFFORT AND SO THAT THERE WILL BE NO HESITATION ON YOUR PART IN SENDING EITHER OF THESE THREE LETTERS REGARDLESS OF THE ORDER IN WHICH YOU SEND THEM.

PRACTICE EXERCISE #1

AFTER YOU HAVE MASTERED THESE THREE LETTERS, YOUR NEXT TASK WILL BE TO SEND THEM IN THE CODE GROUPS AS PRESENTED TO YOU IN THIS PRACTICE EXERCISE. NOTICE THAT THE FOLLOWING CODE GROUPS ARE MADE UP OF VARIOUS COMBINATIONS OF THE DASH LETTERS T, M AND O. IN ADDITION TO SENDING THESE LETTERS CORRECTLY, IT IS ALSO IMPORTANT THAT YOU WATCH YOUR SPACING IN THE FOLLOWING GROUPS, BOTH BETWEEN LETTERS AND BETWEEN GROUPS.

TABLE II

MEMORIZING GROUPS

GROUP #1
T —— DAH
M —— DAH DAH
O —— DAH DAH DAH

GROUP #2
E —— DIT
I —— DIT DIT
S —— DIT DIT DIT
H —— DIT DIT DIT DIT

GROUP #3
A —— DIT DAH
N —— DAH DIT
D —— DAH DIT DIT

GROUP #4
W —— DIT DAH DAH
J —— DIT DAH DAH DAH
B —— DAH DIT DIT DIT

GROUP #5
R —— DIT DAH DIT
F —— DIT DIT DAH DIT
L —— DIT DAH DIT DIT

GROUP #6
U —— DIT DIT DAH
V —— DIT DIT DIT DAH
K —— DAH DIT DAH

GROUP #7
C —— DAH DIT DAH DIT
G —— DAH DAH DIT
Q —— DAH DAH DIT DAH

GROUP #8
Y —— DAH DIT DAH DAH
Z —— DAH DAH DIT DIT
P —— DIT DAH DAH DIT
X —— DAH DIT DIT DAH

GROUP #9
1 —— DIT DAH DAH DAH DAH
2 —— DIT DIT DAH DAH DAH
3 —— DIT DIT DIT DAH DAH
4 —— DIT DIT DIT DIT DAH
5 —— DIT DIT DIT DIT DIT

GROUP #10
6 —— DAH DIT DIT DIT DIT
7 —— DAH DAH DIT DIT DIT
8 —— DAH DAH DAH DIT DIT
9 —— DAH DAH DAH DAH DIT
0 —— DAH DAH DAH DAH DAH

GROUP #11
PERIOD —— DIT DIT DIT DIT DIT DIT
INTERROGATION —— DIT DIT DAH DAH DIT DIT
BREAK OR DOUBLE DASH —— (=) DAH DIT DIT DIT DAH
ERROR —— DIT DIT DIT DIT DIT DIT DIT DIT

GROUP #12
WAIT —— DIT DAH DIT DIT DIT
END OF MESSAGE —— DIT DAH DIT DAH DIT
END OF TRANSMISSION —— DIT DIT DIT DAH DIT DAH

TWO—LETTER CODE GROUPS

TT MM OO MO OM TT MM MT MO TM TO MO TM OT MT OM TM TO
OT TM OM MT OT MT OM OT MT OM TM MM TT MO OM OO MM TT

THREE—LETTER CODE GROUPS

TOM	MOO	OTO	TOM	OMO	MOO	TTM	OMO	MMT	MMT	OTM
TMO	TOO	MTM	MOM	TOM	TMO	MTM	MOT	TMT	TOO	OOM
TMT	TOT	OOM	OOT	NTO	TOM	MOM	TOM	MTM	OOT	MTO

FOUR—LETTER CODE GROUPS

TOMO	TMTM	OTOT	MMOT	MOTO	MTMT	MOMO	TMTO	MOTT	OTOM	MOTO
MTTM	MTOC	TMOT	TOTO	OMTO	MTOM	OOTT	OMTM	TOOM	OMOT	TOTO
OMOT	TOOM	MOOT	OTTO	OMOT	TOTO	MTOM	MOTM	MOOT	TMOO	MTOM

FIVE—LETTER CODE GROUPS

TOTOM	MTMOT	TOTTO	OTTOM	MOTMT	MMOOT	MTOMT	TOMOT	OTOMO	TMOTO	TOMMT
OOMTT	TMOTM	MOTTM	OMOTT	OMOTO	MTOMT	TOMOT	TOTOO	MOTOO	MMTOT	OTTOM
MOTOT	OMMOT	TOMOT	TMOTO	MTOMT	TMOTM	OTMOT	MOTOT	MOTTM	TOMTO	MOTOM

While performing these practice exercises, send slowly at first. It is more important that your sending be clean—cut and accurately spaced than it is to acquire speed. You will develope greater sending speed automatically with continued practice and experience.

At first you might find this work to be somewhat of a strain, causing you to become mentally fatigued in a relatively short time. For this reason, it is not advisable that you study the code for a longer period than 20 minutes at one sitting so as not to become over—tired. Then after a suitable period of relaxation, you can continue your studies again as you see fit.

Now that you are thoroughly familiar with the straight dash letters you can commence memorizing the straight dot letters E, I, S and H as they appear in group #2 of Table II, but by all means don't even attempt to learn group #2 until you are absolutely certain of group #1. Observe carefully in group #2 that E is dit, I is dit dit, S is dit dit dit and H is dit dit dit dit. When you have learned these four letters thoroughly, you can continue with Practice Exercise #2.

PRACTICE EXERCISE #2

This second practice exercise consists of various groupings of the letters E, I, S, and H. Here too you must be very careful of your spacing between letters as well as the spacing between groups.

TWO—LETTER GROUPS

EI	EH	SH	SI	IH	SS	II	HI	HS	EH	ES	IS
SE	IE	HH	EE	HE	EI	ES	IE	HE	SH	IS	SE
HH	EE	HI	IE	IH	SS	EH	HE	SI	ES	SH	IE

THREE-LETTER GROUPS

SIS	SIE	ISI	ESH	HIH	ESE	EIE	ESE	ISH	HIS
HEN	IEI	ISI	EIE	SIH	HEH	ISE	IHI	SHE	ESI
ISE	EHS	IHI	ESI	HEH	HIS	EIE	IEI	NEH	HEN

FOUR-LETTER GROUPS

SISE	ISIS	HSEI	ISHE	EHIS	SISE	ESHE	SHEE	HIHI	SEIS
HESE	HISI	EIEI	SIES	ISHE	SHIS	SHIE	HEHE	ISHI	ESEH
ESIS	ESEH	HISE	EHSI	SIHE	ESHI	SHEE	HISH	EISH	HIHI

FIVE-LETTER GROUPS

ESEES	ESHIE	SISSE	ESSES	HISII	HESHE	SHIHI	ESHIS	IHESI	SHISE
ISHIE	HHIHE	HEESE	SESHE	IHIHE	IIEEI	SHEIE	ISHIE	SHHSE	HISES
EHIES	SHEHI	HIHIE	IESEH	IIHIH	ESEHI	SESSE	ESEEH	ISEHS	SEESE

Upon completion of Practice Exercise #2, you are ready to send code groups which contain letters from both memorizing groups #1 and #2 used in various combinations. Now you will have to watch yourself particularly in your spacing between the letters of a group and between groups, otherwise the characters of the different letters will have a tendency to run together and in this way become confusing to the listener.

It is also advisable that you develope the habit now of making the error sign each time that you make a mistake in keying and then immediately send the signal again correctly.

P R A C T I C E   E X E R C I S E   # 3

This third practice exercise includes code groups containing letters of the straight dash and the straight dot type as extracted from memorizing groups #1 and #2 of Table II.

TETES	TEHOS	ESOTI	EMHIT	EOHSI	HISME	EMITO	IHEME
ISTEM	THIOM	OMITH	HOHOE	HOSEM	OEIST	TIHME	ISOIM
STEITH	EHOIM	SETOI	HOSME	TSEMO	MISSI	MSETH	OMSIT

P R A C T I C E   E X E R C I S E   # 4

By the time you have reached this point of the lesson, you have learned seven letters of the alphabet well and with these seven letters you can already commence spelling out simple words. This will make your code studies still more interesting. The words which you are now to spell follow:

IT	SET	HOT	TOO	HIM	MEET	TOTEM	MITES	ITEMS	MET
HE	MET	NET	THE	SIT	MESS	TOSS	MEMO	THEME	MEMO
ME	TEE	SIM	SOT	HIS	MOST	HOIST	OTTO	SOME	HEM

MEMORIZING GROUP #3

The next three letters which you are to add to your code list are the "A", the "N" and the "D". By referring to memorizing group #3 in Table II you will note that these are your first letters which are a

COMBINATION OF THE DOT AND THE DASH. IN OTHER WORDS, "A" IS DIT DAH, "N" IS DAH DIT AND "D" IS DAH DIT DIT. THE THING TO DO NOW IS TO LEARN THESE THREE LETTERS THOROUGHLY SO THAT YOU CAN SEND EITHER ONE OF THEM WITHOUT HESITATION. WHEN YOU ARE SURE OF THESE THREE LETTERS THEN YOU CAN PROCEED WITH PRACTICE EXERCISE #5.

PRACTICE EXERCISE #5

THIS FIFTH PRACTICE EXERCISE CONSISTS OF CODE GROUPS CONTAINING THE LETTERS T-M-O-E-I-S-H-A-N-D WHICH YOU HAVE SO FAR LEARNED. PRACTICE SENDING ALL OF THESE WITH ACCURACY AND AS SMOOTHLY AS POSSIBLE.

FIVE-LETTER CODE GROUPS

AISHD	DANAS	NINES	DISOM	SMITE	IDSNT	ANOMI
SAMES	DODOS	MISAD	NATID	DITES	MEDIN	OTDIN
DIDAN	ONSET	SNADS	TADAN	SEDNI	INISE	NADAT
MIDAS	MANDA	HDTAN	ADANE	NTMOA	NEADS	AIDIS
OTESA	DIDSN	ENTAH	NEATS	NANED	MADIN	HEOAD
ANDAD	ADNAD	ODONA	OSTEA	SANDS	IMONA	ESINI

TWO AND THREE-LETTER WORDS

TO	THE	ODE	MAD	ATE	SIN	TAN	DIN	SOT
IT	AND	ODD	TEE	TIT	TEN	SET	AID	DIE
AS	TOT	NED	SAT	EAT	TEA	NAT	DEN	TAT

SIMPLE FOUR-LETTER WORDS

THEM	TEND	SODA	ITEM	MOTE	NINE	MOTH	NAME
DATE	NAME	SOME	EAST	INTO	IDEA	MOAN	TEST
HOME	IDES	EASE	EDEN	SAND	MATE	EDIT	TIDE

SIMPLE FIVE-LETTER WORDS

DIDOS	MAIDS	TEEMS	MEANS	HINTS	NAMES	TEAMS
DINES	STINT	DATES	SMASH	DEANS	SODAS	AIDES
STAND	ASHES	DANES	MITES	SAINT	DOMES	MAINS

THE NEXT THREE LETTERS FOR YOU TO LEARN ARE THE W - J AND THE B WHICH ARE INCLUDED IN GROUP #4 OF TABLE II. THE LETTER W, YOU MUST REMEMBER, IS DIT DAH DAH, J IS DIT DAH DAH DAH AND B IS DAH DIT DIT DIT. STAY WITH THESE THREE LETTERS UNTIL YOU LEARN THEM THOROUGHLY AND THEN GO AHEAD WITH PRACTICE EXERCISE #6.

PRACTICE EXERCISE #6

THE FIRST PART OF THIS EXERCISE CONSIST OF CODE GROUPS CONTAINING IN VARIOUS COMBINATIONS ALL OF THE LETTERS WHICH YOU HAVE LEARNED SO FAR, INCLUDING THE LAST THREE LETTERS W-J-B. THE SECOND PART OF THIS EXERCISE SUGGEST SIMPLE BUT COMPLETE SENTENCES WHICH YOU CAN SEND BY USING THE LETTERS WHICH YOU KNOW AT THIS TIME. IT IS IMPORTANT THAT YOU GIVE THIS PARTICULAR EXERCISE YOUR FULLEST ATTENTION.

CODE GROUPS

IWAWE	JABEW	DIJOW	TWIBE	ESIBN	JASBI	TOWID
SHEJD	SEJOW	OBJSI	EWABD	DBEBI	ISHWJ	DBIDJ
NTOJW	OWESJ	JANDB	ANJEB	MIWAD	BADIJ	ATJJS
BIJEW	EJMWD	JASWB	SWEBT	WAIBJ	BOSWE	WISDJ

SIMPLE SENTENCES

This job is to be done by the best man.

James is to meet Sam between ten and noon.
The same man was to be sent at this time.
John and Sam went down town at nine A.M.
Tom waited to see that the bat was sent home.
Joe said he was not a bad man.
Jim boasted that he did not owe Dan.
We joined both ends and waited.

MEMORIZING GROUP #5

The next three letters which you are to learn are the R, the F and the L as given in memorizing group #5 of Table II. Notice that R is dit dah dit, F is dit dit dah dit, and L is dit dah dit dit. Learn these three letters thoroughly and then proceed with Practice Exercise #7.

PRACTICE EXERCISE #7

This practice exercise consits of code groups containing all of the letters which you have learned so far and including the letters R, F, and L. In addition, you are also at this time given some more practice sentences employing these new letters.

THE CODE GROUPS

RARIR	DAFIN	LFRWE	FELWI	TLOFR	IRERT
LELIL	SBLJW	JBARL	DWETW	RIRAR	SLOWE
RFWLB	NWJDB	NRWJT	TRIRE	JOLIB	RFLWJ
TRFLE	BSJWD	RASIR	LJWBL	BRFLW	LFRHM
ITEMS	FEFOS	REFIL	WJBER	FRWJB	IJWFS

SIMPLE SENTENCES

The water is fine.
The owner of the horse saw it stolen.
There will be a row when Jim finds we are late.
Attend to the joint between the windows.
I see that the flow is from both east and west.
That Indian is not a bad man.
The best three are to be sent with John.
He will have one horse and we will want two.
Between the two of them it will be fine.

SOME SPECIAL SUGGESTIONS

ALTHOUGH IT IS PREFERABLE THAT YOU START YOUR CODE STUDIES BY ACTUALLY USING A KEY, YET THIS DOES NOT MEAN THAT YOU SHOULD NEGLECT YOUR CODE STUDIES JUST BECAUSE YOU DON'T AT PRESENT HAVE A CODE PRACTICE SET AVAILABLE. IF SUCH BE THE CASE, YOU CAN START LEARNING THE CODE BY GOING THROUGH ALL THE EXERCISES PRESCRIBED IN THIS LESSON BY PRODUCING THE CODE CHARACTERS WITH YOUR MOUTH. FOR EXAMPLE, FOR THE LETTER "A" SIMPLY UTTER THE SOUNDS DIT DAH, FOR THE LETTER "S" UTTER THE SOUNDS DIT DIT DIT JUST AS YOU WOULD MAKE THEM IF YOU HAD A CODE PRACTICE SET. EVEN THIS ROUTINE, WILL HELP YOU TREMENDOUSLY IN THE TASK OF LEARNING CODE AND THEREBY ENABLE YOU TO BE JUST THAT FAR AHEAD WHEN YOU HAVE ACCESS TO A CODE PRACTICE SET AND THUS MAKE YOUR PROGRESS THROUGH THIS WORK JUST THAT MUCH MORE RAPID.

IT IS ALSO GOOD PRACTICE TO HAVE SOME OTHER PERSON SEND THE DIFFERENT LETTERS OR CODE GROUPS TO YOU SO THAT YOU CAN ADAPT YOURSELF TO THE RECEPTION OF CODE. THESE "SIGNALS" CAN BE SENT TO YOU EITHER BY WORD OF MOUTH OR ELSE BY SOME OTHER PARTY SENDING THEM TO YOU WITH THE KEY WHILE YOU LISTEN-IN ON THE HEADPHONES OF YOUR CODE PRACTICE SET. YOU WILL CONTINUE YOUR CODE WORK IN THE NEXT LESSON.

Examination Questions

strepined

LESSON NO. T-4

1. – HOW MUCH TIME HAVE YOU SPENT SO FAR IN THE STUDY OF THE CODE?
2. – ARE YOU USING A CODE PRACTICE SET WITH WHICH TO LEARN THE CODE?
3. – AT THE PRESENT TIME, HOW MANY CODE LETTERS CAN YOU TRANSMIT WITHOUT REFERRING TO YOUR TEXT?
4. – DRAW A CIRCUIT DIAGRAM OF A CODE PRACTICE SET EMPLOYING A VACUUM TUBE AND EXPLAIN HOW IT IS USED.
5. – WHAT IS THE MEANING OF • —— • ?
6. – HOW WOULD YOU MAKE THE LETTER B BY MEANS OF THE CODE? INDICATE THIS ON YOUR PAPER BY THE PROPER ARRANGEMENT OF DOTS AND DASHES.
7. – WHAT IS THE CORRECT RELATION BETWEEN THE LENGTH OF A DOT AND THE LENGTH OF A DASH.
8. – TRANSCRIBE THE FOLLOWING SENTENCE INTO CODE BY PLACING THE PROPER ARRANGEMENT OF DOTS AND DASHES ON YOUR PAPER, BEING SURE TO INDICATE THE CORRECT SPACING BETWEEN THE LETTERS OF ANY ONE WORD AND BETWEEN WORDS. HERE IS THE SENTENCE: THE WATER IS FINE.
9. – WHAT IS THE CORRECT SPACING BETWEEN THE LETTERS OF A WORD AND BETWEEN WORDS OF A SENTENCE?
10. – TRANSCRIBE INTO CODE THE FOLLOWING SENTENCE: THE OWNER OF THE HORSE SAW IT STOLEN.

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LESSON NO. 5

MASTERING THE CODE
PART II

GUIDED BY THE PRECEDING LESSON, YOU SHOULD BY THIS TIME BE CAPABLE OF BOTH SENDING AND RECEIVING WELL ALL THOSE LETTERS OF THE ALPHABET WHICH ARE INCLUDED IN THE FIRST FIVE MEMORIZING GROUPS IN TABLE II OF THE PREVIOUS LESSON. SINCE YOU WILL AGAIN HAVE NEED FOR THIS SAME TABLE IN THE PRESENT LESSON, IT IS ADVISABLE THAT YOU OPEN THE PREVIOUS LESSON AT THE PAGE UPON WHICH TABLE II APPEARS AND IN THIS WAY HAVE IT HANDY FOR REFERENCE AS YOU CONTINUE YOUR CODE STUDIES ACCORDING TO THE INSTRUCTIONS WHICH WILL NOW BE GIVEN.

YOU ARE AT THE PRESENT TIME PREPARED TO LEARN THOSE LETTERS WHICH ARE INCLUDED IN MEMORIZING GROUP #6, NAMELY, U-V AND K. THE U, YOU WILL OBSERVE, IS DIT DIT DAH; THE V IS DIT DIT DIT DAH AND THE K IS DAH DIT DAH.

WHEN YOU HAVE LEARNED THESE THREE NEW LETTERS THOROUGHLY, PROCEED BY DILIGENTLY PRACTICING THE FOLLOWING CODE GROUPS.

DON'T BE CONTENT BY GOING THROUGH THE FOLLOWING CODE GROUPS ONLY ONCE BUT PRACTICE THEM REPEATEDLY SEVERAL TIMES SO THAT ALL OF THE LETTERS WILL REGISTER IN YOUR MIND WITHOUT ANY HESITATION.

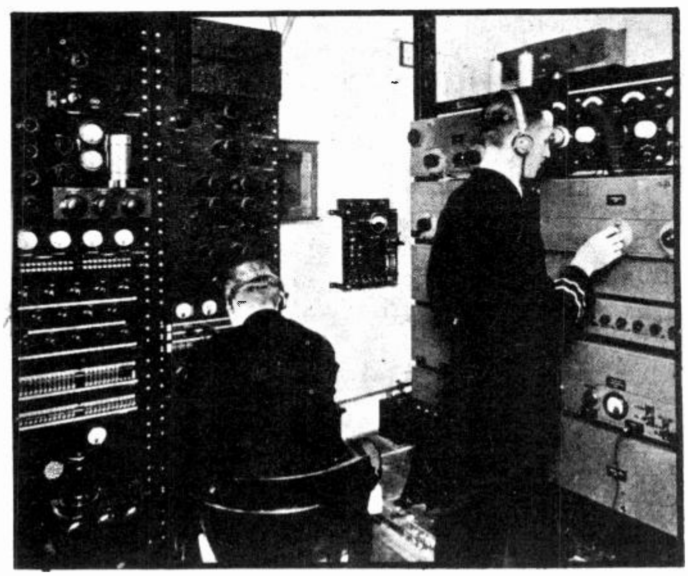

FIG. 1

Commercial Operating Offers Many Opportunities to the Trained Man.

RURUF	RFLUV	KIULR	IUSVH	SEARU	IRULU
VIVOR	FLOSD	KERIF	FAVOR	ULRUL	EKIKU
NIFAO	SLHUT	KINKS	MUVIK	VMKOR	DOVES
SUFLU	KESIK	ERIFS	FELTU	KIKOR	VEVIR
UFRKU	LHUTV	IVMKO	VISOR	VEVFS	UEVIK
FDLEL	THISF	KESTI	ITSEK	FSIHT	LELDF

MEMORIZING GROUP #7

Memorizing group #7 contains the three letters C, G and Q. As you will have noticed by this time, the letters which you are now learning are of a more complex structure than those which you learned first and it will therefore require a little more time and practice in order for you to master them.

The five-letter code groups which follow, offer you splendid practice in sending and receiving the letters C, G and Q as well as some of the others which are included in the more advanced memorizing groups.

CUCKO	FLRQG	LOGOQ	CRUFL	GURQE	GVGUK
QURFQ	RFVUL	LQFGC	CEGIQ	QUQUE	CGQRU
GVQLR	QURCG	CVKLC	QUOGO	QUACK	GKVUG
VOTES	QUART	GUGGO	LFULG	RUCFL	KGIQC
GFRKG	QFCKL	RGFQV	KLGCV	CFLGR	FLUGF
KICKS	CLGQF	GKLFR	GRUCQ	FLUGF	RVQCF
LUCGQ	FORKE	QGFLC	TCMQG	GQMCT	EKROF

When sending words or code groups which contain the letters C, Q, V, L and J you must be particularly careful with the spacing within the letter. For example, the letter C can be incorrectly sent so as to sound almost the same as TR, as NN, or as KE. Similar confusion can also result by incorrect spacing within other letters. Therefore, if you find yourself having acquired any such undesirable habits of sending, it is of utmost importance that you correct this condition now before these habits become too strong and increasingly difficult to correct.

MEMORIZING GROUP #8

The final group of letters which you are to learn are included in memorizing group #8 and these are Y, Z, P and X. These letters are formed in the following manner: Y is dah dit dah dah; Z is dah dah dit dit; P is dit dah dah dit and X is dah dit dit dah. A number of practice code groups which contain the letters Y, Z, P and X, as well as others follow:

YOYOY	YACHT	XADNQ	SGQEH	JAWZX	ZLFRZ
CXZQG	YESTZ	ZONIC	BJXEZ	XUXZC	PAPPA
ZINCS	WAXIW	IZSQL	PAYER	YUSTX	FZQRV
BYZER	ZILOZ	FETQX	FLUXZ	YTZIZ	CEXIG
BUZIX	ZEZIZ	GIRLS	GAGIC	PLAXR	SHZXY
XUXVK	BJKRV	ZINCQ	YCZCX	XEXQR	GWJBX
XTXEX	TOXIG	JAXIJ	DALYP	GIXOT	XBJWG

A GENERAL REVIEW

After you have learned the letters of memorizing group #8 thoroughly

IT IS ADVISABLE THAT YOU CONDUCT A CAREFUL REVIEW OF EVERYTHING WHICH YOU HAVE SO FAR LEARNED ABOUT THE CODE. WHEN YOU HAVE DONE THIS, THEN PRACTICE SENDING AND RECEIVING THE MORE DIFFICULT TYPES OF WORDS WHICH APPEAR IN THE FOLLOWING LIST: GYNECOLOGY, MISSISSIPPI, NECESSITATE, NECESSITOUS, LEGUMINOUS, GYROSCOPE, GLAGITIOUSNESS, CONSCIENTIOUSNESS, AMBIGUOUSLY, ABERRATION, ENFRANCHISEMENT, GRADILOQUENTLY, HERBINOROUS, ISOSCELES, JUVENESCENCE, KALEIDOSCOPIC, LOXODROMICS, MUTINOUSNESS, MYTHOLOGICALLY, ORCHIDACEOUS, PARALLELOPIPED, RECRIMINATORY, RHAPSODICALLY, SILHOUETTE, SOLIDUNGALATE, TERRAQUEOUS, VENTUROUSNESS, XYLOPHONE, XYLOPYROGRAPHY, ZYMURGY.

QUITE OFTEN, LONG WORDS WHICH CONTAIN COMBINATIONS OF LETTERS WHICH ARE NOT USED FREQUENTLY HAVE A TENDENCY TO CAUSE HESITATION AND INACCURACY. WHEN SENDING SUCH A WORD AND YOU MAKE A MISTAKE, THEN TRY YOUR BEST TO REMAIN CALM RATHER THAN BECOME CONFUSED — SIMPLY MAKE THE ERROR SIGN AND PROCEED TO SEND THE WORD AGAIN CORRECTLY.

ON THE OTHER HAND, IF YOU ARE RECEIVING A CODE GROUP, WORD, OR MESSAGE AND YOU FIND THAT YOU CANNOT IMMEDIATELY RECOGNIZE A GIVEN LETTER, THEN DO NOT WASTE VALUABLE TIME BY VAINLY TRYING TO RECALL THAT LETTER BUT SIMPLY SKIP THAT LETTER AND BE READY TO CATCH THE NEXT ONE. IF YOU SHOULD PAUSE FOR TOO GREAT A LENGTH OF TIME ON A SINGLE LETTER, SEVERAL OTHER LETTERS MAY ALREADY BE SENT TO YOU WHILE YOU ARE STILL CONTEMPLATING UPON THE FIRST. THE RESULT IS THAT YOU MAY MISS AN ENTIRE WORD AND THE TRUE MEANING OF A MESSAGE ALL ON ACCOUNT OF ONE LETTER. IT IS MUCH MORE PREFERABLE TO MISS A LETTER AND SATISFACTORILY RECEIVE THE REMAINDER OF THE MESSAGE CORRECTLY.

IN THE FOLLOWING PRACTICE SENTENCES YOU WILL FIND A LARGE VARIETY OF LETTERS USED IN MANY DIFFERENT COMBINATIONS. PRACTICE SENDING THESE SENTENCES SEVERAL TIMES.

PRACTICE SENTENCES

1. — MANY OF THE COUNTRY TOWNS ARE INSTALLING NEW OR ADDITIONAL PLANTS TO REPLACE OBSOLETE AND INEFFICIENT SETS WHICH HAVE BEEN IN USE FOR MANY YEARS PAST THEIR EFFECTIVE LIFE OWING TO THE RECENT STRINGENT CONDITIONS.

2. — HE REPORTS TO A SUPERIOR AND THE DEFENDANT IS TRIED BY A COURT COMPOSED OF THE SUPERINTENDENT AND TWO DISINTERESTED PARTIES.

3. — THE INSPECTOR DOES NOT HAVE A REGULAR SCHEDULE SO NO ONE KNOWS WHEN TO EXPECT HIM.

4. — THIS WILL TAKE CARE OF BOTH DUST AND MOISTURE THAT ARE HIDING TO DO DAMAGE LATER.

5. — MARKING IS BY MEANS OF HOLES IN WHICH STEEL PINS ARE FITTED.

6. — NOW THAT THE ITINERARY OF A WORN OUT ENGINE HAS BEEN TRACED THROUGH ITS REJUVINATION PROCESS AND BACK TO WORK AGAIN WE CAN GO ON TO THE OTHER UNITS.

7. – The light beam is adjusted so that it passes through the negative and falls on the plate of the photo electric cell.

8. – A spring suspension is employed at one end of each strip to keep the strip taut.

9. – The first important point for consideration is that of bonding between the various metallic members of an automobile equipped with a radio set.

10.– To secure the most perfect reproduction at all times it is necessary that the receiver be capable of handling every loud passage or peak that comes in without overloading or distorting.

You will derive excellent practice by sending paragraphs which are printed in newspapers, magazines etc. and if possible have some other party send you these messages by code so that you can practice receiving as well. An excellent method of obtaining receiving practice is to listen to amateur or commercial traffic where code is being employed. You can always find some station in this way which is transmitting code at a moderate speed suitable for a beginner. At first, you may only be able to pick out a few letters but with continued practice you will find yourself receiving more letters and gradually short words and finally complete sentences. It is really surprising how many persons have learned the code with no help other than instructions as these, a code practice set and a short-wave receiver.

NUMERALS

Up to this time your code studies have been devoted solely to the letters of the alphabet used in various arrangements. Your next step will be to learn the numerals but by all means don't even attempt to learn the numerals until you feel absolutely certain of your ability to handle the alphabet satisfactorily.

Commence your study of the numerals with memorizing group #9 and which consists of the numbers 1 to 5 inclusive. Note in particular that all of the numbers contain five characters and that a very definite arrangement is used. For instance, the number 1 is made up of one dit followed by four dahs; the number two is made up of two dits followed by three dah's etc. In other words, the number of dits used in succession of each of the first five numbers is indicative of the number. This is a simple relation, which when noted, will help you to remember these numerals.

When you have both sent and received the first five numerals so that you can send them in any order without hesitation, then continue with the following exercise.

13121	24351	42432	14245	24214	23325
52513	52134	13413	45521	31452	23453
45132	34152	45321	12345	32245	11234
23245	34512	13412	42324	32452	32341
52321	34252	51234	51423	34145	21234
32452	41434	15152	43212	51425	55321
11452	35421	52113	32451	22133	15243

NUMBER AND LETTER GROUPS

THE NEXT STEP IS TO PRACTICE THE FOLLOWING GROUPS WHICH CONTAIN COMBINATIONS OF THE FIRST FIVE NUMERALS AND THE LETTERS T, M, O, E, I, S, AND H. WHEN COPYING CODE GROUPS OF THIS NATURE GREAT CARE MUST BE EXERCISED SO AS NOT TO MISTAKE A I FOR AN I OR AN O FOR ZERO. FOR THIS REASON, IT IS CUSTOMARY TO PLACE A DOT IN THE MIDDLE OF A ZERO WHEN COPYING CODE SO THAT IT WILL NOT LATER BE READ AS THE LETTER O. IN THE CASE OF THE LETTER I EITHER BE SURE TO PLACE CROSS BARS AT EACH OF ITS EXTREMETIES OR ELSE WRITE IT IN THE SCRIPT FORM "I" SO AS NOT TO LATER READ IT AS THE NUMBER I. HERE IS THE PRACTICE EXERCISE:

SI324	H2ITO	04153	1432H	52551	20153
T4245	SIE45	E5532	EI342	42T35	4E321
45234	T4H5T	42138	3345I	E2451	T342I
T3H2I	52423	4315I	32T14	4132S	3S142
5134M	1034M	5H134	1534M	E32I5	H4232

MEMORIZING GROUP #10

THE NUMBERS 6 TO 0 ARE CONTAINED IN MEMORIZING GROUP #10. THESE NUMBERS FOLLOW A SEQUENCE WHICH IS REVERSED TO THAT OF THE NUMBERS I TO 5 IN THAT THE DAHS COME FIRST AND ARE FOLLOWED BY THE DITS WHILE ZERO CONSISTS OF FIVE DAHS PRODUCED ONE AFTER THE OTHER. A PRACTICE EXERCISE CONTAINING THE NUMBERS 6 TO 0 IN VARIOUS COMBINATIONS FOLLOWS:

67890	60097	99680	80997	87979	78786
67897	66078	79680	89679	88776	77896
66867	97860	77889	88769	98760	86908
69798	79680	86668	86908	69798	79680
67789	78608	67780	78676	78907	99870
09876	60708	89760	69886	87606	98076

THE FOLLOWING EXERCISE WILL FURNISH YOU WITH EXCELLENT PRACTICE INVOLVING ALL TEN OF THE NUMBERS. APPLY YOURSELF CONSCIENTIOUSLY TO THIS WORK AND DO NOT RUSH THROUGH IT.

33220	32603	67513	48965	42823	39824
72823	85789	31764	44693	97680	79606
01801	44693	97680	79606	84725	68410
84736	97439	78261	78696	72654	67671
37601	87427	92121	43295	42690	46743
46821	63891	87462	12814	42391	84765
09875	45121	58798	95864	32165	51232
90001	70663	37680	79805	02370	35506
52436	89706	50362	44551	87294	75613
46789	32176	42638	23578	77654	46803

A REVIEW EXERCISE

A GOOD REVIEW EXERCISE FOLLOWS. BY PERFORMING THIS EXERCISE YOU WILL HAVE AN OPPORTUNITY TO USE ALL OF THE LETTERS IN THE ALPHABET AS WELL AS ALL TEN NUMERALS.

3HOWS	6GI4J	V3LUJ	4S3XA	QOS37	429DO
Y64UT	3K403	F390G	W6FMO	7MOHS	56NQR
52RNL	PQ6HT	KOH4I	P78BC	8NOR5	78ANY
ID9EV	IO3AX	TOM59	Y23ZU	BE752	228OK

When you have reached this stage of your code studies, you should be able to send any form of letter, word or number combination with ease and accuracy. However, it takes a great deal of patient practice and earnest study in order to be able to do this.

Having mastered this part of the work, you are now ready to learn the most used punctuation marks and special abreviations which appear in memorizing groups #11 and #12. These consist of the period; the interrogation or question mark; the break or double dash; the error sign which you should already have been using as per previous instructions; the wait sign; the end of message and the end of transmission signs. In addition, you can also at this time learn the signs for "received O.K." (dit dah dit) and "invitation to transmit (go ahead)" which appears as dah dit dah in your complete code TABLE I in the previous lesson.

In order to qualify for an Amateur's License this completes your code knowledge as far as TABLE I of the previous lesson is concerned. To become thoroughly qualified as a commercial operator, however, you should also learn the remaining portions of this same TABLE I but this can be done gradually over a period of time and as you become more experienced in this line of work.

THE "Q" CODE

Now in addition to the Morse Code, we also have what is known as the "Q" code. This "Q" code is nothing more than a series of abreviations which has been devised for use in international Radio communications. This "Q" code appears in TABLE I of this lesson and as you will observe, each of the abreviations starts with the letter Q and from which it derives the significant name "Q-code".

These various abreviations have the meanings as specified in the "ANSWER" column of TABLE I. Whenever any of these abreviations is followed by a question mark, then its meaning becomes as specified in the "Question column" of TABLE I. For example, if you suspect that the signals between you and the party with whom you are communicating are being subjected to interference, then you would send the signal QRM. If such be the case, then the other party can answer your question by simply sending the abbreviation QRM, which means that he is being interfered with.

You will also observe in Table I that the different types of wave forms are referred to as waves of type A1, A2, A3 and B. These particular abreviations have the following meaning:

Type A1 waves are unmodulated continuous waves which are varied by telegraphic keying; type A2 waves are continuous waves which are modulated at audible frequency and with which is combined telegraphic keying; type A3 waves are continuous waves which are modulated by speech or by music; type B waves are damped waves.

TABLE I

THE Q CODE

Abbreviation	*Question*	*Answer*
QRA	What is the name of your station?	The name of my station is ....
QRB	At what approximate distance are you from my station?	The approximate distance between our stations is ...... nautical miles (or ...... kilometers).
QRC	By what private company (or government administration) are the accounts for charges of your station liquidated?	The accounts for charges of my station are liquidated by the .... private company (or by the government administration of ....).
QRD	Where are you going?	I am going to ......
QRE	What is the nationality of your station?	The nationality of my station is ....
QRF	Where do you come from?	I come from ....
QRG	Will you indicate to me my exact wave length in meters (or frequency in kilocycles)?	Your exact wave length is ...... meters (or .... kilocycles).
QRH	What is your exact wave length in meters (frequency in kilocycles)?	My exact wave length is .... meters (frequency .... kilocycles).
QRI	Is my tone bad?	Your tone is bad.
QRJ	Are you receiving me badly? Are my signals weak?	I can not receive you. Your signals are too weak.
QRK	Are you receiving me well? Are my signals good?	I receive you well. Your signals are good.
QRL	Are you busy?	I am busy. Or, (I am busy with ......). Please do not interfere.
QRM	Are you being interfered with?	I am being interfered with.
QRN	Are you troubled by atmospherics?	I am troubled by atmospherics.
QRO	Must I increase power?	Increase power.
QRP	Must I decrease power?	Decrease power.
QRQ	Must I send faster?	Send faster (...... words per minute).
QRS	Must I send more slowly?	Send more slowly (........ words per minute).
QRT	Must I stop sending?	Stop sending.
QRU	Have you anything for me?	I have nothing for you.
QRV	Must I send a series of V's?	Send a series of V's.
QRW	Must I advise .... that you are calling him?	Please advise .... that I am calling him.
QRX	Must I wait? When will you call me again?	Wait until I have finished communicating with .... I will call you immediately (or at .... o'clock).
QRY	Which is my turn?	Your turn is No. .... (or according to any other indication).
QRZ	By whom am I being called?	You are being called by ....
QSA	What is the strength of my signals (1 to 5)?	The strength of your signals is .... (1 to 5).
QSB	Does the strength of my signals vary?	The strength of your signals varies.
QSC	Do my signals disappear entirely at intervals?	Your signals disappear entirely at intervals.
QSD	Is my keying bad?	Your keying is bad. Your signals are unreadable.
QSE	Are my signals distinct?	Your signals run together.
QSF	Is my automatic transmission good?	Your automatic transmission fades out.
QSG	Must I transmit the telegrams by a series of 5, 10 (or according to any other indication)?	Transmit the telegrams by a series of 5, 10 (or according to any other indication).
QSH	Must I send one telegram at a time, repeating it twice?	Transmit one telegram at a time, repeating it twice.
QSI	Must I send the telegrams in alternate order without repetition?	Send the telegrams in alternate order without repetition.
QSJ	What is the charge to be collected per word for .... including your internal telegraph charge?	The charge to be collected per word for .... is .... francs, including my internal telegraph charge.
QSK	Must I suspend traffic? At what time will you call me again?	Suspend traffic. I will call you again at .... (o'clock).
QSL	Can you give me acknowledgment of receipt?	I give you acknowledgment of receipt.
QSM	Have you received my acknowledgment of receipt?	I have not received your acknowledgment of receipt.
QSN	Can you receive me now? Must I continue to listen?	I can not receive you now. Continue to listen.
QSO	Can you communicate with .... directly (or through the intermediary of ....)?	I can communicate with .... directly (or through the intermediary of ......).

Abbreviation	*Question*	*Answer*
QSP	Will you relay to .... free of charge?	I will relay to .... free of charge.
QSQ	Must I send each word or group once only?	Send each word or group once only.
QSR	Has the distress call received from .... been attended to?	The distress call received from .... has been attended to by ....
QSU	Must I send on .... meters (or .... kilocycles) waves of type A1, A2, A3, or B?	Send on .... meters (or on .... kilocycles), waves of Type A1, A2, A3 or B. I am listening for you.
QSV	Must I shift to the wave of .... meters (or of .... kilocycles), for the balance of our communications, and continue after having sent several V's?	Shift to wave of .... meters (or of ... kilocycles) for the balance of our communications and continue after having sent several V's.
QSW	Will you send on .... meters (or on .. kilocycles) waves of Type A1, A2, A3 or B?	I will send on .... meters (or .... kilocycles) waves of Type A1, A2, A3 or B. Continue to listen.
QSX	Does my wave length (frequency) vary?	Your wave length (frequency) varies.
QSY	Must I send on the wave of .... meters (or .... kilocycles) without changing the type of wave?	Send on the wave of .... meters (or .... kilocycles) without changing the type of wave.
QSZ	Must I send each word or group twice.	Send each word or group twice.
QTA	Must I cancel telegram No. .... as if it had not been sent?	Cancel telegram No. .... as if it had not been sent.
QTB	Do you agree with my word count?	I do not agree with your word count; I shall repeat the first letter of each word and the first figure of each number.
QTC	How many telegrams have you to send?	I have .... telegrams for you or for ....
QTD	Is the word-count which I am confirming to you accepted?	The word count which you confirm to me is accepted.
QTE	What is my true bearing? (or) What is my true bearing relative to?	Your true bearing is .... degrees (or) Your true bearing relative to .... is .... degrees at .... (o'clock).
QTF	Will you give me the position of my station based on the bearings taken by the radiocompass stations which you control?	The position of your station based on the bearings taken by the radiocompass stations which I control is .... latitude .... longitude.
QTG	Will you transmit your call signal for one minute on a wave length of .... meters (or .... kilocycles) in order that I may take your radiocompass bearing?	I am sending my call signal for one minute on the wave length of .... meters (or .... kilocycles) in order that you may take my radiocompass bearing.
QTH	What is your position in latitude and longitude (or by any other way of showing it)?	My position is .... latitude .... longitude (or by any other way of showing it).
QTI	What is your true course?	My true course is .... degrees.
QTJ	What is your speed?	My speed is .... knots (or .... kilometres) per hour.
QTM	Send radioelectric signals and submarine sound signals to enable me to fix my bearing and my distance.	I will send radioelectric signals and submarine sound signals to enable you to fix your bearing and your distance.
QTO	Have you left dock (or port)?	I have just left dock (or port).
QTP	Are you going to enter dock (or port)?	I am going to enter dock (or port).
QTQ	Can you communicate with my station by means of the International Code of Signals?	I am going to communicate with your station by means of the International Code of Signals.
QTR	What is the exact time?	The exact time is ....
QTU	What are the hours during which your station is open?	My station is open from .... to ....
QUA	Have you news of .... (call sign of the mobile station)?	Here is news of .... (call sign of the mobile station).
QUB	Can you give me in this order, information concerning: visibility, height of clouds, ground wind for .... (place of observation)?	Here is the information requested ....
QUC	What is the last message received by you from .... (call sign of the mobile station)?	The last message received by me from .... (call sign of the mobile station) is ....
QUD	Have you received the urgency signal sent by .... (call sign of the mobile station)?	I have received the urgency signal sent by .... (call sign of the mobile station) at .... (time).
QUF	Have you received the distress signal sent by .... (call sign of the mobile station)?	I have received the distress signal sent by .... (call sign of the mobile station) at .... (time).

Abbreviation	Question	Answer
QUG	Are you being forced to alight in the sea (or to land)?	I am forced to alight (or land) at .... (place).
QUH	Will you indicate the present barometric pressure at sea level?	The present barometric pressure at sea level is .... (units).
QUJ	Will you indicate the true course for me to follow, with no wind, to make for you?	The true course for you to follow, with no wind, to make for me is .... degrees at .... (time).

TABLE II

ABBREVIATIONS MORE ESPECIALLY USED IN AIRCRAFT RADIO SERVICE

Abbreviation	Question	Answer
QAA.............	At what time do you expect to arrive at ......?	I expect to arrive at ...... at ...... (o'clock).
QAB.............	Are you en route to......?..............	I am en route to ...... or Go to ......
QAC.............	Are you returning to......?.............	I am returning to ...... or Return to....
QAD.............	At what time did you leave ...... ? (place of departure).	I left ...... (place of departure) at ...... (o'clock).
QAE.............	Have you news of ...... (call signal of the aircraft station)?	I have no news of ...... (call signal of the aircraft station).
QAF.............	At what time did you pass......?.........	I passed ...... at ...... (o'clock).
QAH.............	What is your height?....................	My height is ...... meters (or according to any other indication).
QAI.............	Has any aircraft signaled in my neighborhood?	No aircraft has signaled in your neighborhood.
QAJ.............	Must I look for another aircraft in my neighborhood?	Look for another aircraft in your neighborhood (or) Look for ...... (call signal of the aircraft station) which was flying near ...... (or in the direction of ......) at ...... (o'clock).
QAK.............	On what wave are you going to send the meteorological warning messages?	I am going to send the meteorological warning messages on wave length of ...... meters (or ...... kilocycles).
QAL.............	Are you going to land at ......?..........	I am going to land at ...... or Land ......
QAM.............	Can you give me the latest meteorological message concerning weather for ...... (place of observation)?	Here is the latest meteorological message concerning weather for ...... (place of observation).
QAN.............	Can you give me the latest meterological message concerning surface wind for ...... (place of observation)?	Here is the latest meteorological message concerning surface wind for ...... (place of observation).
QAO.............	Can you give me the latest meteorological message concerning upper wind for ...... (place of observation)?	Here is the latest meteorological message concerning upper wind for ...... (place of observation).
QAP.............	Must I continue to listen for you (or for ......) on ...... meters (or ...... kilocycles?	Continue to listen for me (or for ......) on ...... meters (or ...... kilocycles).
QAQ.............	Will you hasten the reply to message No. ...... (or in accordance with any other indication)?	I hasten the reply to message No. ...... (or in accordance with any other indication).
QAR.............	Must I reply to ...... for you?.........	Reply to ...... for me.
QAS.............	Must I send message No. ...... (or in accordance with any other indication) to ......?	Send message No. ...... (or in accordance with any other indication) to ......
QAT.............	Must I continue to send....	Listen before sending; you are interfering; or Listen before sending; you are sending at the same time as ......
QAU.............	What is the last message received by you from ......?	The last message received by me from ...... is ......
QAV.............	Are you calling me?...................... or Are you calling ...... (call signal of the aircraft station?	I am calling you or I am calling ...... (call signal of the aircraft station).
QAW.............	Must I cease listening until ...... (o'clock)?.	Cease listening until ...... (o'clock).
QAX.............	Have you received the urgent signal sent by ...... (call signal of the aircraft station)?	I received the urgent signal sent by ...... call signal of the aircraft station) at ...... (o'clock).
QAY.............	Have you received the distress signal sent by ...... (call signal of the aircraft station)?	I received the distress signal sent by ...... (call signal of the aircraft station) at ...... (o'clock).
QAZ.............	Can you receive in spite of the storm?	I can no longer receive. I am going off watch because of the storm.

TABLE III

Miscellaneous Abbreviations

Abbreviation	*Meaning*
C	Yes.
N	No.
P	Indicator of private telegram in the mobile service (to be used as a prefix).
W	Word or words.
AA	All after .... (to be used after a note of interrogation to ask for a repetition).
AB	All before .... (to be used after a note of interrogation to ask for a repetition).
AL	All that has just been sent (to be used after a note of interrogation to ask for a repetition).
BN	All between .... (to be used after a note of interrogation to ask for a repetition).
BQ	A reply to an RQ
CL	I am closing my station.
CS	Call sign (to be used to ask for a call sign or to have one repeated).
DB	I cannot give you a bearing, you are not in the calibrated sector of this station.
DC	The minimum of your signal is suitable for the bearing.
DF	Your bearing at .... (time) was .... degrees, in the doubtful sector of this station, with a possible error of two degrees.
DG	Please advise me if you note an error in the bearing given.
DI	Bearing doubtful in consequence of the bad quality of your signal.
DJ	Bearing doubtful because of interference.
DL	Your bearing at .... (time) was .... degrees in the doubtful sector of this station.
DO	Bearing doubtful. Ask for another bearing later, or at .... (time).
DP	Beyond 50 miles, the possible error of bearing may amount to two degrees.
DS	Adjust your transmitter, the minimum of your signal is too broad.
DT	I cannot furnish you with a bearing; the minimum of your signal is too broad.
DY	This station is two-way, what is your approximate direction in degrees in relation to this station?
DZ	Your bearing is reciprocal (to be used only by the control station of a group of direction-finding stations when it is addressing other stations of the same group).
ER	Here .... (to be used before the name of the mobile station in the sending of route indications).
GA	Resume sending (to be used more specially in the fixed service).
JM	If I may transmit, send a series of dashes. To stop my transmission, send a series of dots [not to be used on 500 kc/s (600 m)].
MN	Minute or minutes (to be used to indicate the duration of a wait).
NW	I resume transmission (to be used more especially in the fixed service).
OK	Agreed.
RQ	Designation of a request.
SA	Indicator preceding the name of an aircraft station (to be used in the sending of particulars of flight).
SF	Indicator preceding the name of an aeronautical station.
SN	Indicator preceding the name of a coast station.
SS	Indicator preceding the name of a ship station (to be used in sending particulars of voyage).
TR	Indicator used in sending particulars concerning a mobile station.
UA	Are we agreed?
WA	Word after .... (to be used after a note of interrogation to request a repetition).
WB	Word before .... (to be used after a note of interrogation to request a repetition).
XS	Atmospherics.
YS	Your service message.
ABV	Repeat (or I repeat) the figures in abbreviated form.
ADR	Address (to be used after a note of interrogation to request a repetition).
CFM	Confirm (or I confirm).
COL	Collate (or I collate).
ITP	Stops (punctuation) count.
MSG	Telegram concerning the service of the ship (to be used as a prefix).
NIL	I have nothing for you (to be used after an abbreviation of the Q code to mean that the answer to the question put is negative).
PBL	Preamble (to be used after a note of interrogation to request a repetition).
REF	Referring to .... (or Refer to ....).
RPT	Repeat (or I repeat) (to be used to ask for or to give repetition of all or part of the traffic the relative particulars being sent after the abbreviation).
SIG	Signature (to be used after a note of interrogation to request a repetition).
SVC	Indicator of service telegram concerning private traffic (to be used as a prefix).
TFC	Traffic.
TXT	Text (to be used after a note of interrogation to request a repetition).

TABLE II, YOU WILL NOTICE, IS ALSO A Q CODE BUT APPLIED PARTICULARLY TO AIRCRAFT RADIO SERVICE.

MISCELLANEOUS ABBREVIATIONS

THE MISCELLANEOUS ABBREVIATIONS WHICH APPEAR IN TABLE III HAVE BEEN ADOPTED BY UNIVERSAL AGREEMENT AND SHOULD THEREFORE NOT BE EMPLOYED IN OTHER THAN THE MEANINGS SPECIFIED NOR SHOULD OTHER THAN THE SPECIFIED ABBREVIATION BE EMPLOYED TO CONVEY ANY MEANING LISTED IN THIS TABLE.

THE AUDIBILITY SCALE

BY AGAIN REFERRING TO TABLE I OF THIS LESSON AND "LOOKING-UP" THE MEANING FOR THE ABREVIATION QSA, YOU WILL FIND THIS ABBREVIATION TO BE USED TO SPECIFY SIGNAL STRENGTH IN TERMS OF NUMBERS EXTENDING FROM 1 TO 5. THIS NUMBERING SYSTEM HAS THE FOLLOWING MEANING:

QSA1 = HARDLY PERCEPTIBLE, UNREADABLE
QSA2 = WEAK, READABLE NOW AND THEN
QSA3 = FAIRLY GOOD, READABLE BUT WITH DIFFICULTY
QSA4 = GOOD, READABLE
QSA5 = VERY GOOD, PERFECTLY READABLE.

IN AMATEUR WORK, THE "R" SYSTEM OF INDICATING AUDIBILITY IS ALSO NOW BEING USED EXTENSIVELY. THE "R SYSTEM" FOLLOWS:

R1 = FAINT SIGNALS, JUST AUDIBLE
R2 = WEAK SIGNALS, BARELY AUDIBLE
R3 = WEAK SIGNALS, COPIABLE (IN ABSENCE OF ANY DIFFICULTY)
R4 = FAIR SIGNALS, READABLE
R5 = MODERATELY STRONG SIGNALS
R6 = STRONG SIGNALS
R7 = GOOD STRONG SIGNALS (SUCH AS COPIABLE THROUGH INTERFERENCE)
R8 = VERY STRONG SIGNALS; CAN BE HEARD SEVERAL FEET FROM PHONES
R9 = EXTREMELY STRONG SIGNALS.

IN THIS LESSON YOU HAVE BEEN GIVEN A GREAT DEAL OF INFORMATION REGARDING THE CODE AND INFORMATION OF THE TYPE WHICH WILL REQUIRE STUDY OVER A CONSIDERABLE PERIOD OF TIME IN ORDER FOR YOU TO LEARN IT. DO NOT EXPECT TO LEARN THIS ALL AT ONCE BUT LEARN A FEW OF THE ABBREVIATIONS AT A TIME, STARTING WITH THOSE WHICH OBSERVATION AND LISTENING EXPERIENCE WILL SHOW YOU TO BE THE MOST IMPORTANT AND MOST USED. IN DUE TIME, YOU WILL FIND YOURSELF TO REMEMBER QUITE A NUMBER OF THEM.

SO THAT YOUR LESSONS MAY BE KEPT AS INTERESTING AS POSSIBLE, YOU ARE GOING TO HAVE A COMPLETE CHANGE OF SUBJECT MATTER IN YOUR NEXT LESSON. THIS FOLLOWING LESSON IS GOING TO TELL YOU ALL ABOUT CRYSTAL CONTROLLED OSCILLATORS AS USED IN TRANSMITTERS AND AFTER WHICH YOU WILL LEARN ABOUT AMPLIFYING STAGES AS USED IN TRANSMITTERS, POWER SUPPLIES, SPECIAL KEY CIRCUITS, ANTENNA SYSTEMS ETC.

THIS TECHNICAL INSTRUCTION WILL THEN BE FOLLOWED BY A COMPLETE EXPLANATION REGARDING THE TECHNIQUE OF CONDUCTING RADIO COMMUNICATION BY MEANS OF THE CODE, THE CORRECT PROCEDURE FOR HANDLING MESSAGES ETC.

Examination Questions

LESSON NO. T-5

> Men may learn from past experience but bemoaning lost yesterdays is worse than futile when the calendar is filled with priceless tomorrows.

1. – AT THE TIME OF ANSWERING THIS EXAMINATION, HOW MANY CODE LETTERS CAN YOU TRANSMIT WITHOUT REFERRING TO YOUR TEXT?

2. – WHAT PARTICULAR PRECAUTIONS SHOULD BE EXERCISED WHEN SENDING THE LETTERS C, Q, V, L AND J?

3. – WHEN COPYING CODE, WHY IS IT ADVISABLE TO SKIP A LETTER IF YOU CAN'T REMEMBER IT AT THE TIME?

4. – HOW IS THE NUMBER 9 PRODUCED BY MEANS OF THE CODE?

5. – WHEN COPYING CODE, WHAT PRECAUTIONS ARE TAKEN SO THAT A ZERO IS NOT READ FROM THE WRITTEN COPY AS THE LETTER O?

6. – WHEN COPYING CODE, WHAT PRECAUTIONS ARE TAKEN SO THAT THE LETTER I IS NOT MISTAKEN FOR THE NUMERAL 1?

7. – WHAT IS THE MEANING OF THE ABBREVIATION QRX?

8. – SHOW BY MEANS OF THE PROPER ARRANGEMENT OF DOTS AND DASHES HOW YOU WOULD MAKE THE QUESTION MARK BY MEANS OF THE CODE.

9. – IF YOU SHOULD SEND SOMEONE THE SIGNAL ABBREVIATION QSA FOLLOWED BY A QUESTION MARK AND THEY SENT YOU AN ANSWER OF QSA5, WHAT WOULD THIS ANSWER INDICATE?

10. – EXPLAIN WHAT TYPES OF WAVES ARE INDICATED BY THE FOLLOWING ABBREVIATIONS: TYPE A1, A2, A3 AND B.

RADIO - TELEVISION

Practical • J. A. ROSENKRANZ, Pres. • Training

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Transmitters

LESSON NO. 6

CRYSTAL-CONTROLLED OSCILLATORS

As you will recall from your previous studies concerning vacuum tube oscillator circuits of the simple type, it is of utmost importance that such circuits be carefully tuned so that the transmitter will operate on the correct frequency. However, in spite of the fact that such an oscillator circuit is properly adjusted for a given frequency, yet conditions arise in practice which may cause the oscillator to change its frequency on its own accord. Whenever any such frequency variation occurs during the course of operation we say that the oscillator is UNSTABLE or that the transmitter is subject to "frequency instability".

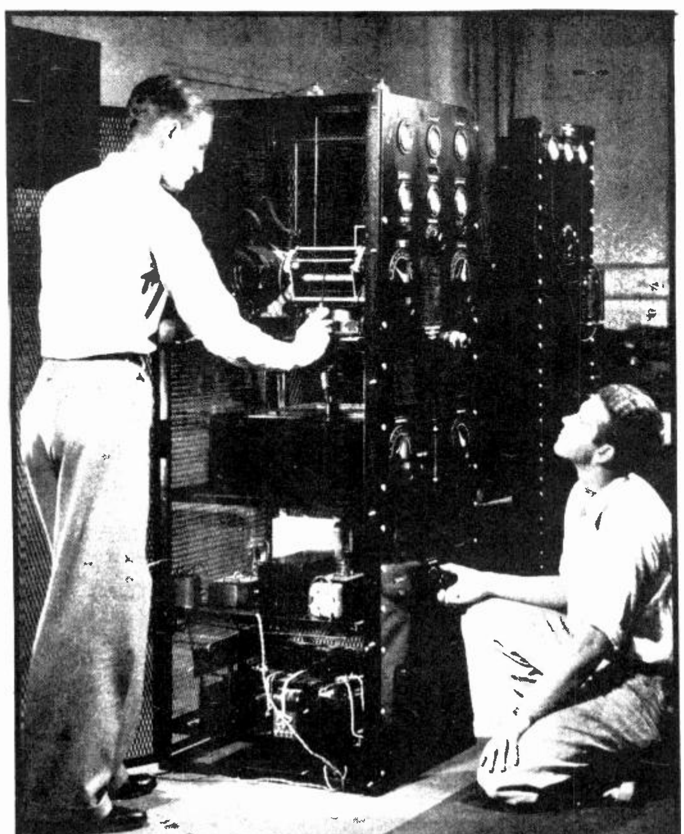

FIG. 1
Students Conducting Tests On One of National's Crystal-Controlled Transmitters.

The reason why simple or self-controlled oscillators are subject to frequency instability can be explained in the following manner: The frequency to which an oscillator circuit is tuned is governed chiefly by the inductance value of the coil and the capacitive value of the condenser which are used in

THE TUNING CIRCUITS. IN THE CASE OF THE TUNED GRID CIRCUIT, THE CAPACITANCE OF THIS CIRCUIT IS ALSO SHUNTED BY THE INPUT CAPACITY OF THE TUBE AND THIS INPUT CAPACITY IS A FUNCTION OF THE PLATE LOAD AND THE GRID-PLATE CAPACITY OF THE TUBE. EXPRESSED AS A FORMULA THIS WOULD BE:

$$C_i = C_{gf} + C_{gp}\left(\frac{\mu R_o}{R_o + R_p} + 1\right)$$

WHERE C_i = INPUT CAPACITY; C_{gf} = GRID-FILAMENT CAPACITY; C_{gp} = GRID-PLATE CAPACITY; μ = AMPLIFICATION FACTOR OF THE TUBE; R_o = OUTPUT LOAD RESISTANCE AND R_p = THE TUBE'S PLATE RESISTANCE.

BY STUDYING THIS FORMULA CAREFULLY, YOU WILL NOTICE THAT ANY CHANGE IN THE PLATE RESISTANCE, IN THE GRID-PLATE CAPACITY, OR THE OUTPUT LOAD WILL PRODUCE A CHANGE IN THE GRID-FILAMENT CAPACITY AND WHICH IN TURN IS CAPABLE OF DETERMINING THE FREQUENCY AT WHICH THE CIRCUIT OSCILLATES. IT IS ALSO TRUE THAT CHANGES IN FILAMENT TEMPERATURE, IN C BIAS, OR IN PLATE VOLTAGE WILL AFFECT THE PLATE RESISTANCE OF THE TUBE AND THEREBY CHANGE ITS RELATION TO THE LOAD RESISTANCE. CHANGES OF THIS NATURE WILL ALSO AFFECT THE FREQUENCY OF THE OSCILLATOR'S OUTPUT. IT IS INTERESTING TO NOTE THAT THE SMALLER THE PLATE LOAD, THE LARGER WILL BE THE GRID-PLATE CAPACITY; AND THE GREATER THE PLATE RESISTANCE OF THE TUBE, THE MORE WILL THE GENERATED FREQUENCY DEPEND UPON THESE FACTORS.

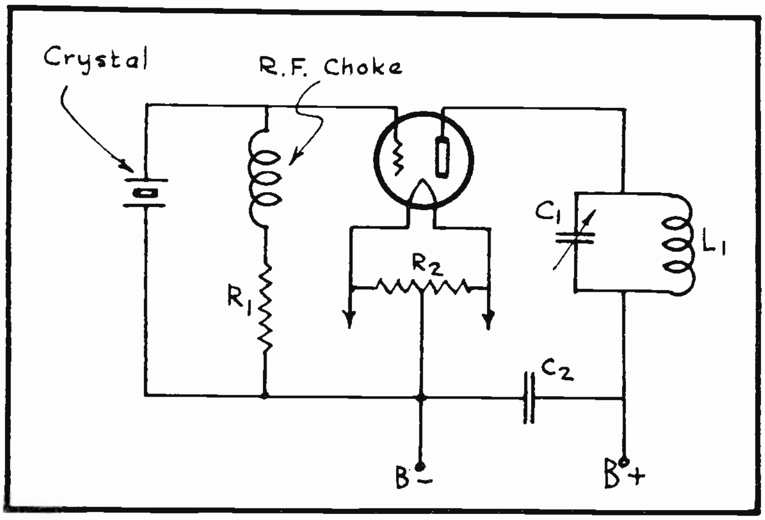

FIG. 2
Application of the Crystal.

IMPROVING STABILITY

ONE METHOD OF MAKING THE OSCILLATOR FREQUENCY MORE INDEPENDENT FROM THE TUBE CHARACTERISTICS IS TO USE A RATHER LARGE FIXED INPUT CAPACITY TO THE NORMAL GRID-FILAMENT CAPACITY SO THAT CHANGES IN THE LATTER ARE UNIMPORTANT. IN THIS WAY, BY SHUNTING A FAIRLY LARGE CAPACITY ACROSS THE GRID AND FILAMENT, THE TOTAL EFFECTIVE INPUT CAPACITY WILL BE INCREASED TO SUCH AN EXTENT THAT SMALL CHANGES IN THE INTERNAL CAPACITY OF THE TUBE WILL HAVE RATHER LITTLE EFFECT UPON THE TUNING.

A STILL DIFFERENT METHOD WHICH IS COMMONLY USED TO IMPROVE THE FREQUENCY STABILITY OF AN OSCILLATOR IS TO USE A TUNING CONDENSER OF RATHER LARGE CAPACITY AND A COIL OF PROPORTIONATELY LOWER INDUCTANCE — IN OTHER WORDS, A HIGH CAPACITY — LOW INDUCTANCE TUNING CIRCUIT.

IN THE SMALLER TRANSMITTERS WHERE THE OSCILLATOR IS COUPLED DIRECTLY TO THE ANTENNA SYSTEM WITHOUT ANY STAGE OF AMPLIFICATION BETWEEN THE OSCILLATOR AND THE ANTENNA, IT IS ALSO A COMMON OCCURRENCE FOR ANY CHANGE IN THE CAPACITY OF THE ANTENNA AS CAUSED BY SWAYING IN THE WIND ETC. TO REACT BACK UPON THE OSCILLATOR CIRCUIT AND IN THIS WAY ALTER THE FREQUEN-

QUENCY WHICH IS BEING GENERATED BY THE OSCILLATOR.

THE CRYSTAL OSCILLATOR

IN MODERN TRANSMITTERS WHICH ARE REQUIRED TO POSSESS EXCELLENT FREQUENCY STABILITY, THE USUAL RESONANT CIRCUIT IN THE OSCILLATOR TUBE'S GRID CIRCUIT IS REPLACED WITH A QUARTZ CRYSTAL AND WHOSE CHARACTERISTICS ARE SUCH THAT THE VARIATIONS IN FREQUENCY ARE PRACTICALLY NEGLIGIBLE EVEN WHEN SOME OF THE OTHER CIRCUIT CONSTANTS ARE VARIED APPRECIABLY. OSCILLATORS WHICH EMPLOY SUCH A CRYSTAL IN ORDER TO INSURE FREQUENCY STABILITY ARE KNOWN AS CRYSTAL CONTROLLED OSCILLATORS.

IN FIG. 2 YOU ARE SHOWN A DIAGRAM OF AN OSCILLATOR CIRCUIT IN WHICH A CRYSTAL IS EMPLOYED. HERE YOU WILL OBSERVE THAT WE HAVE A TRIODE OSCILLATOR TUBE HAVING A TUNING CIRCUIT CONSISTING OF C_1 AND L_1 INSTALLED IN ITS PLATE CIRCUIT. THE CRYSTAL, ON THE OTHER HAND IS CONNECTED ACROSS THE GRID CIRCUIT OF THIS TUBE AND IS SHUNTED BY THE LEAK RESISTOR R_1 AND THE R.F. CHOKE WHICH ARE CONNECTED TOGETHER IN SERIES.

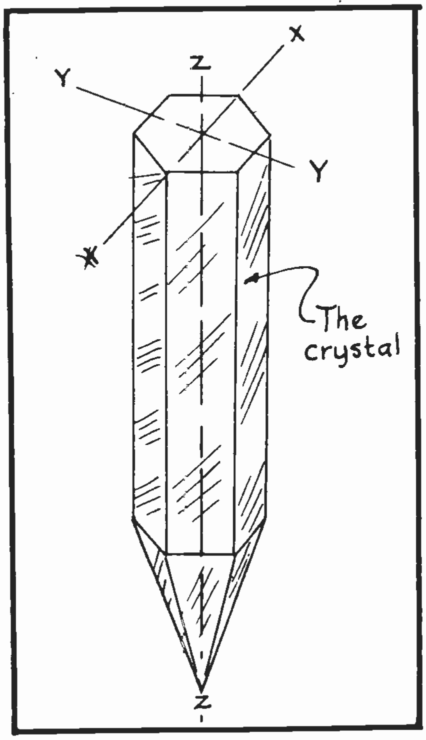

FIG. 3
The Crystalline Structure.

THE CRYSTAL IS SO CONSTRUCTED THAT IT WILL PERMIT THE CIRCUIT TO OSCILLATE AT ONLY ONE PARTICULAR FREQUENCY. BY PROPER ADJUSTMENT OF THE PLATE CIRCUIT, THE FEED-BACK ENERGY WILL BE IMPRESSED UPON THE GRID CIRCUIT THROUGH THE GRID-PLATE CAPACITY OF THE TUBE AND THEREBY CAUSE THE CIRCUIT TO OSCILLATE.

WHEN TUNING AN OSCILLATOR OF THIS TYPE, THE PROCEDURE IS AS FOLLOWS: THE ANTENNA (LOAD) IS DISCONNECTED AND WITH A MILLIAMMETER CONNECTED IN SERIES WITH THE PLATE CIRCUIT OF THE OSCILLATOR, CONDENSER C_1 IS ADJUSTED UNTIL THE MILLIAMMETER READING DROPS SUDDENLY AND WHICH SHOWS THAT OSCILLATION HAS COMMENCED. CONDENSER C_1 IS THEN FURTHER ADJUSTED UNTIL THE MILLIAMMETER OFFERS A MINIMUM READING AND WHICH SHOWS THAT THE PLATE CIRCUIT IS NOW TUNED TO RESONANCE WITH THE CRYSTAL-CONTROLLED GRID CIRCUIT. HOWEVER, IF THE OSCILLATOR IS PERMITTED TO OPERATE IN THIS CONDITION, ANY SLIGHT CHANGE IN THE CIRCUIT CONSTANTS MAY CAUSE THE CRYSTAL TO STOP OSCILLATING. FOR THIS REASON, CONDENSER C_1 IS ADJUSTED FOR A FREQUENCY WHICH IS A TRIFLE HIGHER THAN THE SETTING WHICH HAS JUST BEEN DETERMINED — THE CRYSTAL NEVERTHELESS CONTINUES TO OSCILLATE AT ITS NATURAL FREQUENCY IN SPITE OF THIS SLIGHT ALTERATION IN PLATE CIRCUIT TUNING. IN FACT, FOR SEVERAL DEGREES OF THE PLATE TUNING CONDENSER, THE OSCILLATOR'S OUTPUT FREQUENCY IS THAT OF THE CRYSTAL AND IN THIS MANNER CHANGES IN THE PLATE RESISTANCE OF THE TUBE, POWER SUPPLY VOLTAGES ETC., WILL HAVE RELATIVELY SMALL EFFECT ON CONTROLLING THE FREQUENCY AT WHICH THE CIRCUIT OSCILLATES.

NOW THAT YOU ARE IN A GENERAL WAY FAMILIAR WITH THE MANNER IN WHICH

THE CRYSTAL IS USED IN AN OSCILLATOR CIRCUIT, YOU WILL NO DOUBT BE INTERESTED IN LEARNING MORE ABOUT THE CONSTRUCTIONAL FEATURES OF THE CRYSTAL AND THE PROPERTIES WHICH IT POSSESSES THAT ENABLES IT TO CONTROL THE FREQUENCY OF THE OSCILLATOR. THIS THEN WILL BE OUR NEXT STEP.

PIEZO-ELECTRIC PROPERTIES

ALL CRYSTALS WHICH ARE SUITABLE FOR CONTROLLING THE FREQUENCY OF AN OSCILLATOR POSSESS WHAT ARE KNOWN AS PIEZO - ELECTRIC PROPERTIES. QUITE A NUMBER OF CRYSTALLINE SUBSTANCES HAVE PIEZO-ELECTRIC PROPERTIES AND AMONG THESE WE FIND QUARTZ, TOURMALINE, ROCHELLE SALTS AND SEVERAL OTHERS BUT OF ALL THESE QUARTZ IS USED EXCLUSIVELY IN CRYSTAL CONTROLLED OSCILLATORS. THE EXTENSIVE USE OF QUARTZ IS PRIMARILY DUE TO ITS COMPARATIVELY LOW COST, MECHANICAL RUGGEDNESS, AND LOW TEMPERATURE COEFFICIENT.

IN FIG. 3 YOU ARE SHOWN THE GENERAL SHAPE OF A NATURAL QUARTZ CRYSTAL. NOTICE, THAT ITS CROSS-SECTION IS A HEXAGON OR SIX-SIDED FIGURE AND THAT IT HAS THREE MAJOR AXES, NAMELY, THE X AXIS, THE Y AXIS AND THE Z AXIS.

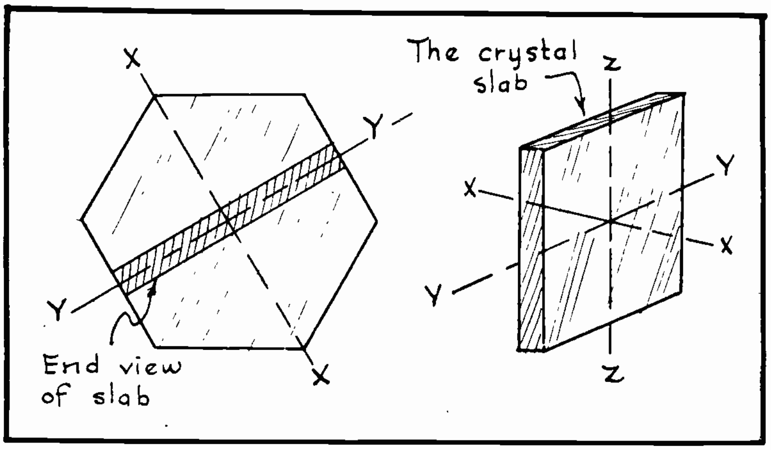

FIG. 4
The "X Cut" or "Curie-Cut" Crystal.

THE X AXIS PROJECTS THROUGH OPPOSITE CORNERS OF THE HEXAGON CROSS-SECTION AND IT IS KNOWN AS THE "ELECTRICAL AXIS". WITH A HEXAGON FIGURE, IT IS OF COURSE APPARENT THAT THREE SUCH X AXES EXIST.

THE Y AXIS PROJECTS THROUGH THE CENTER OF THE CROSS-SECTION AND IS PERPENDICULAR TO OPPOSITE SIDES OF THE FIGURE. THE Y AXIS IS KNOWN AS THE "MECHANICAL AXIS" AND FOR THE ONE CRYSTALLINE STRUCTURE, THERE ARE THREE SUCH Y AXES.

THE Z AXIS IS KNOWN AS THE "OPTICAL AXIS" AND IT PROJECTS LONGITUDINALLY THROUGH THE CENTER OF THE STRUCTURE.

THE ILLUSTRATION IN FIG. 3, YOU WILL RECALL, IS THE NATURAL SHAPE OF THE QUARTZ CRYSTAL BUT FOR USE IN THE TRANSMITTER, THE CRYSTALS ARE GENERALLY CUT FROM THE ORIGINAL STRUCTURE SO THAT THE FINISHED UNIT IS A SQUARE-SHAPED SLAB.

THERE ARE TWO METHODS OF CUTTING A FLAT SECTION OR SLAB FOR TRANSMITTER USE FROM THE ORIGINAL CRYSTAL STRUCTURE. ONE OF THESE METHODS RESULTS IN WHAT IS KNOWN AS AN "X-CUT" OR "CURIE-CUT" CRYSTAL WHILE THE OTHER METHOD OF CUTTING RESULTS IN WHAT IS KNOWN AS A "Y-CUT" OR "30° - CUT" CRYSTAL.

THE "X-CUT" CRYSTAL

FIG. 4 SHOWS YOU HOW AN "X-CUT" OR "CURIE-CUT" CRYSTAL IS OBTAINED.

AT THE LEFT OF FIG. 4 YOU ARE LOOKING AT THE CROSS-SECTION OF THE ORIGINAL CRYSTAL AS SEEN FROM ABOVE, AND HERE THE EDGE OF THE SLAB FACES UPWARD AND IS INDICATED BY THE SHADED AREA IN THIS ILLUSTRATION. THE FLAT SIDES OF THE CRYSTAL SLAB WILL THEREFORE IN THIS INSTANCE BE PARALLEL TO THE Y AXIS AND PERPENDICULAR TO THE X AXIS. AFTER THE FINAL CRYSTAL HAS BEEN CUT FROM THE ORIGINAL STRUCTURE IN THIS MANNER, IT WILL APPEAR AS ILLUSTRATED AT THE RIGHT OF FIG. 4 AND HERE AGAIN ITS AXIS HAVE BEEN INDICATED FOR YOUR CONVENIENCE.

IN THE X-CUT CRYSTAL, WE FIND THAT ANY MECHANICAL STRESSES WHICH ARE APPLIED ALONG THE Y OR MECHANICAL AXIS WILL PRODUCE ELECTRICAL CHARGES ON THE FLAT SIDES OF THE SLAB. FURTHERMORE, IF THE DIRECTION OF THESE STRESSES IS CHANGED FROM TENSION TO COMPRESSION OR VICE VERSA, THEN THE POLARITY OF THE CHARGES ON THE FLAT SIDES OF THE CRYSTAL IS REVERSED.

THE REVERSE OF THIS PROCESS IS ALSO TRUE. THAT IS, IF ELECTRICAL CHARGES ARE PLACED ON THE FLAT SIDES OF THE CRYSTAL BY APPLYING A VOLTAGE ACROSS THESE FACES, THEN A MECHANICAL STRESS WILL BE PRODUCED IN THE DIRECTION OF THE Y-AXIS. THIS CHARACTERISTIC BY MEANS OF WHICH THE ELECTRICAL AND MECHANICAL PROPERTIES ARE RELATED IN A CRYSTAL IS KNOWN AS THE PIEZO-ELECTRIC EFFECT AND IT IS A NATURAL CHARACTERISTIC OF THE SUBSTANCE.

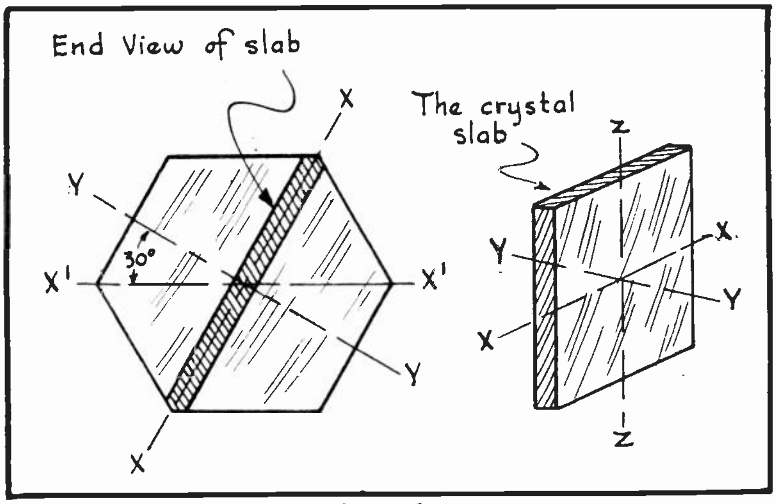

FIG. 5
The "Y Cut" or "30°-Cut" Crystal.

THE "Y-CUT" CRYSTAL

FIG. 5 SHOWS YOU HOW A "Y-CUT" OR "30°-CUT" CRYSTAL IS OBTAINED FROM THE ORIGINAL CRYSTALLINE STRUCTURE. HERE YOU ARE AGAIN SHOWN A TOP VIEW OF THE ORIGINAL CRYSTAL'S STRUCTURE AT THE LEFT AND WITH THE EDGE OF THE FINAL SLAB INDICATED BY THE SHADED AREA. THE Y-CUT CRYSTAL YOU WILL HERE OBSERVE HAS ITS FLAT SIDES PARALLEL WITH THE X AXIS AND PERPENDICULAR TO THE Y AXIS. THE FINISHED Y-CUT CRYSTAL SLAB IS SHOWN AT THE RIGHT OF FIG. 5 WITH ITS AXIS INDICATED FOR YOUR CONVENIENCE.

WITH THE Y-CUT CRYSTAL, WE FIND THAT WHEN MECHANICAL STRESSES ARE APPLIED ACROSS ITS FACES, THEN ELECTRICAL CHARGES WILL BE ESTABLISHED ALONG ITS X AXIS AND VICE VERSA.

EFFECT OF THE CRYSTAL'S RESONANT FREQUENCY

CONTINUING OUR INVESTIGATION OF THE PIEZO-ELECTRIC PROPERTIES OF QUARTZ CRYSTALS WE NEXT COME TO THE POINT WHERE WE CONSIDER THE BEHAVIOR OF THE CRYSTAL WHEN SUBJECTED TO A.C. VOLTAGES.

WHENEVER AN A.C. VOLTAGE IS APPLIED ACROSS A QUARTZ CRYSTAL IN SUCH A DIRECTION THAT THERE IS A COMPONENT OF ELECTRICAL STRESS IN THE DIRECTION OF AN ELECTRICAL AXIS, THEN ALTERNATING MECHANICAL STRESSES WILL BE PRODUCED IN THE DIRECTION OF THE Y AXIS. THESE STRESSES WILL CAUSE THE CRYSTAL TO VIBRATE AND IF THE FREQUENCY OF THE APPLIED A.C. VOLTAGE IS NEAR THE NATURAL MECHANICAL VIBRATING FREQUENCY OF THE CRYSTAL, THEN A CONDITION OF MECHANICAL RESONANCE WILL EXIST IN THE CRYSTAL AND THE AMPLITUDE OF THE VIBRATIONS WILL THEREFORE BE RELATIVELY LARGE. IT IS ALSO INTERESTING TO NOTE THAT THE CURRENT WHICH IS DRAWN AT THE RESONANT FREQUENCY BY THE CRYSTAL DUE TO THE VIBRATIONS IS EQUAL TO THE SAME VALUE OF CURRENT WHICH IS DRAWN BY A CIRCUIT CONSISTING OF RESISTANCE, INDUCTANCE, AND CAPACITY.

FREQUENCY OF CRYSTALS

IN PRACTICE, BOTH X AND Y-CUT CRYSTALS ARE USED — EACH HAVING ITS INDIVIDUAL CHARACTERISTICS AND THEREFORE BEST ADAPTED FOR DIFFERENT USES. FOR A GIVEN FREQUENCY, AN X-CUT PLATE IS THICKER THAN A Y-CUT PLATE; THE X-CUT PLATE HAS BUT ONE MAJOR FREQUENCY OF OSCILLATION WHICH IS DETERMINED BY ITS THICKNESS, WHEREAS A Y-CUT PLATE SOMETIMES HAS TWO — A KILOCYCLE OR TWO APART; AS A GENERAL RULE, THE Y-CUT PLATE OSCILLATES MORE READILY, ALTHOUGH WHEN PROPERLY GROUND AND MOUNTED, CRYSTALS OF EITHER CUT WILL OSCILLATE PROPERLY IN A WELL-DESIGNED CIRCUIT.

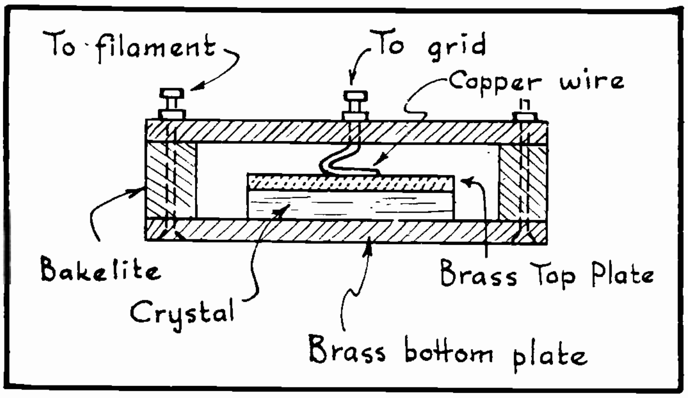

FIG. 6
A Typical Crystal Holder.

AS HAS ALREADY BEEN STATED, THE THICKNESS OF THE CRYSTAL DETERMINES AT WHICH FREQUENCY THE OSCILLATOR WILL OSCILLATE. THE APPROXIMATE FORMULAS WHICH EXPRESS THE RELATION BETWEEN THE THICKNESS AND FREQUENCY OF A CRYSTAL SLAB ARE AS FOLLOWS:

FOR AN X-CUT CRYSTAL $f \times t = 112.6$ WHEREAS FOR THE Y-CUT PLATE THE FORMULA BECOMES $f \times t = 77.0$. IN BOTH OF THESE FORMULAS, f = THE FREQUENCY EXPRESSED IN KILOCYCLES, t = THICKNESS OF THE PLATE EXPRESSED IN INCHES AND THE VALUES 112.6 AND 77.0 ARE CONSTANTS IN THE RESPECTIVE FORMULAS. EITHER OF THESE TWO FORMULAS CAN BE TRANSPOSED ALGEBRAICALLY SO THAT EITHER THE FREQUENCY OR THICKNESS OF THE CRYSTAL CAN BE DETERMINED IN TERMS OF THE OTHER FACTOR. THAT IS TO SAY FOR THE X-CUT CRYSTAL $f = \frac{112.6}{t}$ OR $t = \frac{112.6}{f}$ WHEREAS FOR THE Y-CUT CRYSTAL $f = \frac{77}{t}$ OR $t = \frac{77}{f}$.

SINCE THE THICKNESS OF A CRYSTAL IS INVERSELY PROPORTIONAL TO ITS FREQUENCY, IT IS OBVIOUS THAT THE CRYSTAL SLABS BECOME VERY THIN AND FRAGIL WHEN GROUND FOR THE HIGHER FREQUENCIES (3500 KC. OR HIGHER). IT IS FOR THIS REASON THAT FOR TRANSMITTERS OPERATING AT FREQUENCIES HIGHER THAN 3500 KC., IT IS GENERALLY ALTHOUGH NOT ALWAYS THE PRACTICE TO EMPLOY AN

OSCILLATOR CIRCUIT WHOSE FREQUENCY OF OSCILLATION IS ONLY ONE-HALF THAT OF THE CARRIER WAVE WHICH IS RADIATED. THE CARRIER OF HIGHER FREQUENCY IN SUCH A CASE IS OBTAINED BY INCLUDING A SPECIAL CIRCUIT KNOWN AS A "FREQUENCY DOUBLER" BETWEEN THE OSCILLATOR AND THE ANTENNA SYSTEM. THESE FREQUENCY DOUBLERS ARE EXPLAINED IN DETAIL IN A LATER LESSON.

CRYSTAL MOUNTINGS

THE MAJORITY OF TRANSMITTER CRYSTALS ARE APPROXIMATELY 1" SQUARE, PERFECTLY FLAT AND THE TWO MAJOR SURFACES ARE PARALLEL. WHEN IN USE, THE CRYSTAL IS ENCASED IN A HOLDER AND OF WHICH THERE ARE A NUMBER OF DIFFERENT TYPES.

A SIMPLE FORM OF CRYSTAL HOLDER IS SHOWN YOU IN FIG.6. HERE THE CRYSTAL IS LAID FLAT BETWEEN TWO BRASS PLATES WHICH ARE APPROXIMATELY 1/16" THICK. THE SURFACE AREA OF THE TOP PLATE IS FREQUENTLY MADE THE SAME AS THAT OF THE CRYSTAL, ALTHOUGH IT IS ALSO A COMMON PRACTICE TO MAKE THE UPPER PLATE CIRCULAR IN SHAPE AND SOMEWHAT SMALLER IN DIAMETER THAN THE CRYSTAL. THE BOTTOM PLATE IS GENERALLY MADE LARGE ENOUGH SO AS TO SERVE AS A BASE FOR THE ENTIRE CRYSTAL ASSEMBLY.

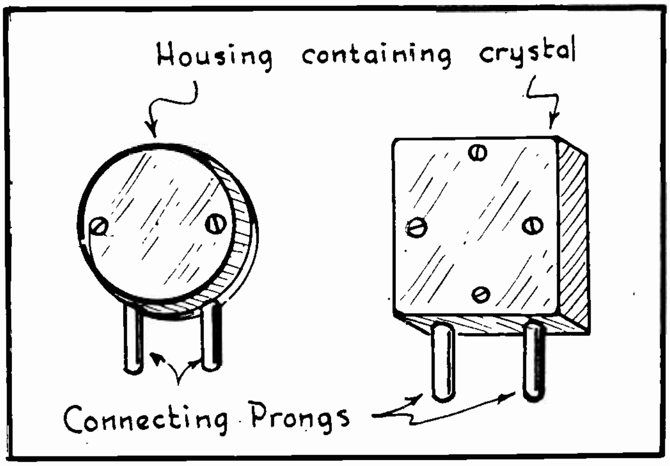

FIG. 7
Two Popular Crystal Holders.

THE CRYSTAL IS ENCLOSED IN A BOX MADE OF SOME SUCH INSULATING MATERIAL AS BAKELITE AND TERMINALS ARE PROVIDED WHEREBY THE BRASS PLATES OF THE ASSEMBLY CAN BE CONNECTED TO THE TRANSMITTER CIRCUIT. A LIGHT LEAF OF SPRING BRASS OR A SMALL SPIRAL OF FINE COPPER WIRE IS GENERALLY EMPLOYED FOR COMPLETING THE ELECTRICAL CONNECTION TO THE TOP PLATE OF THE CRYSTAL ASSEMBLY.

TWO POPULAR CRYSTAL HOLDERS OF THE COMMERCIAL TYPE ARE ILLUSTRATED IN FIG. 7. ONE OF THESE CONSISTS OF A BOX-SHAPED CRYSTAL CONTAINER WHILE THE OTHER IS ROUND. BOTH UNITS, HOWEVER, ARE FITTED WITH A PAIR OF PRONGS WHEREBY THE CRYSTAL CAN BE CONNECTED IN THE OSCILLATOR CIRCUIT BY SIMPLY INSERTING THE CRYSTAL HOLDER INTO A SUITABLE SOCKET.

IN SOME CRYSTAL UNITS YOU WILL ALSO FIND THAT THE TOP BRASS PLATE OF THE ASSEMBLY DOES NOT LIE FLAT UPON THE UPPER SURFACE OF THE CRYSTAL BUT THAT THERE IS AN AIR GAP OF APPROXIMATELY ONE-THOUSANDTH OF AN INCH BETWEEN THE TOP PLATE AND THE UPPER SURFACE OF THE CRYSTAL. THIS AIR SPACE PERMITS A SLIGHT ADJUSTMENT OF THE FREQUENCY SINCE A SLIGHT CHANGE IN THIS SPACING WILL AFFECT THE FREQUENCY.

TEMPERATURE CONTROL

THE FREQUENCY OF A CRYSTAL IS ALSO AFFECTED MATERIALLY BY THE TEMP

ERATURE OF THE CRYSTAL AND THEREFORE IF THE FREQUENCY STABILITY OF THE OSCILLATOR IS TO BE AT ITS BEST, IT IS NECESSARY THAT THE TEMPERATURE OF THE CRYSTAL BE MAINTAINED AT A CONSTANT VALUE. THIS IS KNOWN AS TEMPERATURE CONTROL AND SINCE THIS FEATURE MAKES THE TRANSMITTER MORE EXPENSIVE TO BUILD, IT IS EMPLOYED ONLY IN TRANSMITTERS OF HIGHER QUALITY.

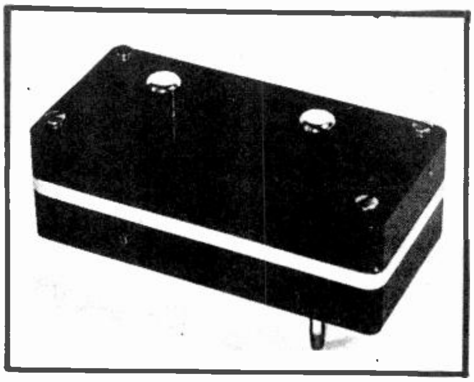

FIG. 8
The Crystal Oven.

THE TEMPERATURE COEFFICIENT OF AN X-CUT CRYSTAL IS NEGATIVE, WHICH MEANS THAT THE FREQUENCY GOES DOWN WITH A RISING TEMPERATURE. THE TEMPERATURE COEFF. OF Y-CUT CRYSTAL IS POSITIVE AND WHICH MEANS THAT THE FREQUENCY INCREASES WITH A RISING TEMPERATURE. IN EITHER CASE, THE FREQUENCY OF THE OSCILLATOR WILL "CREEP" IF THE TEMPERATURE OF THE CRYSTAL CHANGES DURING OPERATION.

SO AS TO MAINTAIN THE TEMPERATURE OF THE CRYSTAL AT A CONSTANT VALUE, THE CRYSTAL IS PLACED IN A CRYSTAL OVEN. AN EXTERNAL VIEW OF A TYPICAL CRYSTAL OVEN IS SHOWN YOU IN FIG. 8, WHILE THE INTERNAL CONSTRUCTION OF THE SAME UNIT IS SHOWN IN FIG. 9.

THE PARTICULAR CRYSTAL OVEN HERE SHOWN IS DESIGNED TO ACCOMMODATE TWO CRYSTALS. BY STUDYING FIG. 9 CAREFULLY, YOU WILL NOTE THAT WE HAVE HERE FIRST A BOTTOM PIECE WHICH IS MOLDED OF A HEAT-RESISTING MATERIAL KNOWN AS DUREZ. WITHIN THE CHAMBER OF THIS BOTTOM PIECE ARE CONTAINED TWO WIRE HEATER ELEMENTS AND A THERMOSTAT. THESE HEATER ELEMENTS ARE CONNECTED ACROSS A VOLTAGE SOURCE OF 10 TO 12 VOLTS. A SET OF THERMOSTATICALLY OPERATED POINTS ARE CONNECTED IN THIS HEATER CIRCUIT AND IN THIS MANNER THE TEMPERATURE WITHIN THE CHAMBER IS KEPT CONSTANT. THE THERMOSTAT OF THIS PARTICULAR UNIT IS ADJUSTABLE AND MAY BE SET FOR TEMPERATURES BETWEEN 35 AND 50 DEGREES CENTIGRADE (95 AND 122 DEGREES FAHRENHEIT).

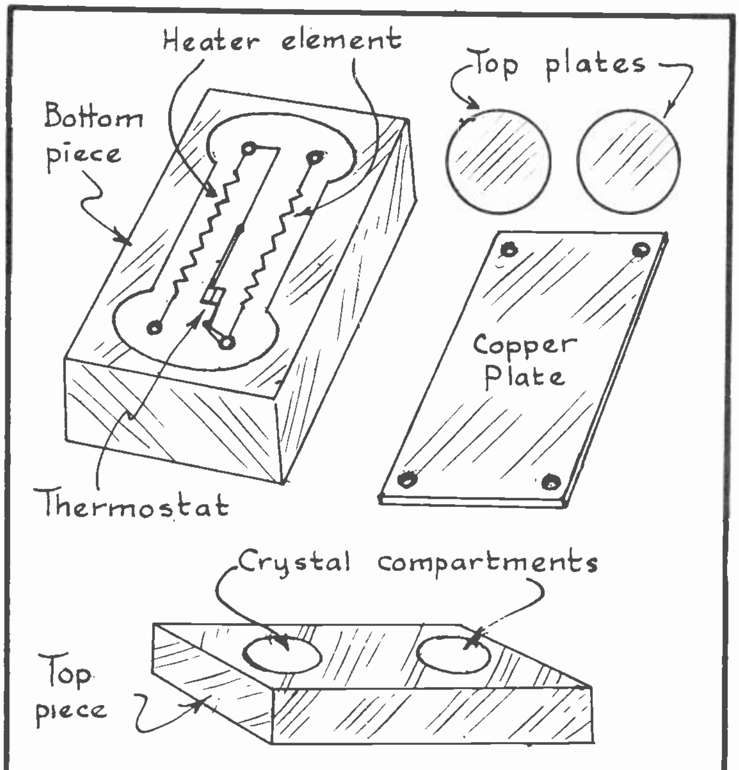

FIG. 9
Details of the Crystal Oven.

A HEAVY COPPER PLATE IS PLACED OVER

THIS HEATING CHAMBER AND AT THE SAME TIME SERVES AS THE BOTTOM PLATE FOR THE CRYSTAL HOLDER. THE HEAT DISTRIBUTION OVER THIS ENTIRE PLATE IS UNIFORM BECAUSE OF THE HIGH THERMAL CONDUCTIVITY OF COPPER AND THE THICKNESS OF THE PLATE.

THE TOP PIECE OF THIS OVEN HAS COMPARTMENTS FOR TWO CRYSTALS. THE TWO DISCS WHICH ARE SHOWN IN FIG. 9 ARE THE TOP PLATES FOR THE CRYSTAL HOLDER AND ARE MADE OF MONEL METAL. CONNECTIONS TO THE HEATER ARE MADE BY MEANS OF TWO PLUGS ON THE BOTTOM PLATE OF THE HOLDERS AND CONNECTION TO THE TOP PLATES IS MADE BY SLIPPING A GRID CLIP OVER THE CAP STUDS WHICH PROJECT FROM THE TOP OF THE CASE.

SOME OF THE CRYSTAL OVENS ARE EVEN MORE ELABORATE IN DESIGN THAN THE ONE ILLUSTRATED IN FIGS. 8 AND 9. FOR INSTANCE, IN SOME CASES, THE CRYSTAL IS HOUSED WITHIN A HEATED CHAMBER WHICH IS HEAT-INSULATED FROM AN OUTER CASING AND WHICH SERVES AS AN ENCLOSURE FOR THE ENTIRE ASSMEBLY. QUITE OFTEN, A THERMOMETER IS ALSO USED AS A PART OF THE CRYSTAL OVEN EQUIPMENT WHEREBY THE OPERATOR CAN AT ALL TIMES ASCERTAIN THE TEMPERATURE AT WHICH THE CRYSTAL IS OPERATING.

APPLICATIONS OF THE CRYSTAL

THERE ARE A NUMBER OF METHODS IN WHICH A CRYSTAL CAN BE APPLIED IN AN OSCILLATOR CIRCUIT. IN FIG.2, FOR EXAMPLE, YOU WERE SHOWN HOW A CRYSTAL CAN BE EMPLOYED IN A CIRCUIT IN WHICH A TRIODE IS EMPLOYED.

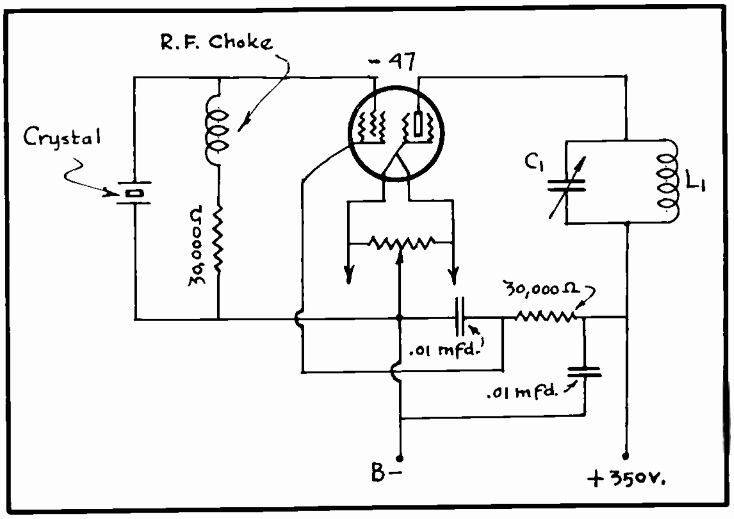

FIG. 10
Pentode Crystal Controlled Oscillator

FIG. 10 SHOWS YOU A CIRCUIT IN WHICH A PENTODE TUBE IS USED AS THE OSCILLATOR, TOGETHER WITH CRYSTAL CONTROL FEATURES. THE TUBE HERE SHOWN IS A TYPE 47.

IN FIG. 11 YOU WILL SEE HOW A CRYSTAL MAY BE EMPLOYED WHEN TWO OSCILLATOR TUBES ARE CONNECTED IN PUSH-PULL. THE TUBES USED IN THIS PARTICULAR ILLUSTRATION ARE ALSO BOTH OF THE PENTODE TYPE.

THE POWER WHICH CAN BE OBTAINED FROM A CRYSTAL OSCILLATOR WILL DEPEND UPON THE TYPE OF OSCILLATOR TUBE USED, THE PLATE VOLTAGE AND THE AMPLITUDE OF THE R.F. VOLTAGE WHICH IS DEVELOPED AS A RESULT OF THE CRYSTAL'S MECHANICAL VIBRATION. IN THE EVENT THAT THE FEED-BACK VOLTAGE IS TOO GREAT, THE MECHANICAL STRAIN IMPOSED UPON THE CRYSTAL AS A RESULT OF THE VIBRATION WILL CAUSE THE CRYSTAL TO HEAT CONSIDERABLY AND MAY IN DUE

TIME CAUSE THE CRYSTAL TO CRACK AND THEREBY BECOME RUINED.

ONE OF THE ADVANTAGES OF USING A PENTODE AS AN OSCILLATOR IN CRYSTAL CONTROLLED TRANSMITTERS IS THAT THIS TYPE OF TUBE HAS A RELATIVELY LOW GRID-PLATE CAPACITY AND THEREFORE HAS A TENDENCY TO REDUCE THE FEED-BACK SOMEWHAT. IN ADDITION, PENTODES ARE CAPABLE OF DELIVERING FAIRLY LARGE POWER OUTPUTS WITH A SMALL EXITING GRID VOLTAGE.

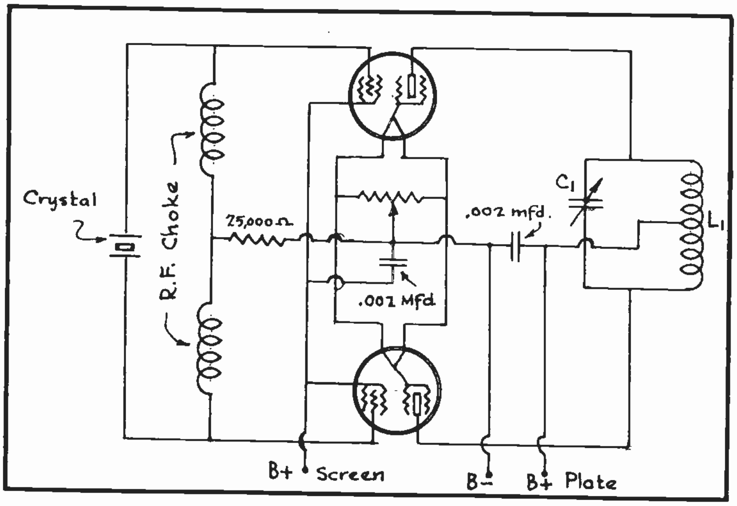

FIG. II
The Push-Pull Crystal Oscillator.

IT IS INTERESTING TO NOTE THAT FOR A GIVEN APPLIED PLATE VOLTAGE, HEATING OF THE CRYSTAL WILL BE LESS WITH A PENTODE THAN WITH A TRIODE AS THE OSCILLATOR TUBE. THIS BEING THE CASE, IT IS EQUALLY TRUE THAT FOR THE SAME AMPLITUDE OF CRYSTAL VIBRATION, HIGHER PLATE VOLTAGES CAN BE USED WITH THE PENTODE WITH ITS RESULTING INCREASED POWER OUTPUT.

FIG. 12 SHOWS YOU HOW A 2A5 HEATER TYPE TUBE MAY BE USED IN A CRYSTAL CONTROLLED OSCILLATOR CIRCUIT AND AS YOU WILL OBSERVE THE BASIC DESIGN OF THIS CIRCUIT IS SIMILAR TO OTHERS WHICH APPEAR IN THIS LESSON ONLY THAT THE CATHODE CIRCUIT SERVES TO COMPLETE THE B- CIRCUIT.

GRINDING CRYSTALS

ALTHOUGH CRYSTALS CAN BE PURCHASED WHICH ARE ALREADY ACCURATELY GROUND FOR THE FREQUENCY DESIRED, YET ONE CAN ALSO PURCHASE BLANK CRYSTALS WHICH ARE CUT TO SIZE BUT NOT SUBJECTED TO THE FINAL GRINDING PROCESS WHICH DETERMINES THEIR RESONANT FREQUENCY. NO DOUBT YOU WILL BE INTERESTED IN KNOWING HOW BLANK CRYSTALS ARE GROUND AND SO THIS WILL NOW BE EXPLAINED.

TO BEGIN WITH, THE APPROXIMATE THICKNESS

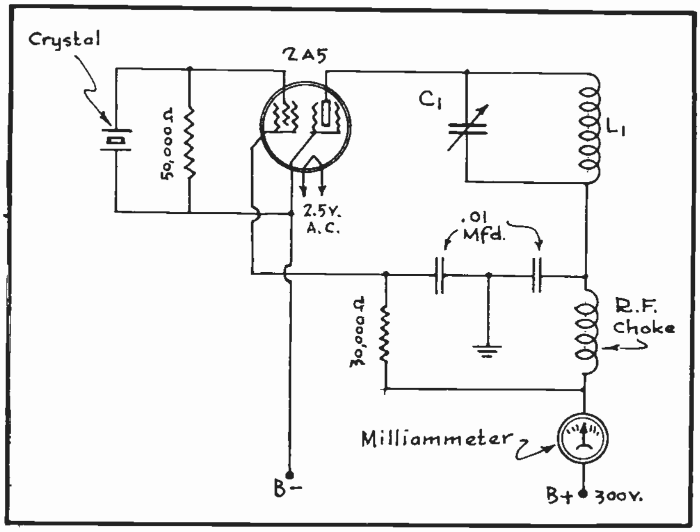

FIG. 12
A Heater-Type Pentode Crystal Oscillator.

OF THE CRYSTAL FOR THE FREQUENCY DESIRED CAN BE DETERMINED FROM THE FORMULAS WHICH WERE GIVEN EARLIER IN THIS LESSON. AS THE GRINDING PROCESS PROCEEDS, THIS THICKNESS CAN BE CHECKED WITH AN ACCURATE MICROMETER CALIPER. THIS SAME INSTRUMENT CAN ALSO BE EMPLOYED AS A MEANS FOR CHECKING THE THICKNESS FOR UNIFORMITY AND IN THIS WAY AVOID GRINDING BUMPS AND HOLLOW AREAS IN THE SURFACES OF THE CRYSTAL.

THE GRINDING PROCESS IS GENERALLY ACCOMPLISHED BY ROTATING THE FLAT SURFACES OF THE CRYSTAL IN IRREGULAR SPIRALS ON A PIECE OF PLATE GLASS AND ON WHOSE SURFACE HAS BEEN SMEARED A MIXTURE OF #102 CARBORUNDUM AND WATER OR KEROSENE.

SO THAT THE CRYSTAL SURFACES WILL BE GROUND ABSOLUTELY FLAT, IT IS ESSENTIAL THAT AN EVEN PRESSURE BE APPLIED OVER THE WHOLE AREA OF THE CRYSTAL. THIS CAN BEST BE ACCOMPLISHED BY STICKING THE CRYSTAL TO A PERFECTLY FLAT PIECE OF THIN BRASS OR A TO A GLASS MICROSCOPE SLIDE, WHICH SERVES AS A PRESSURE PLATE. BY MOISTENING THE CRYSTAL SURFACE WITH KEROSENE IT CAN BE MADE TO ADHERE TO THE BRASS OR GLASS SLIDE SUFFICIENTLY WELL FOR THIS PURPOSE. THIS WILL PERMIT ONE TO APPLY THE PRESSURE OF THE FINGERS TO THE PRESSURE PLATE AS THE EXPOSED SURFACE OF THE CRYSTAL IS MOVED OVER THE GRINDING COMPOUND.

AS THE GRINDING PROCESS PROGRESSES, THE CRYSTAL SHOULD BE CHECKED FOR ITS FREQUENCY OF OSCILLATION BY CONNECTING IT IN A TEST OSCILLATOR CIRCUIT AND LISTENING TO THE SIGNAL IN A RECEIVER WHOSE DIAL HAS BEEN ACCURATELY CALIBRATED. IN THE EVENT THAT THE CRYSTAL SHOULD STOP OSCILLATING DURING THE GRINDING PROCESS THEN ITS EDGES SHOULD BE GROUND CAREFULLY UNTIL OSCILLATION RESUMES.

AS THE FREQUENCY COMES WITHIN A FEW KILOCYCLES OF THE DESIRED VALUE, ANY FURTHER GRINDING MUST BE DONE WITH EXTREME CARE, USING A FINER GRADE OF CARBORUNDUM POWDER SUCH AS GRADES FF AND FFF FOR THE FINAL GRINDING.

SO FAR, ALL OF THE TRANSMITTER CIRCUITS WHICH WERE EXPLAINED TO YOU EMPLOYED NOTHING MORE THAN AN OSCILLATOR STAGE IN THE TRANSMITTER PROPER. IN THE FOLLOWING LESSON, HOWEVER, YOU ARE GOING TO BE SHOWN HOW THE OUTPUT OF THE OSCILLATOR CAN BE AMPLIFIED BY ADDING SOME AMPLIFYING STAGES TO THE CIRCUIT AND IN THIS WAY MAKE GREATER POWER OUTPUTS POSSIBLE.

Examination Questions

LESSON NO. T-6

Answered Nov 13, 1941

> Setbacks never whip a fighter, they only sharpen his faculties. The more he fights the better he becomes. So roll up your sleaves and give Life the greatest battle it ever had.

1. – WHAT IS THE REASON FOR USING A QUARTZ CRYSTAL IN THE OSCILLATOR CIRCUIT OF A TRANSMITTER?

2. – EXPLAIN THE PIEZO-ELECTRIC EFFECT.

3. – DESCRIBE IN DETAIL AN X-CUT CRYSTAL.

4. – DESCRIBE IN DETAIL A Y-CUT CRYSTAL.

5. – WHAT FACTORS DETERMINE AT WHAT FREQUENCY A QUARTZ CRYSTAL WILL RESONATE?

6. – DESCRIBE HOW A CRYSTAL MAY BE MOUNTED IN A TRANSMITTER.

7. – DESCRIBE A TYPICAL CRYSTAL OVEN AND EXPLAIN THE REASON FOR ITS USE.

8. – DRAW A CIRCUIT DIAGRAM OF A CRYSTAL CONTROLLED OSCILLATOR.

9. – EXPLAIN HOW YOU WOULD ADJUST THE OSCILLATOR WHOSE CIRCUIT YOU HAVE DRAWN IN ANSWER TO QUESTION #8 AND ALSO EXPLAIN IN DETAIL HOW THIS CIRCUIT FUNCTIONS.

10. – WHAT PRECAUTIONS MUST BE TAKEN IN THE DESIGN OF A CRYSTAL CONTROLLED OSCILLATOR AS REGARDS THE FEED-BACK VOLTAGE?

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Transmitters

LESSON NO. T-7

OSCILLATOR-AMPLIFIER TRANSMITTERS

In the previous lesson you were told that if an oscillator without crystal control features is coupled directly to the antenna system, the oscillator may not only be subject to changing its frequency because of changing conditions which originate in its own circuit but that changes in the resonant frequency of the antenna circuit caused by swingingwires etc. may also cause the oscillator to undergo a shift in frequency. This last mentioned condition can be eliminated, however, by placing a stage of radio frequency amplification between the oscillator and the antenna circuit and when used for this purpose, this R.F. stage is generally called a BUFFER. Besides serving as a buffer, this R.F. stage provides another advantage and that is that it amplifies the oscillator's output so that greater radio frequency energy can be supplied to the antenna system.

The crystal controlled oscillator on the other hand, has such excellent frequency stability so that if it be coupled directly to the antenna system, its frequency will remain constant even though the characteristics of the antenna circuit may vary somewhat during operation. The crystal oscillator, however, is a low-power device and therefore it is desirable to build up its output power to a higher level by means of one or more stages of radio frequency amplification which are placed between the oscillator and the antenna.

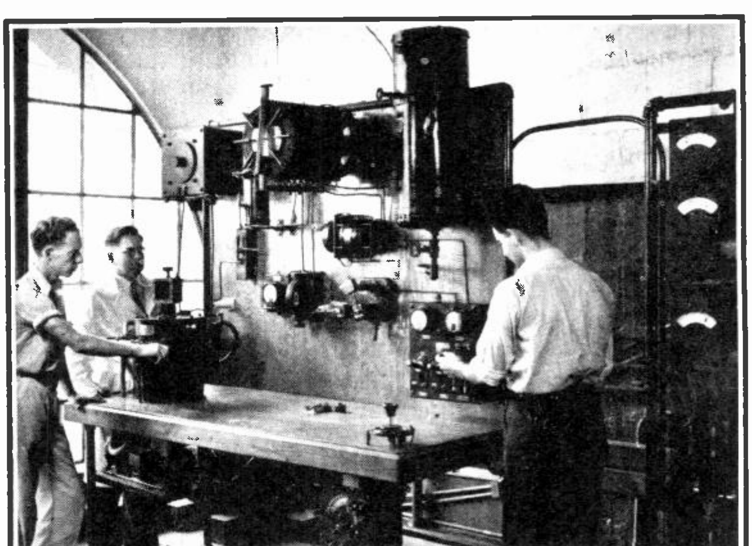

Fig. 1
Spark Transmitter Installed
At National

THUS YOU WILL SEE THAT REGARDLESS OF WHETHER THE OSCILLATOR BE SELF-TUNING OR HAS ITS FREQUENCY CONTROLLED BY MEANS OF A CRYSTAL, A RADIO FREQUENCY AMPLIFYING SYSTEM BETWEEN THE OSCILLATOR AND THE ANTENNA IS DESIRABLE.

EFFECT OF ANTENNA UPON OSCILLATOR

BEFORE WE GO INTO DETAILS CONCERNING THE R.F. STAGES THEMSELVES AS EMPLOYED IN TRANSMITTERS, LET US FIRST SEE JUST HOW IT IS THAT THE ANTENNA MAY INFLUENCE THE TUNING OF A SIMPLE OSCILLATOR.

A GLANCE AT THE TYPICAL SINGLE-TUBE TRANSMITTER DIAGRAM IN FIG.2 WILL SHOW THAT THE ANTENNA IS ENERGIZED BY THE SECONDARY OF AN R.F.TRANSFORMER, THE PRIMARY BEING IN THE PLATE CIRCUIT OF THE TUBE. THE INDUCTANCE OF THE ANTENNA SYSTEM IS TUNED BY THE VARIABLE CONDENSER WHICH IS CONNECTED ACROSS THE SECONDARY COIL. YOU WILL ALSO OBSERVE THAT THE DISTRIBUTED CAPACITANCE OF THE FEEDERS MAY BE CONSIDERED AS BEING IN PARALLEL WITH THIS CAPACITANCE.

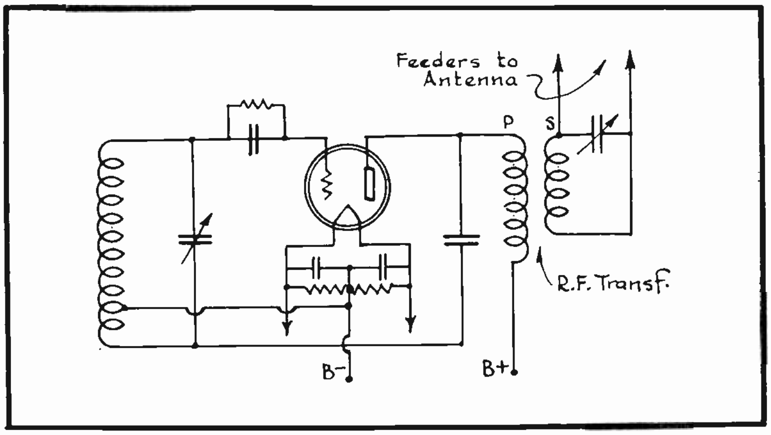

FIG. 2
A Single Tube Hartley Transmitter.

JUST AS ANY CHANGE IN THE DIELECTRIC SPACING BETWEEN THE PLATES OF A CONDENSER CAUSES A CHANGE IN CAPACITANCE, SO ANY CHANGE IN SPACING BETWEEN THE TWO FEEDER WIRES DUE TO WIND, FOR EXAMPLE, WILL CAUSE A CHANGE IN CAPACITANCE WHICH WILL CHANGE THE RESONANT FREQUENCY OF THE SYSTEM. SINCE A RESONANT CONDITION IN A SECONDARY COIL IS "REFLECTED" BACK INTO THE PRIMARY CIRCUIT, THIS SWING IN ANTENNA RESONANCE MAY CAUSE THE OSCILLATOR TO VARY IN FREQUENCY.

SO YOU SEE AN R.F. AMPLIFIER IN THIS CASE REALLY SERVES A DUAL PURPOSE, NAMELY, TO BOOST THE OUTPUT AND AT THE SAME TIME TENDING TO STABILIZE FREQUENCY.

R.F. AMPLIFIER DESIGN PRACTICE

THERE ARE SEVERAL METHODS OF COUPLING THE OSCILLATOR TUBE TO THE BUFFER STAGE AND WHICH DIFFERS FROM THE INTER-STAGE CIRCUITS USED IN RECEIVING SETS ONLY IN THE TYPE OF EQUIPMENT USED AND IN MINOR DETAILS. THE OBJECTIVES OF THE ENGINEER IN DESIGNING ANY VACUUM TUBE AMPLIFIER, WHETHER IT BE FOR A RECEIVER, A SPEECH AMPLIFIER, OR FOR A RADIO TRANSMITTER ARE:

1. TO PLACE IN THE PLATE CIRCUIT OF THE TUBE A SUITABLE IMPEDANCE SO THAT THE ALTERNATE RISE AND FALL OF PLATE CURRENT WILL CAUSE AN ALTERNATE RISE AND FALL IN THE I TIMES Z VOLTAGE DROP, THUS

PROVIDING AN ALTERNATING OUTPUT VOLTAGE.

2. TO PROVIDE SOME MEANS OF APPLYING THIS SIGNAL VOLTAGE TO THE GRID OF THE NEXT TUBE AND AT THE SAME TIME BLOCKING FROM THIS GRID THE HIGH POSITIVE PLATE POTENTIAL.

3. TO CONNECT THE GRID TO A POINT OF THE CORRECT BIAS POTENTIAL THROUGH A RESISTOR OR INDUCTOR OF SUFFICIENT IMPEDANCE. AN ADDITIONAL OBJECTIVE, IF THE AMPLIFIER IS TO BE OF THE TUNED RADIO FREQUENCY TYPE IS:

4. TO CONTROL FREQUENCY BY PLACING A RESONANT CIRCUIT IN GRID CIRCUIT, PLATE CIRCUIT, OR BOTH. SUCH A TUNED CIRCUIT IN A TRANSMITTER IS USUALLY CALLED A "TANK CIRCUIT."

IT IS INTERESTING TO NOTE IN THE FOLLOWING REPRESENTATIVE INTER-

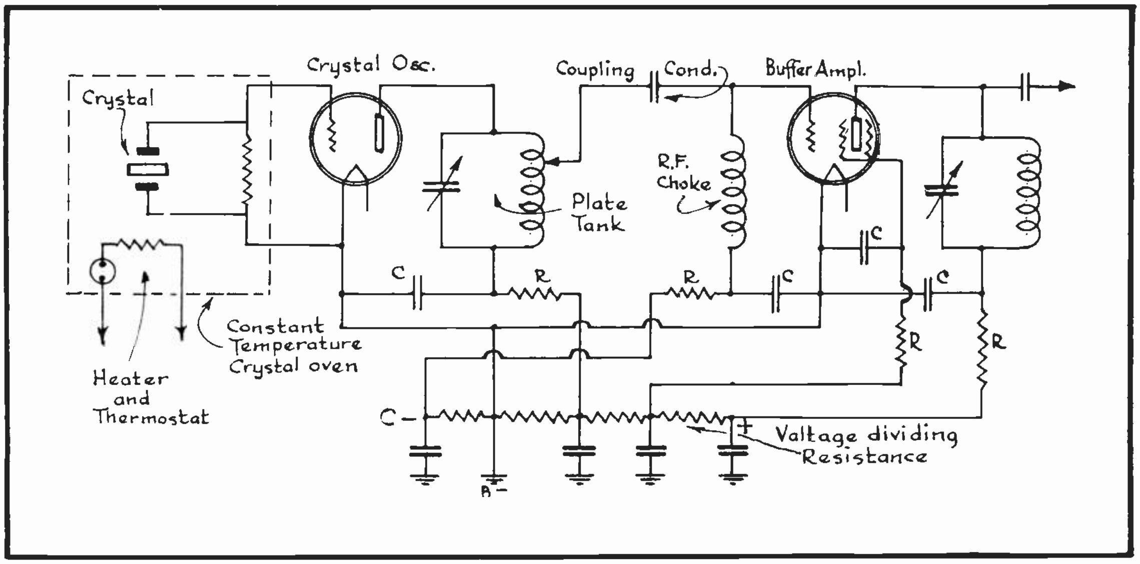

FIG. 3
Oscillator and Buffer Amplifier Circuit.

STAGE COUPLING CIRCUITS HOW THE ABOVE OBJECTIVES ARE ATTAINED.

APPLICATION OF THE BUFFER AMPLIFIER

FIG. 3, FOR INSTANCE, SHOWS THE OSCILLATOR AND BUFFER STAGES OF A WIDELY USED 20-40 KW COMMERCIAL CODE TRANSMITTER. THE PARALLEL-RESONANT TANK CIRCUIT OF THE OSCILLATOR PROVIDES ADEQUATE PLATE CIRCUIT IMPEDANCE AND AIDS IN TUNING THE SYSTEM, WHILE CAPACITANCE COUPLING LEADS THE RADIO FREQUENCY POWER TO THE GRID OF THE AMPLIFIER TUBE. THE COUPLING CONDENSER SHOULD BE A HIGH QUALITY MICA CONDENSER WITH A VOLTAGE RATING AT LEAST 2 OR 3 TIMES THE DC VOLTAGE APPEARING ACROSS IT. THIS VOLTAGE, YOU WILL NOTE, IS THE SUM OF THE OSCILLATOR PLATE VOLTAGE AND THE AMPLIFIER GRID BIAS BECAUSE THE PLATE IS MORE POSITIVE THAN GROUND WHILE THE GRID IS MORE NEGATIVE THAN GROUND. THE D.C. BIAS VOLTAGE IS APPLIED TO THE GRID OF THE AMPLIFIER TUBE THROUGH AN R.F. CHOKE WHICH EFFECTIVELY PREVENTS THE HIGH FREQUENCY SIGNALS FROM PASSING TO GROUND THROUGH THE BIAS SUPPLY.

YOU WILL ALSO OBSERVE IN FIG. 3 THAT A VARIABLE TAP CONNECTION ON THE TANK COIL IS USED TO PASS THE ENERGY ON TO THE AMPLIFIER STAGE. BY MEANS OF THIS TAP THE ENERGY WHICH IS DELIVERED TO THE GRID CIRCUIT OF THE AMPLIFIER FROM THE OSCILLATOR CAN BE CONTROLLED AND THUS PREVENT OVERLOADING THE AMPLIFIER TUBE. THE NEARER THIS TAP IS TO THE PLATE END, THE GREATER WILL BE THE EXITING VOLTAGE DELIVERED TO THE AMPLIFIER.

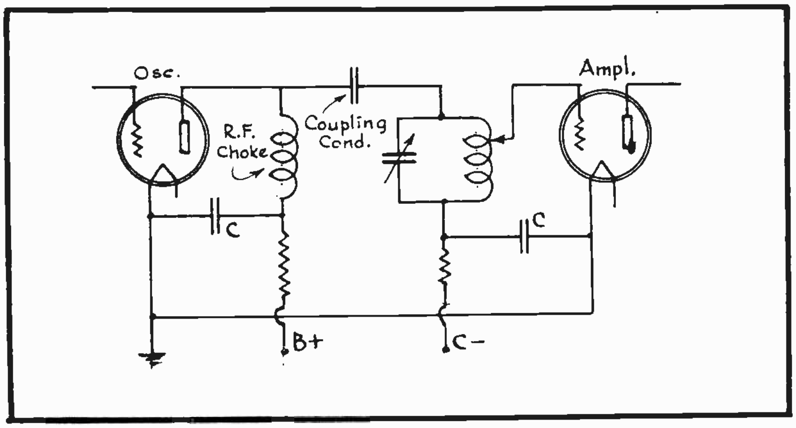

FIG. 4

Untuned Plate-Tuned Grid Circuit.

THE BLOCKING RESISTORS MARKED "R" AND THE BY-PASS CONDENSERS "C" PREVENT ANY UNDESIRABLE COUPLING BETWEEN THE TWO TUBES THROUGH THE POWER SUPPLY. IN SPITE OF THE FACT THAT IN THIS COMPLETE TRANSMITTER NINE HEAVY DUTY TUBES FOLLOW THE TWO TUBES SHOWN, THE FREQUENCY GENERATED BY THE CRYSTAL OSCILLATOR WILL NOT VARY FROM A GIVEN VALUE BY MORE THAN 1 PART IN 4000. FACTORS CONTRIBUTING TO THIS EXCELLENT FREQUENCY STABILITY ARE:

1. LOCATION OF THE CRYSTAL IN AN OVEN WHERE TEMPERATURE IS KEPT AT 45 DEGREES, C. TO AN ACCURACY OF 0.25 DEGREE, C. (CENTIGRADE)

2. USE OF A BUFFER AMPLIFIER.

3. USE OF A SEPARATE POWER SUPPLY FOR OSCILLATOR AND BUFFER TUBES.

4. CAREFUL SHIELDING.

COUPLING UNTUNED PLATE TO TUNED GRID CIRCUIT

THE SYSTEM OF FIG. 4 IS SIMILAR IN OPERATING CHARACTERISTICS TO THAT OF FIG. 3. THE R.F. CHOKE COIL IN THIS CASE ACTS AS THE PLATE CIRCUIT IMPEDANCE AND THE COUPLING CONDENSER CARRIES THE SIGNAL FROM PLATE TO GRID CIRCUIT, WHILE A TUNED GRID CIRCUIT CONNECTS THE GRID TO THE PROPER NEGATIVE POTENTIAL. IN THIS CIRCUIT, THE GRID OF THE AMPLIFIER TUBE IS CONNECTED TO A TAP

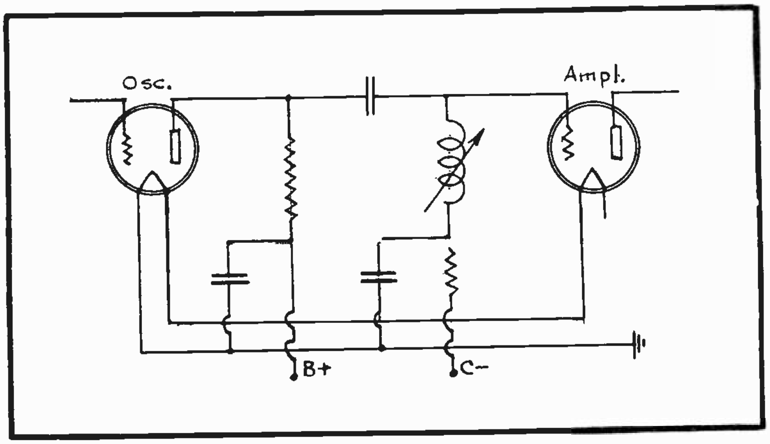

FIG. 5

Distributed Capacitance Tunes Variable Inductance.

ON THE TUNED GRID WINDING SO THAT THE SIGNAL VOLTAGE MAY BE REDUCED IF THE TUBE IS OVERLOADED.

NO TUNING CONDENSER USED

IN SOME CASES, ESPECIALLY AT HIGH LEVELS OF R.F. VOLTAGE WHICH TEND TO BREAK DOWN THE CONDENSER DIELECTRIC, TUNED CIRCUITS EMPLOY ONLY THE CAPACITIES SUPPLIED BY TUBES, LEADS AND THE COIL ITSELF AND ARE ADJUSTED BY VARYING THE CIRCUIT INDUCTANCE. AN EXAMPLE OF THIS IS ILLUSTRATED IN FIG. 5 WHERE YOU ARE SHOWN THE INTERSTAGE COUPLING IN A 50 WATT SHORT-WAVE TELEPHONE TRANSMITTER DESIGNED FOR AIRCRAFT USE.

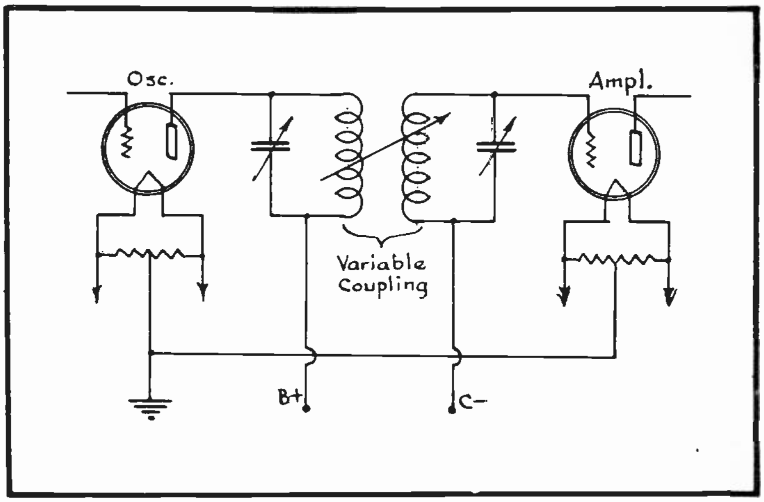

FIG. 6
Inductive Coupling.

TRANSFORMER COUPLING

TRANSFORMER COUPLING BETWEEN STAGES HAS THE ADVANTAGE THAT, IF COUPLING IS SUFFICIENTLY LOOSE, IT IS SOMEWHAT MORE EFFICIENT AT THE HIGHER FREQUENCIES THAN IS CAPACITY COUPLING. MAXIMUM EFFICIENCY IS OBTAINED BY USING DIRECT INDUCTIVE COUPLING AS IN FIG. 6 AND VARYING THE COUPLING UNTIL OPTIMUM RESULTS ARE OBTAINED, OR BY USING AN UNTUNED TRANSMISSION LINE, INDUCTIVELY COUPLED TO THE TANK COILS AT BOTH ENDS AS SHOWN IN FIG. 7. IN PRACTICE, THE NUMBER OF TURNS ON THE SMALLER COILS IS VARIED UNTIL THE PROPER COUPLING IS REACHED. THIS SYSTEM, WHICH IS ALSO KNOWN AS "LINK COUPLING", IS ADVANTAGEOUS WHEN THE TWO TUBES ARE TO BE MOUNTED AT SOME DISTANCE FROM EACH OTHER. FOR FREQUENCIES ABOVE 1500 KC., TWO TO FIVE TURNS ARE USED ON EACH OF THE TRANSMISSION LINE COILS AND THE TRANSMISSION LINE MAY BE A TWISTED PAIR SEVERAL FEET LONG.

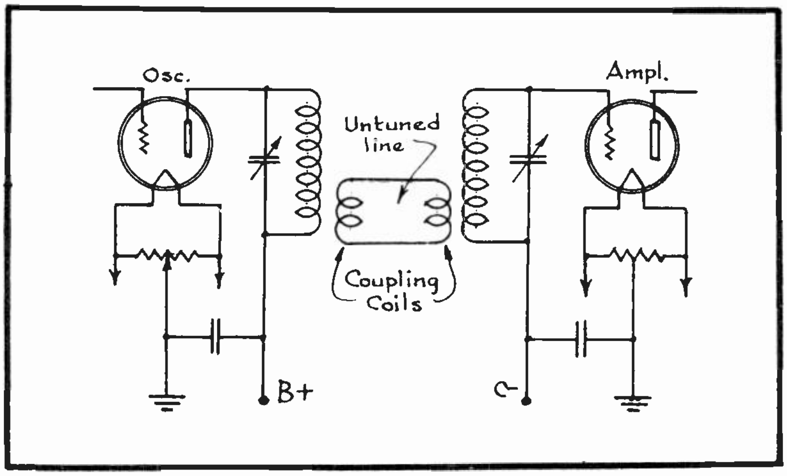

FIG. 7
Link Coupling.

PUSH-PULL CIRCUITS ARE ESPECIALLY SUITABLE FOR R.F. AMPLIFIERS, WHEN IN THE STAGE FOLLOWING THE OSCILLATOR OR IN SUCCEEDING STAGES OF

THE TRANSMITTER. WHEN DRIVEN BY A SINGLE TUBE, EITHER TRANSFORMER OR CAPACITY COUPLING CAN BE EMPLOYED AS SHOWN IN THE CIRCUITS OF FIGS. 8 AND 9. IN FIG. 8, WHERE TRANSFORMER COUPLING IS USED, YOU WILL OBSERVE A MARKED RESEMBLANCE TO THE AUDIO FREQUENCY CIRCUITS ABOUT WHICH YOU STUDIED IN PREVIOUS LESSONS. THE THEORY OF OPERATION IS THE SAME, THE DIFFERENCE BEING THAT IN THIS CASE RADIO FREQUENCY TRANSFORMERS ARE USED WITH BOTH PRIMARY AND SECONDARY COILS TUNED BY VARIABLE CONDENSERS, WHILE IN THE CASE OF AUDIO SYSTEMS, WE WERE WORKING WITH IRON-CORE A.F. TRANSFORMERS.

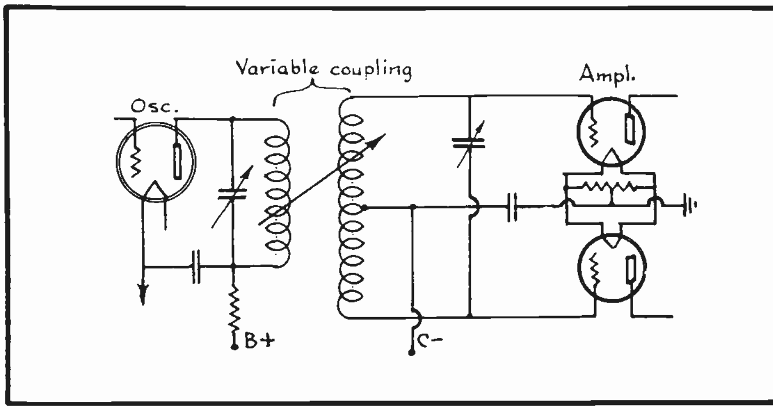

FIG. 8
Single Driver Push-Pull Ampl.

IN FIG. 9 IS SHOWN CAPACITY COUPLING. THE PLATE COIL IS TAPPED AT THE CENTER POINT, THUS BECOMING AN AUTO-TRANSFORMER WITH THE HALF NEXT TO THE PLATE ACTING AS THE PRIMARY AND THE OTHER HALF ACTING AS THE SECONDARY. THE R.F. VOLTAGES AT THE LOWER END OF THE COIL WILL BE EQUAL TO, BUT OPPOSITE IN SIGN (POLARITY) TO THE R.F. VOLTAGES AT THE PLATE AND CAN THEREFORE BE USED TO ENERGIZE THE GRID OF THE LOWER PUSH-PULL TUBE. THIS COUPLING METHOD IS THE SAME AS THAT EMPLOYED IN THE CIRCUIT OF FIG. 3 IN THIS LESSON ONLY THAT IT IS ADAPTED TO THE PUSH-PULL SYSTEM.

FIG. 10 SHOWS TWO METHODS OF COUPLING WHICH ARE SATISFACTORY FOR APPLICATION WHEN BOTH DRIVER AND DRIVEN STAGES ARE BALANCED CIRCUITS. THE TWO CAPACITORS SHOWN IN EACH PLATE TANK OF THESE TWO CIRCUITS ARE A SINGLE "SPLIT STATOR" VARIABLE CONDENSER.

OCCASIONALLY IT IS NECESSARY TO COUPLE A PUSH-PULL STAGE TO A SINGLE TUBE WHICH FOLLOWS IT. IN SUCH A CASE INDUCTIVE COUPLING IS ADVISABLE AND EITHER OF THE TWO CIRCUITS SHOWN IN FIG. 11 WILL BE FOUND SATISFACTORY. IT IS ALSO WELL TO MENTION AT THIS TIME THAT WHEN AN UNTUNED TRANSMISSION LINE IS USED, THEN THE COILS OF THIS LINE SHOULD BE SPACED AS FAR AS POSSIBLE FROM THAT PART OF THETHE TANK COIL WHICH IS CONNECTED TO THE GRID OR PLATE. IN THIS MANNER, UNDESIRABLE CAPACITY

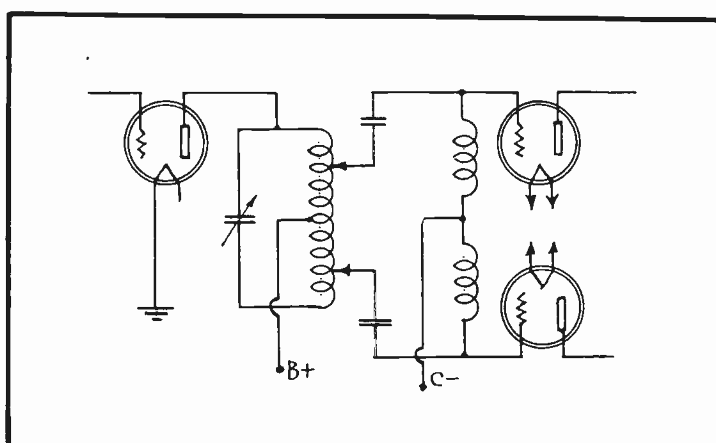

FIG. 9
Capacitance Coupling Between Single Driver and Push-Pull Amplifier.

EFFECTS ARE AVOIDED.

NEUTRALIZING R.F. AMPLIFIERS

As has already been outlined, a vacuum tube will act as an oscillator whenever a part of the power in the plate circuit is fed back into the grid circuit in such a way as to make the tube self-exciting. A problem which always enters the picture when a three element tube is used as a radio frequency amplifier is feed-back through the grid-plate capacity. In a tetrode or pentode the screen grid acts as an electrostatic shield which effectively prevents oscillation, but in a triode amplifier, it is necessary to nullify the feed-back through the inter-electrode capacitance by feeding back a neutralizing voltage which is equal to, but 180 degrees out of phase with the voltage causing the tube to oscillate. The two systems most commonly used are shown in Fig.12. In circuit "A" of Fig.12 the A.C. component of plate current flowing through section "X" induces by mutual induction a neutralizing voltage in section "Y"

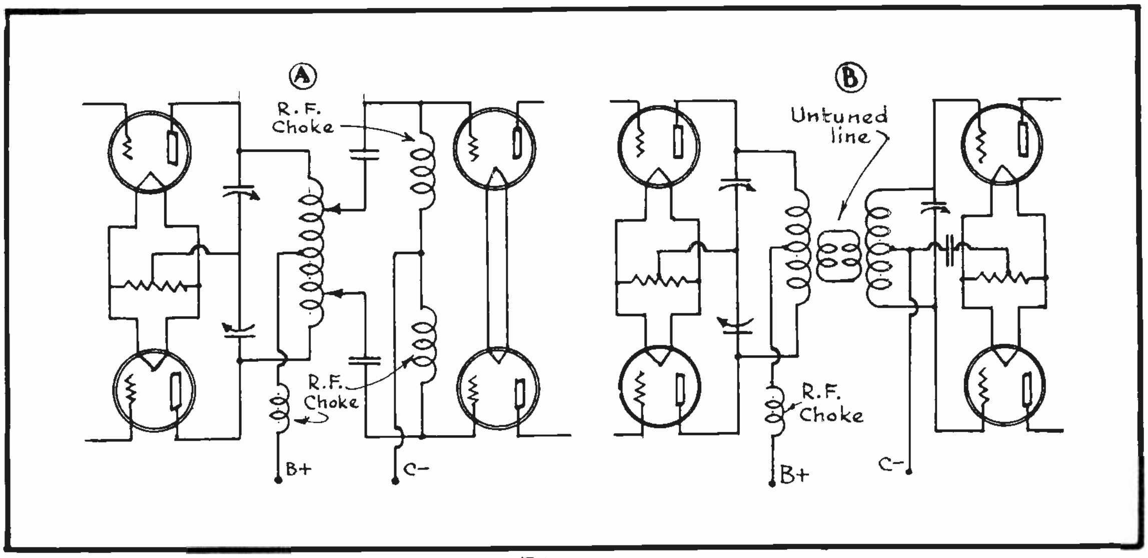

FIG.10

Interstage Coupling Between Push- Pull Amplifier.

which is led to the grid through the small condenser "C", to neutralize the voltage which appears across the grid and plate.

In "B" of Fig. 12 a split-stator tuning condenser is used with its rotor grounded and connected to the filament. The neutralizing voltage is obtained as a voltage drop across the lower section of the condenser and is fed to the grid through the neutralizing condenser "C".

Push-pull stages, as well as single amplifiers, require neutralizing. Fig. 13-A, for example, uses the principle of Fig. 12-A adapted to the balanced circuit, while Fig. 13-B is similar in principle to Fig.12-B. The use of the split-stator condenser in Figs. 12-B and 13-B renders greater frequency stability at very high frequencies than does the use of the tapped coil and it is therefore more popular in short wave work.

As a general rule, the tap on the tank coil should be at the center. Correct neutralization will then be obtained when the neutralizing

CONDENSER HAS A CAPACITY ABOUT EQUAL TO THE GRID-PLATE CAPACITY OF THE TUBE. IT IS EVIDENT, THEN, THAT THE VALUE OF THIS CAPACITANCE DEPENDS UPON THAT OF THE TUBE USED.

ALL BY-PASS CONDENSERS AND SUNDRY PARTS NOT ACTIVELY TAKING PART IN THE PROCESS OF NEUTRALIZATION ARE OF THE USUAL VALUES.

THE PROCEDURE TO BE FOLLOWED IN NEUTRALIZING AN R.F. STAGE IS NOT ESPECIALLY DIFFICULT. IT IS THE SAME REGARDLESS OF THE TYPE OF CIRCUIT EMPLOYED AND IS CARRIED OUT IN THE FOLLOWING STEPS:

1. DISCONNECT PLATE VOLTAGE FROM TUBE.

2. WITH THE FILAMENT LIGHTED, FEED THE GRID IN THE NORMAL WAY FROM THE OUTPUT OF THE PRECEDING TUBE.

3. COUPLE A RESONANCE INDICATOR (SEE YOUR LESSON NO.51.) INDUCTIVELY TO THE PLATE TANK COIL.

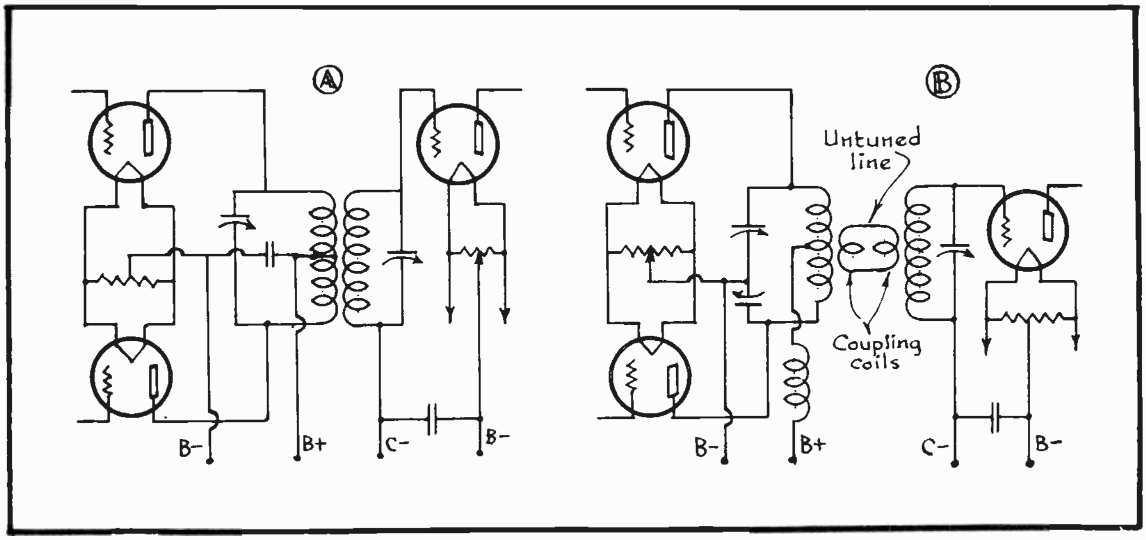

FIG. 11
Single Tubes Driven By Push-Pull Stages.

4. SET THE RESONANCE INDICATOR AT THE FREQUENCY ON WHICH THE TRANSMITTER IS TO OPERATE, AND TUNE THE PLATE CIRCUIT TO RESONANCE.

5. NOW ADJUST THE NEUTRALIZING CONDENSER TO THAT POSITION WHICH CAUSES MINIMUM R.F. PLATE CURRENT AS INDICATED BY THE RESONANCE INDICATOR. THIS INDICATION SHOULD BE VIRTUALLY ZERO.

6. THE LAST STEP HAS PROBABLY DETUNED THE DRIVER TANK, SO GO BACK AND RETUNE THIS STAGE.

7. NOW COME BACK TO THE STAGE BEING NEUTRALIZED, TUNE ITS TANK TO RESONANCE, AND NEUTRALIZE ONCE MORE. THIS WORKING BACK AND FORTH BETWEEN THESE TWO STAGES IS NECESSARY BECAUSE ANY CHANGE IN ONE CIRCUIT HAS A TENDENCY TO UPSET THE OTHER.

8. WHEN THE RESONANCE INDICATOR GIVES NO INDICATION WITH THE PLATE

TANK TUNED TO THE RESONANT FREQUENCY, WE KNOW THAT THE SIGNAL CARRIED THROUGH THE NEUTRALIZING CONDENSER IS EQUAL, AND OPPOSITE IN PHASE, TO THE SIGNAL CARRIED THROUGH THE GRID-PLATE CAPACITY OF THE TUBE, AND THE STAGE IS NEUTRALIZED.

9. NOW RESTORE PLATE VOLTAGE TO THE TUBE AND THE STAGE IS READY TO OPERATE.

SCREEN-GRID AMPLIFIERS

IN FIG. 14 YOU ARE SHOWN THE BASIC AMPLIFIER CIRCUIT FOR A TRANSMITTER WHEN SCREEN-GRID TUBES ARE USED. THE CIRCUIT AT THE LEFT OF FIG. 14 SHOWS YOU HOW A TETRODE IS USED FOR THIS PURPOSE, WHILE THE CIRCUIT AT THE RIGHT OF THIS SAME ILLUSTRATION SHOWS YOU HOW THE PENTODE IS EMPLOYED. THE EXACT VOLTAGES WHICH ARE TO BE APPLIED TO THE ELEMENTS OF THESE TUBES NATURALLY DEPEND UPON THE OPERATING CHARACTERISTICS OF THE

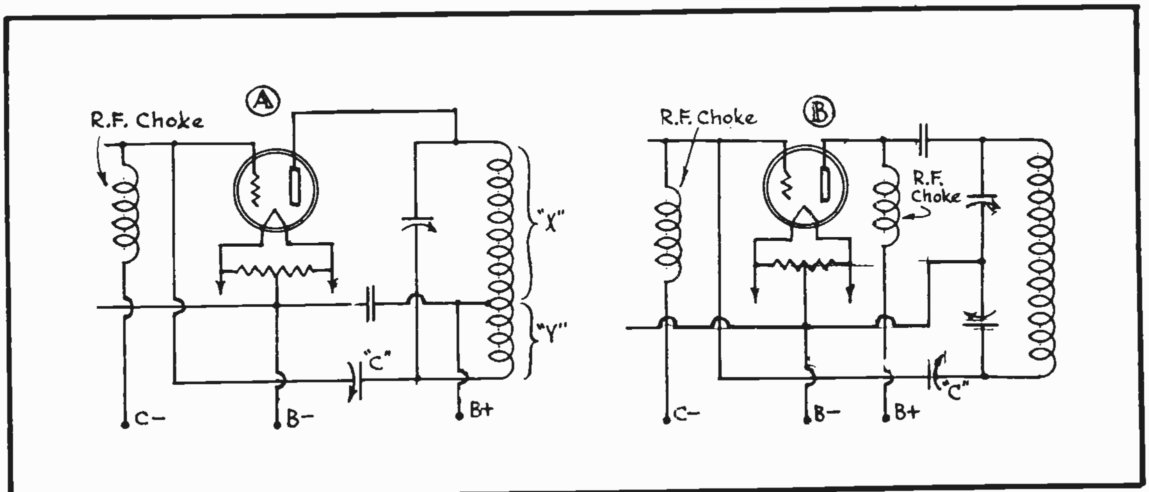

FIG. 12
Two Methods of Neutralizing.

TUBES IN QUESTION. IN A LATER LESSON, YOU WILL BE FURNISHED WITH COMPLETE DATA OF THIS NATURE PERTAINING TO TRANSMITTER TUBES.

SINCE THE TETRODE AND PENTODE TUBES BOTH HAVE INTERNAL SHIELDS, NO REGENERATIVE FEED-BACK CAN BE PASSED THROUGH THESE TUBES WHEN THEY ARE USED PROPERLY AND FOR THIS REASON NO NEUTRALIZING PROVISIONS NEED BE MADE. HOWEVER, IT IS IMPORTANT THAT THE INPUT AND OUTPUT CIRCUITS OF THE TUBE BE SUFFICIENTLY ISOLATED SO THAT STRAY MAGNETIC OR CAPACITIVE COUPLING CANNOT TAKE PLACE BETWEEN THEM. FOR THIS SAME REASON, IT IS FREQUENTLY THE PRACTICE IN DESIGNING CIRCUITS OF THIS TYPE TO SHIELD THE INPUT AND OUTPUT CIRCUITS OF THE TUBE.

TRANSMITTING CONDENSERS

YOU ARE BY THIS TIME ALREADY QUITE FAMILIAR WITH THE GENERAL CONSTRUCTIONAL FEATURES OF THE R.F. TRANSFORMERS AND COILS USED IN THE TUNING CIRCUITS OF TRANSMITTERS — THAT IS, THAT THESE WINDINGS ARE GENERALLY MADE OF COPPER TUBING OR LARGE-SIZE COPPER WIRE SO THAT LOSSES CAN BE REDUCED TO A MINIMUM. YOU WERE ALSO SHOWN WHAT PRECAUTIONS ARE TAKEN SO THAT THESE WINDINGS ARE WELL-INSULATED FROM ALL SURROUNDING BODIES BY

USING LARGE HIGH-QUALITY INSULATORS AS SUPPORTS. HOWEVER, LITTLE HAS AS YET BEEN MENTIONED ABOUT THE TUNING CONDENSERS AS USED IN TRANSMITTERS AND SO IT WILL BE WELL TO CONSIDER THIS POINT NEXT.

IN FIG. 15 YOU ARE SHOWN TWO TYPICAL VARIABLE CONDENSERS AS USED IN HIGH-POWER TRANSMITTERS FOR TUNING PURPOSES. FUNDAMENTALLY, THESE CONDENSERS ARE THE SAME AS THOSE USED IN RECEIVERS, IN THAT THEY ALSO CONSIST OF A STATOR PLATE GROUP AND A ROTOR PLATE GROUP — IN FACT, FOR LOW POWER TRANSMITTERS GOOD RECEIVER TYPE TUNING CONDENSERS CAN BE USED SATISFACTORILY. IN THE CASE OF HIGH-POWER TRANSMITTERS, HOWEVER, SOME REFINEMENTS ARE MADE IN THE CONSTRUCTION OF THE TUNING CONDENSERS AS WILL BE APPARANT FROM AN INSPECTION OF FIG. 15.

TO BEGIN WITH, REGULAR TRANSMITTING CONDENSERS ARE CONSTRUCTED WITH GREATER PRECISION THAN ARE THE CONVENTIONAL RECEIVER TYPE CONDENSERS. YOU WILL ALSO OBSERVE IN FIG. 15 THAT GREATER SPACING IS ALLOWED BETWEEN THE

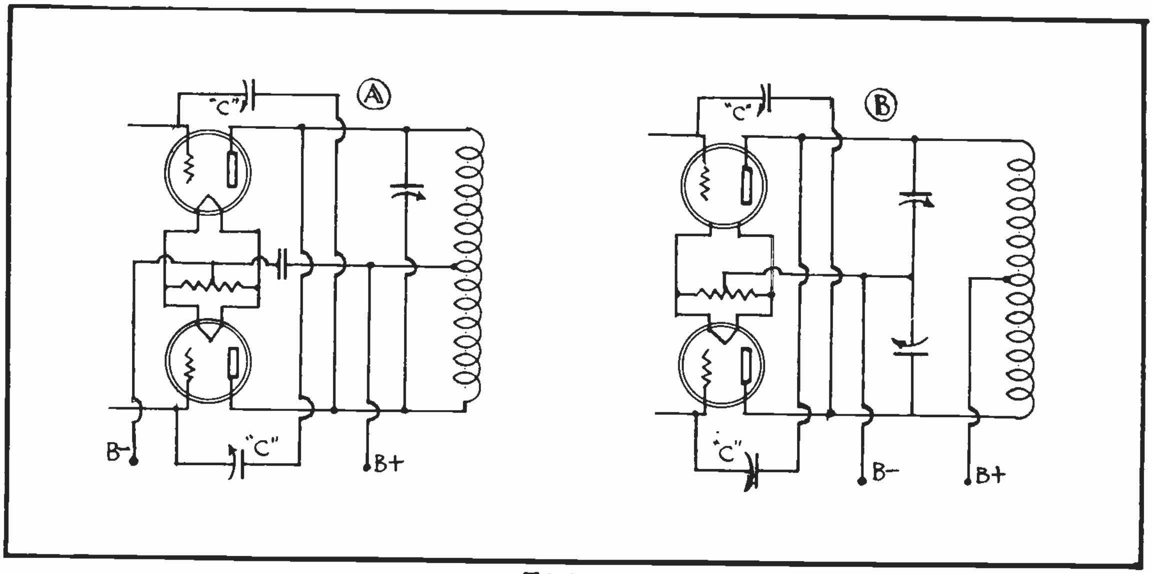

FIG. 13
Neutralization of Push-Pull Stages.

PLATES OF THE UNIT — THIS IS DONE SO THAT THERE WILL BE NO POSSIBILITY OF THE HIGH VOLTAGES ENCOUNTERED IN TRANSMITTERS FROM CAUSING ARCING BETWEEN THE PLATES.

THE FRAMES, AS WELL AS ALL PARTS OF THE TRANSMITTING CONDENSER, ARE CONSTRUCTED OF HEAVY MATERIAL SO THAT THE ENTIRE UNIT WILL BE ASSURED OF GREATER RIGIDITY AND FREEDOM FROM VIBRATION — ALL OF WHICH PLAY AN IMPORTANT PART IN MAKING A STEADY SIGNAL POSSIBLE. THE BEST OF INSULATION, SUCH AS ISOLANTITE, IS ALSO GENERALLY USED SO THAT THE UNIT MAY OPERATE AT UTMOST EFFICIENCY.

THE CONDENSER WHICH IS SHOWN IN THE UPPER PORTION OF FIG. 15 IS OF THE SPLIT-STATOR TYPE, SUCH AS USED IN SEVERAL OF THE CIRCUITS WHICH ARE ILLUSTRATED IN THIS LESSON. IN CONDENSERS OF THIS TYPE A SINGLE SHAFT HAS ALL OF THE ROTOR PLATES OF THE ENTIRE UNIT ATTACHED TO IT. THE STATOR PLATES, HOWEVER, ARE CONNECTED TOGETHER IN SUCH A MANNER AS TO FORM TWO SEPARATE GROUPS — EACH GROUP HAVING ITS OWN TERMINAL CONNECTION. IN

EFFECT, THIS ARRANGEMENT WOULD BE THE SAME AS TWO SECTIONS OF A RECEIVER

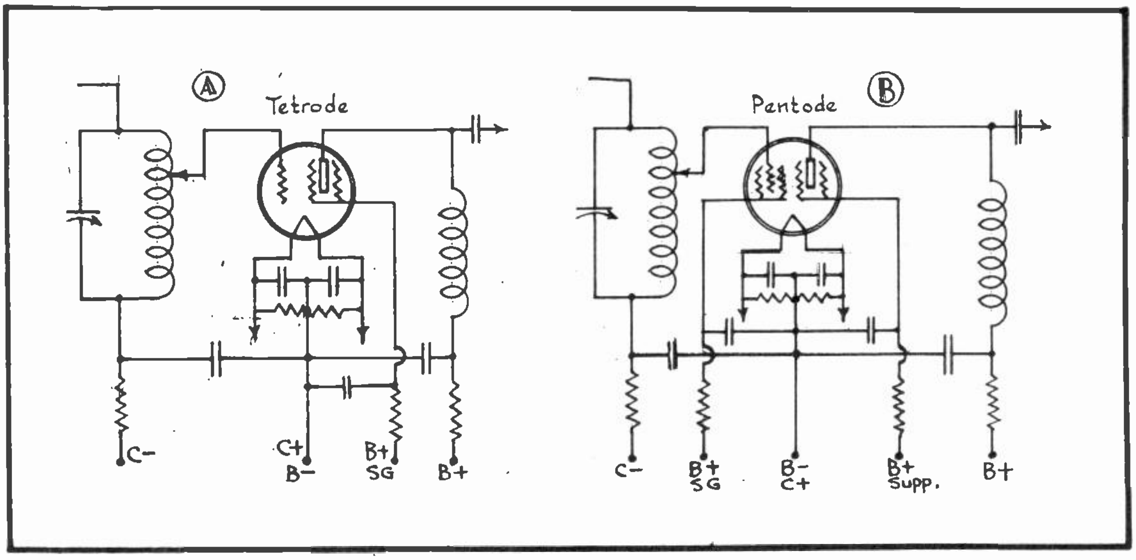

FIG. 14
Application of Screen Grid Amplifiers.

TYPE GANG CONDENSER CONNECTED IN SERIES.

BY USING A SPLIT STATOR CONDENSER IN A TRANSMITTER, THE ROTOR AND CONTROL SHAFT CAN AT ALL TIMES BE MAINTAINED AT GROUND POTENTIAL EVEN WHEN THE CONDENSER IS EMPLOYED IN THE PLATE CIRCUIT OF A TUBE. THIS IS CLEARLY ILLUSTRATED IN FIG. 10 OF THIS LESSON, WHERE YOU WILL FIND THE ROTOR PLATES OF THE SPLIT-STATOR CONDENSER CONNECTED TO THE ELECTRICAL CENTER OF THE FILAMENT CIRCUIT. THIS ARRANGEMENT ALSO ELIMINATES THE PROBABILITY OF R.F. BURNS THROUGH THE CONDENSER HANDLE AND AT THE SAME TIME GREATLY REDUCES HAND-CAPACITY EFFECTS.

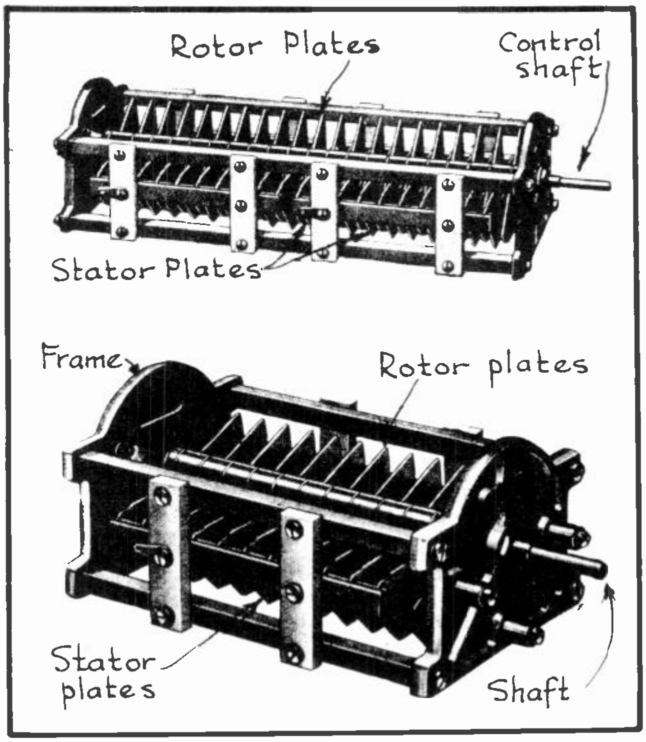

FIG. 15
Typical Transmitter Tuning Condensers.

IN THE NEXT LESSON YOU ARE GOING TO CONTINUE YOUR STUDIES OF R.F. AMPLIFIERS AS USED IN TRANSMITTERS BY LEARNING THE PROPER PROCEDURE, FOR TUNING SUCH AMPLIFIERS. YOU WILL ALSO FIND THIS NEXT LESSON TO FURNISH YOU WITH COMPLETE INSTRUCTIONS REGARDING FREQUENCY MULTIPLIERS, POWER AMPLIFIERS, ETC.

GRADUALLY, YOU ARE LEARNING MORE AND MORE ABOUT TRANSMITTERS AND WHEN YOU HAVE COMPLETED THIS SERIES OF LESSONS, YOU WILL HAVE A MOST THOROUGH KNOWLEDGE OF THIS SUBJECT.

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EXAMINATION QUESTIONS

LESSON NO. T-7

1. – EXPLAIN HOW THE SWINGING OF A TRANSMITTER ANTENNA MAY AFFECT AN OSCILLATOR NOT EMPLOYING CRYSTAL CONTROL AND WHICH IS COUPLED DIRECTLY TO THE ANTENNA SYSTEM. HOW MAY THIS TROUBLE BE REMEDIED?

2. – WHAT IS A "BUFFER AMPLIFIER"?

3. – WHY IN THE CIRCUIT OF FIG. 3 IS A "TAP CONNECTION" USED BETWEEN THE PLATE CIRCUIT OF THE OSCILLATOR AND THE GRID CIRCUIT OF THE BUFFER AMPLIFIER?

4. – DRAW A CIRCUIT DIAGRAM WHICH ILLUSTRATES HOW LINK COUPLING MAY BE USED BETWEEN TWO STAGES OF A TRANSMITTER.

5. – DRAW A CIRCUIT DIAGRAM SHOWING HOW A SPLIT-STATOR TUNING CONDENSER MAY BE USED IN A TRANSMITTER CIRCUIT.

6. – DESCRIBE THE CONSTRUCTIONAL FEATURES OF A SPLIT-STATOR CONDENSER AND EXPLAIN WHAT ADVANTAGES ARE OBTAINED THRU ITS USE.

7. – DRAW A CIRCUIT DIAGRAM WHICH ILLUSTRATES THE NEUTRALIZING SYSTEM OF A TRANSMITTER'S R.F. AMPLIFIER AND IN WHICH A SINGLE TRIODE IS EMPLOYED.

8. – EXPLAIN IN DETAIL HOW YOU WOULD GO ABOUT THE TASK OF NEUTRALIZING AN R.F. STAGE OF A TRANSMITTER.

9. – DRAW A CIRCUIT DIAGRAM OF A PUSH-PULL R.F. STAGE FOR A TRANSMITTER USING A PAIR OF TRIODES AND ALSO SHOW THE NEUTRALIZING CIRCUIT WHICH MAY BE EMPLOYED IN THIS CASE.

10. – EXPLAIN IN DETAIL THE OPERATION OF THE CIRCUIT WHICH IS ILLUSTRATED IN FIG. 9 OF THIS LESSON.

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LESSON NO. 8

TUNING AMPLIFIERS - APPLICATION OF FREQUENCY MULTIPLIERS

IN PREVIOUS LESSONS YOU WERE TOLD HOW TO GO ABOUT THE TASK OF TUNING THE OSCILLATOR OF A TRANSMITTER WHETHER IT BE OF THE SIMPLE SELF-TUNING TYPE OR CRYSTAL CONTROLLED AND NOW THAT YOU ARE FAMILIAR WITH THE APPLICATIONS OF R.F. AMPLIFIERS IN TRANSMITTERS, OUR NEXT STEP WILL BE TO GO INTO THE DETAILS CONCERNING THE PROCEDURE WHICH SHOULD BE FOLLOWED IN ORDER TO TUNE SUCH AMPLIFIERS CORRECTLY.

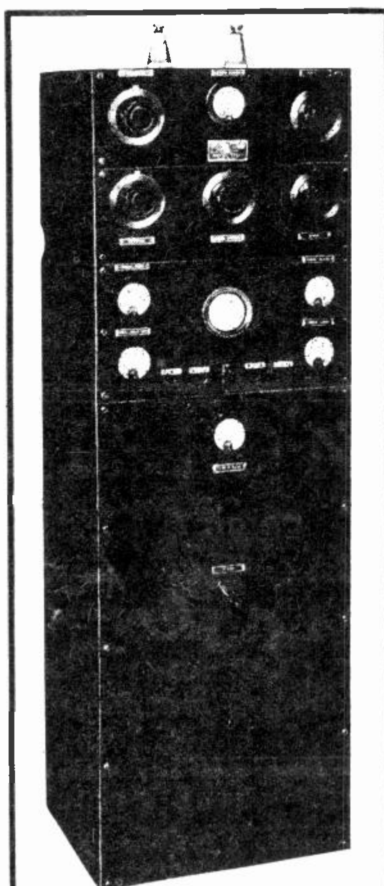

FIG.1
A 100-Watt Transmitter.

TUNING THE AMPLIFIER

BEFORE COMMENCING TO TUNE THE R.F. AMPLIFIER, IT IS NECESSARY THAT IT BE PROPERLY NEUTRALIZED, ASSUMING THAT TRIODES ARE BEING USED. SHOULD THE AMPLIFIER IN QUESTION EMPLOY TUBES OF THE SCREEN-GRID TYPE, THEN IT IS OF COURSE NECESSARY THAT THE CIRCUIT ARRANGEMENT BE SUCH THAT THERE IS NO POSSIBILITY OF FEEDBACK BETWEEN ITS OUTPUT AND INPUT CIRCUITS. WITH THESE CONDITIONS TAKEN CARE OF, WE PROCEED TO TUNE THE AMPLIFIER AS SHALL NOW BE EXPLAINED.

FIRST DISCONNECT THE PLATE VOLTAGE FROM THE AMPLIFIER, SET THE OSCILLATOR INTO OPERATION AND CAREFULLY ADJUST IT TO THE FREQUENCY AT WHICH THE TRANSMITTER IS TO OPERATE. THE CORRECT METHOD FOR ADJUSTING THE OSCILLATOR HAS ALREADY BEEN EXPLAINED IN PREVIOUS LESSONS.

WITH THE OSCILLATOR ADJUSTED FOR THE PROPER FREQUENCY, THE NEXT STEP IS TO MAKE FURTHER ADJUSTMENTS SO THAT MAXIMUM ENERGY WILL

BE TRANSFERRED FROM THE OSCILLATOR'S OUTPUT TO THE GRID CIRCUIT OF THE AMPLIFIER WHICH IT IS DRIVING. ONE METHOD OF DETERMINING THE EXITATION POWER WHICH IS BEING DELIVERED BY THE OSCILLATOR TO THE R.F. STAGE, OR FROM ANY DRIVER STAGE TO THE FOLLOWING STAGE FOR THAT MATTER, IS TO CONNECT A D.C. MILLIAMMETER IN SERIES WITH THE GRID RETURN CIRCUIT OF THE AMPLIFIER STAGE WHICH IS RECEIVING THIS EXITING ENERGY. WHEN EMPLOYING THIS METHOD, WE FIND THAT THE GREATER THE EXITATION ENERGY BEING RECEIVED BY THIS CIRCUIT, THE GREATER WILL BE THE RECTIFIED GRID CURRENT WHICH IS INDICATED BY THE METER.

THE EXACT MANNER IN WHICH SUCH A MILLIAMMETER IS TO BE CONNECTED IN THE GRID CIRCUIT OF THE AMPLIFIER WILL NATURALLY DEPEND UPON THE CIRCUIT ARRANGEMENT OF THE PARTICULAR AMPLIFIER IN QUESTION. IN FIGS. 2, 3 AND 4 YOU ARE SHOWN SOME TYPICAL CIRCUITS IN WHICH THE MILLIAMMETER CONNECTIONS ARE ILLUSTRATED IN ORDER TO MEASURE THE RECTIFIED GRID CURRENT IN THE AMPLIFIER STAGE. BY FAMILIARIZING YOURSELF THOROUGHLY WITH THESE CONNECTIONS IN PARTICULAR, YOU SHOULD HAVE NO DIFFICULTY IN APPLYING THE SAME METHOD TO ANY OTHER SIMILAR CIRCUIT WHICH MAY DIFFER IN CERTAIN RESPECTS. THE DRIVER STAGE IN ANY OF THESE CIRCUITS MAY BE EITHER AN OSCILLATOR OR ANOTHER STAGE OF R.F. AMPLIFICATION PRECEDING THE R.F. STAGE IN WHICH THE ADJUSTMENTS ARE AT THE TIME BEING MADE. NOTICE ALSO IN FIGS. 2, 3 AND 4 THAT THE POLARITY OF THE MILLIAMMETER IS INDICATED AND THE CIRCUIT CONNECTIONS SHOULD BE MADE ACCORDINGLY.

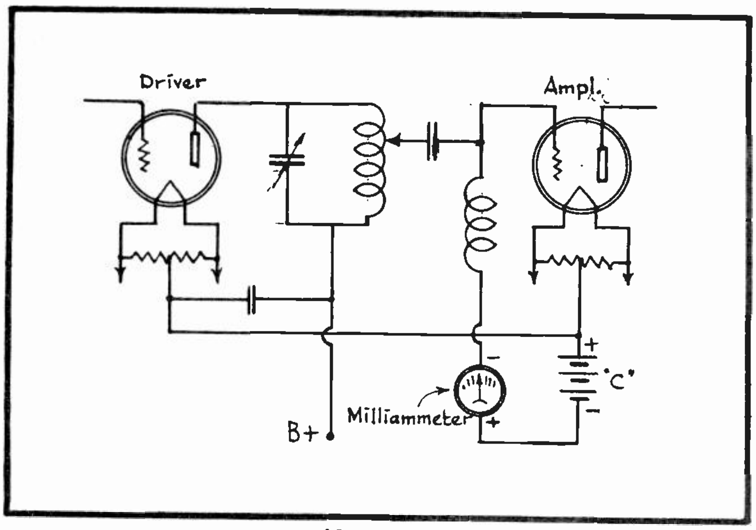

FIG. 2
Milliammeter Connection.

WITH THE MILLIAMMETER PROPERLY CONNECTED IN THE CIRCUIT, THE DRIVER STAGE TUNING CIRCUIT SHOULD BE ADJUSTED FOR MAXIMUM GRID CURRENT. THE COUPLING BETWEEN THE DRIVER STAGE AND THE AMPLIFIER SHOULD THEN ALSO BE ADJUSTED FOR MAXIMUM GRID CURRENT. IN THE EVENT THAT TRANSFORMER COUPLING IS EMPLOYED, THE COUPLING BETWEEN THE TWO STAGES CAN BE ADJUSTED BY VARYING THE DISTANCE AND ANGLE OF COUPLING OR BOTH BETWEEN THE PRIMARY AND SECONDARY WINDINGS OF THE TRANSFORMER.

IF THE CIRCUIT ARRANGEMENT IS SUCH THAT A TAP CONNECTION IS USED BETWEEN THE OUTPUT OF THE DRIVER TUBE AND THE INPUT OF THE AMPLIFIER AS IN FIGS. 2 AND 3, THEN THE POSITION OF THE TAP CONNECTION ON ITS COIL SHOULD BE ALTERED UNTIL MAXIMUM GRID CURRENT IS INDICATED IN THE AMPLIFIER CIRCUIT. SHOULD SUCH A TAP CONNECTION BE USED IN A PUSH-PULL ARRANGEMENT, THEN BOTH TAPS SHOULD BE CHANGED SIMULTANEOUSLY AND IN SUCH A MANNER SO THAT EACH TAP WILL BE THE SAME NUMBER OF TURNS FROM THE CENTER OF THE COIL.

WHEN LINK COUPLING IS USED, THE DEGREE OF COUPLING CAN BE CHANGED

BY MOVING THE TRANSMISSION LINE COUPLING COILS CLOSER TO THE TANK COILS WITH WHICH THEY ARE COUPLED OR ELSE TO CHANGE THE NUMBER OF TURNS USED ON THE COUPLING COILS.

WHENEVER, THE COUPLING IS CHANGED, REGARDLESS OF THE TYPE USED, THE DRIVER CIRCUIT SHOULD BE RETUNED TO RESONANCE BECAUSE ANY CHANGE IN THE DEGREE OF COUPLING IS LIKELY TO DETUNE THE PLATE TANK CIRCUIT OF THE DRIVER STAGE. IN THE EVENT THAT A TANK CIRCUIT (TUNING CIRCUIT) IS ALSO USED IN THE GRID CIRCUIT OF THE AMPLIFIER STAGE WHICH IS BEING ADJUSTED, AS IS THE CASE IN FIG. 4, FOR INSTANCE, THEN THIS CIRCUIT SHOULD ALSO BE RETUNED WHENEVER ANY CHANGES ARE MADE IN COUPLING SO THAT MAXIMUM GRID CURRENT WILL BE INDICATED BY THE MILLIAMMETER.

WITH THESE ADJUSTMENTS COMPLETED, THE PLATE TANK CIRCUIT OF THE AMPLIFIER SHOULD BE SET APPROXIMATELY AT RESONANCE AND WITH THE EXITING VOLTAGE AS SUPPLIED BY THE OUTPUT OF THE OSCILLATOR OR PRECEDING AMPLIFIER STAGE BEING APPLIED TO THE GRID CIRCUIT OF THE R.F. STAGE WHICH IS BEING ADJUSTED, YOU CAN PROCEED TO CONNECT THE PLATE VOLTAGE TO THE R.F. TUBE AND TUNE ITS PLATE TANK CIRCUIT TO RESONANCE. A CONDITION OF RESONANCE WILL BE INDICATED BY A PRONOUNCED DIP OF THE NEEDLE OF A D.C. MILLIAMMETER WHICH IS CONNECTED IN SERIES WITH THE PLATE CIRCUIT OF THE AMPLIFIER BEING ADJUSTED. THIS TUNING ADJUSTMENT FOR MINIMUM PLATE CURRENT SHOULD BE MADE QUICKLY BECAUSE IF THIS PLATE TANK CIRCUIT IS PERMITTED TO REMAIN FAR REMOVED FROM RESONANCE FOR AN APPRECIABLE LENGTH OF TIME WHILE THE PLATE CIRCUIT IS COMPLETE, THE RESULTING HIGH PLATE CURRENT MAY DAMAGE THE TUBE.

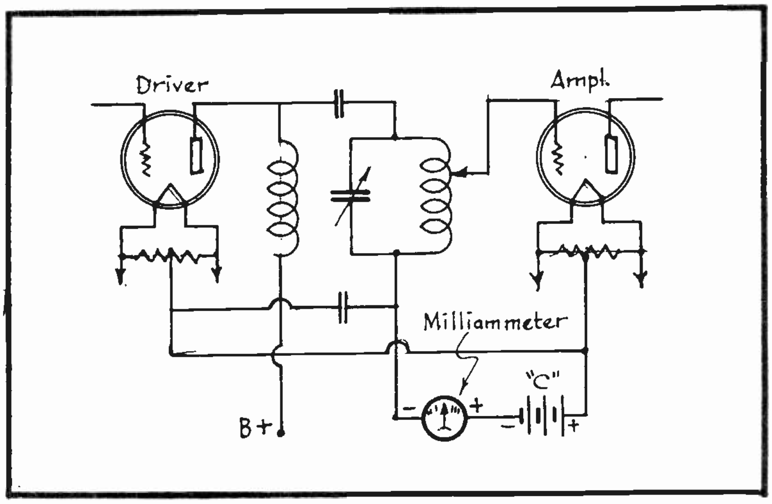

FIG. 3
Milliammeter Connection When Using Tuned-Grid Circuit.

AFTER THIS TANK CIRCUIT HAS BEEN TUNED FOR MINIMUM PLATE CURRENT, THE OUTPUT LOAD CIRCUIT MAY BE CONNECTED TO THE AMPLIFIER. THIS OUTPUT LOAD MAY BE THE GRID CIRCUIT OF A FOLLOWING STAGE OF R.F. AMPLIFICATION OR ELSE THE ANTENNA CIRCUIT, DEPENDING UPON THE PARTICULAR TRANSMITTER CIRCUIT IN QUESTION. UPON CONNECTING THE LOAD, THE PLATE CURRENT READING OF THE AMPLIFIER WILL INCREASE SOMEWHAT AND SINCE ITS TANK CIRCUIT MAY BE DETUNED SOMEWHAT AT THE TIME THE LOAD IS APPLIED, IT SHOULD BE AGAIN CAREFULLY ADJUSTED FOR MINIMUM PLATE CURRENT. THE MINIMUM PLATE CURRENT AT THIS TIME, HOWEVER, WILL NOT BE AS LOW AS THAT WHICH WAS OBTAINED BEFORE THE LOAD WAS CONNECTED. THE COUPLING AT THE OUTPUT END OF THIS AMPLIFIER STAGE SHOULD BE ADJUSTED SO THAT THE PLATE CURRENT DRAWN BY THE AMPLIFIER TUBE WILL BE NEAR THE NORMAL PLATE CURRENT VALUE FOR WHICH THE TUBE IS RATED.

IF ANOTHER AMPLIFIER STAGE FOLLOWS, ITS CIRCUIT SHOULD BE ADJUSTED IN THE SAME MANNER AS HAS JUST BEEN EXPLAINED. ON THE OTHER HAND, IF THE ANTENNA CIRCUIT IS FED BY THIS AMPLIFIER, THEN THE ANTENNA CIRCUIT SHOULD BE ADJUSTED AS DESCRIBED IN THE NEXT LESSON. YOU WILL ALSO BE SHOWN LATER IN THIS LESSON HOW DUMMY ANTENNAS ARE ARE SOMETIMES USED FOR THE PRELIMINARY TUNING OF AMPLIFIERS.

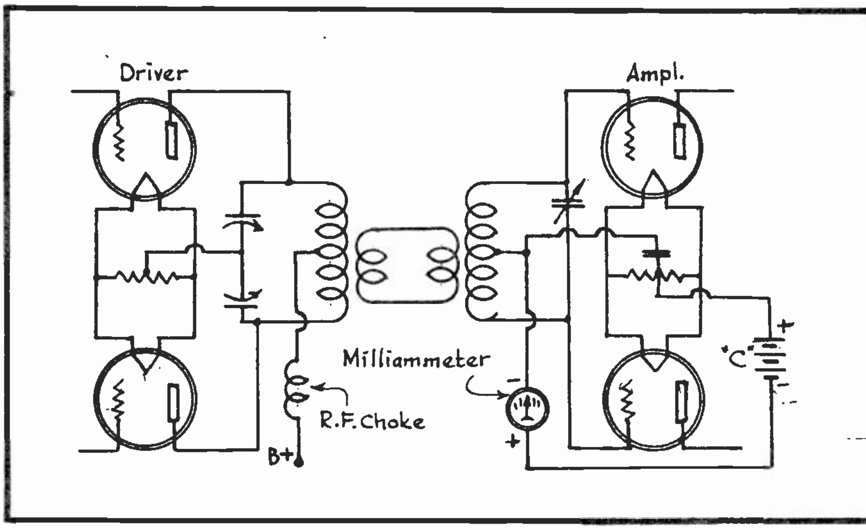

FIG. 4
Milliammeter Connections In Push-Pull Circuit.

FREQUENCY MULTIPLIERS

IN BROADCAST TRANSMITTERS, THE OPERATING FREQUENCY IS SUFFICIENTLY LOW SO THAT THE CRYSTAL AS USED IN ITS OSCILLATOR CIRCUIT CAN BE MADE THICK ENOUGH TO POSSESS THE REQUIRED MECHANICAL STRENGTH TO INSURE LONG LIFE. IN SUCH A CASE, IT IS PRACTICAL TO DESIGN ALL OF THE R.F. STAGES, AS WELL AS THE ANTENNA CIRCUIT, TO RESONATE AT THE SAME FREQUENCY AS THAT FOR WHICH THE OSCILLATOR IS TUNED AND WHICH IN TURN IS GOVERNED BY THE FREQUENCY FOR WHICH THE CRYSTAL HAS BEEN GROUND. HOWEVER, IN THOSE SHORT-WAVE TRANSMITTERS WHICH RADIATE THEIR ENERGY AT VERY HIGH FREQUENCIES (APPROXIMATELY 7 MEGACYCLES OR OVER), IT HAS BECOME THE COMMON PRACTICE TO OPERATE THE OSCILLATOR AT A RELATIVELY LOW FREQUENCY AND WITH WHICH A CRYSTAL OF SUFFICIENT THICKNESS TO INSURE STRENGTH CAN BE USED. THIS FUNDAMENTAL FREQUENCY AS GENERATED BY THE OSCILLATOR IS THEN DOUBLED

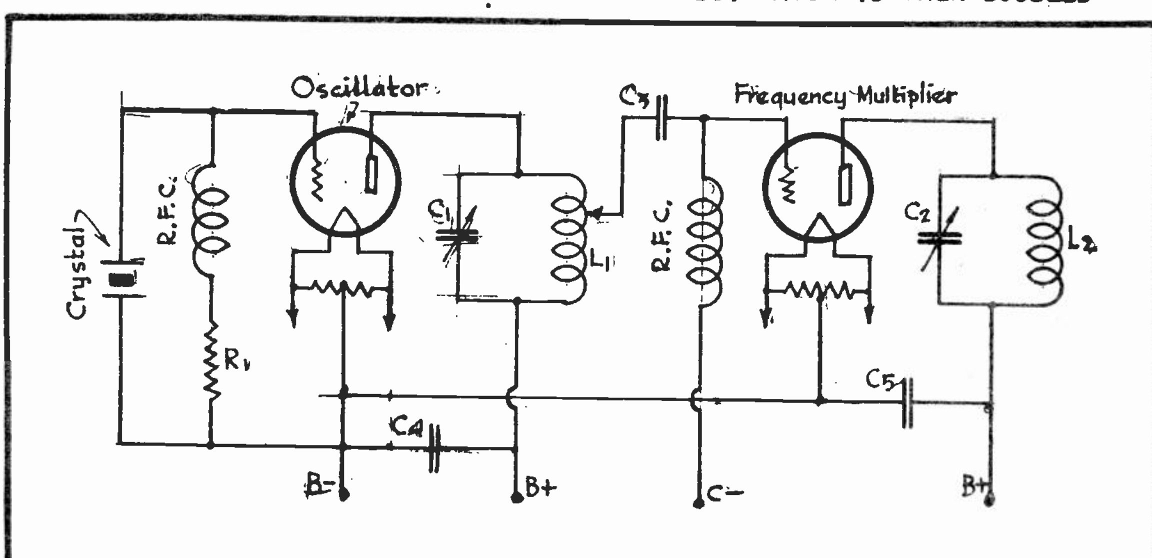

FIG. 5
Application of the Frequency Multiplier.

OR TRIPLED BY MEANS OF SPECIAL CIRCUITS WHICH ARE KNOWN AS FREQUENCY MULTIPLIERS OR "HARMONIC GENERATORS".

FIG. 5 SHOWS YOU A TYPICAL EXAMPLE OF HOW A FREQUENCY MULTIPLIER IS USED IN CONJUNCTION WITH A CRYSTAL CONTROLLED OSCILLATOR. FOR THE SAKE OF EXPLANATION, LET US ASSUME THAT THE CRYSTAL IS GROUND FOR A FREQUENCY OF 3500 KC. THE PLATE TANK CIRCUIT OF THIS OSCILLATOR, CONSISTING OF C_1 AND L_1, WILL IN THIS CASE ALSO BE TUNED TO RESONANCE AT 3500 KC. THIS OSCILLATOR FREQUENCY OF 3500 KC. WILL BE APPLIED ACROSS THE GRID CIRCUIT OF THE FREQUENCY MULTIPLIER TUBE THROUGH COUPLING CONDENSER C_3.

THE CIRCUITS EMPLOYED IN THE FREQUENCY MULTIPLIER STAGE ARE EXACTLY THE SAME AS THOSE OF A CONVENTIONAL AMPLIFIER AND THE ONLY REAL DIFFERENCE IS THAT THE TUBE IS BEING OPERATED AT A HIGHER NEGATIVE GRID BIAS VOLTAGE THAN ORDINARILY. UNDER THESE CONDITIONS, A RELATIVELY STRONG HARMONIC OUTPUT WILL APPEAR IN THE PLATE CIRCUIT OF THE FREQUENCY MULTIPLIER TUBE. THE SECOND HARMONIC WILL BE MOST PROMINENT AND IN OUR PARTICULAR EXAMPLE THIS WOULD BE EQUAL TO A FREQUENCY OF TWICE 3500 KC. OR 7000 KC. THE PLATE TANK CIRCUIT OF THIS FREQUENCY MULTIPLIER STAGE IS THEREFORE TUNED TO A FREQUENCY OF 7000 KC. SO THAT IT WILL RESONATE AT THE SECOND HARMONIC AND THEREBY BE CAPABLE OF TRANSFERRING MAXIMUM ENERGY AT THIS HARMONIC FREQUENCY TO THE FOLLOWING CIRCUIT.

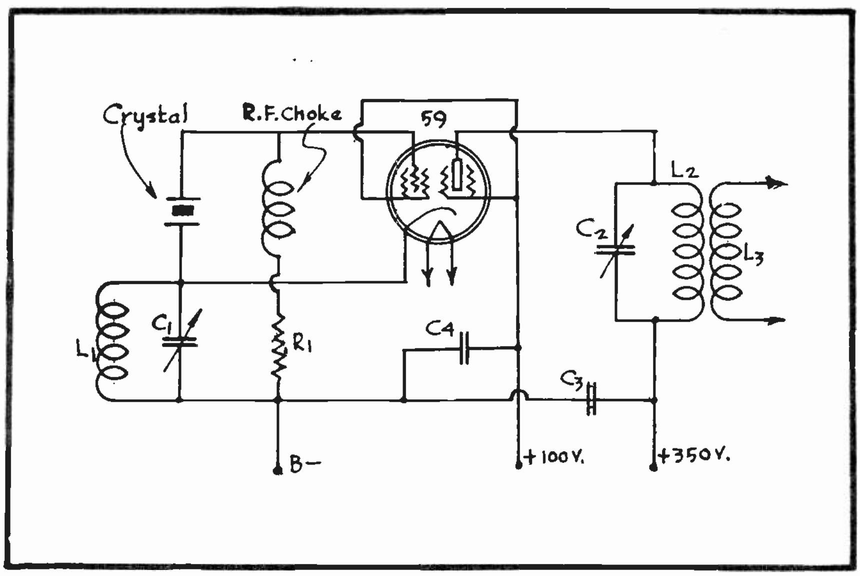

FIG.6
The Tri-Tet Circuit.

SINCE THE ORIGINAL FREQUENCY HAS IN THIS PARTICULAR CASE BEEN DOUBLED, THE FREQUENCY MULTIPLIER IN THIS INSTANCE WOULD BE LOGICALLY CALLED A FREQUENCY DOUBLER.

ALTHOUGH IT IS TRUE THAT A FREQUENCY MULTIPLIER CAN BE DESIGNED TO DELIVER A HARMONIC WHICH IS HIGHER THAN THE SECOND HARMONIC OF THE FREQUENCY APPLIED ACROSS ITS INPUT CIRCUIT, YET IT IS EQUALLY TRUE THAT THE PLATE EFFICIENCY OF A FREQUENCY MULTIPLIER IS APPRECIABLY LESS THAN THAT OF A STRAIGHT AMPLIFIER AND DECREASES RAPIDLY AS THE PLATE CIRCUIT IS TUNED TO A HARMONIC HIGHER THAN THE SECOND. IT IS FOR THIS REASON THAT MOST FREQUENCY MULTIPLIERS ARE DESIGNED TO FUNCTION AS DOUBLERS. SOMETIMES, HOWEVER, ANOTHER DOUBLER FOLLOWS THE FIRST SO THAT THE FREQUENCY CAN BE DOUBLED ONCE MORE AND THUS BECOME FOUR TIMES THAT OF THE ORIGINAL OSCILLATOR OR FUNDAMENTAL FREQUENCY.

GRID BIAS FOR AMPLIFIERS

IN ORDER TO REALIZE GOOD PLATE EFFICIENCY FROM A POWER AMPLIFIER

TUBE, IT IS NECESSARY THAT THE GRID BIAS VOLTAGE UNDER OPERATING CONDITIONS BE GREATER THAN THAT WHICH IS ACTUALLY REQUIRED IN ORDER TO "CUT-OFF" THE PLATE CURRENT WHEN THE AMPLIFIER IS NOT RECEIVING ANY EXITING R.F. ENERGY. A STRAIGHT AMPLIFIER TUBE SHOULD BE OPERATED WITH A BIAS VOLTAGE WHICH IS EQUAL TO APPROXIMATELY TWICE THE "CUT-OFF" BIAS FOR THE TUBE BEING USED. THE CUT-OFF BIAS FOR A GIVEN TUBE IS GENERALLY GIVEN IN THE SPECIFICATIONS WHICH ARE ISSUED BY THE TUBE MANUFACTURER BUT IN THE CASE OF TRIODES IS APPROXIMATELY EQUAL TO THE PLATE VOLTAGE AT WHICH THE TUBE IS BEING OPERATED DIVIDED BY ITS AMPLIFICATION FACTOR. IN THE CASE OF A FREQUENCY MULTIPLIER, THIS TUBE SHOULD BE OPERATED WITH A GRID BIAS VOLTAGE CONSIDERABLY ABOVE DOUBLE CUT-OFF AND EXITED WITH A CORRESPONDINGLY GREATER R.F. VOLTAGE — IN FACT, THE DRIVING POWER REQUIRED FOR GOOD DOUBLING EFFICIENCY IS ABOUT TWO OR THREE TIMES THAT WHICH IS NECESSARY FOR EFFICIENT STRAIGHT AMPLIFICATION.

THERE ARE SEVERAL METHODS WHEREBY THE BIAS VOLTAGE MAY BE OBTAINED FOR THE R.F. AMPLIFIER IN A TRANSMITTER. ONE METHOD IS TO USE BATTERIES AS A "C" SUPPLY AND IN SUCH CASES A BANK OF REGULAR "B" BATTERIES ARE USED, ONLY THAT THEY ARE EMPLOYED IN THE CIRCUIT AS "C" BATTERIES. ALTHOUGH BATTERIES PROVIDE A RELATIVELY CONSTANT BIAS VOLTAGE REGARDLESS OF WHETHER THE AMPLIFIER IS BEING EXITED OR NOT, YET THE GRID CURRENT WHICH FLOWS WHEN THE TRANSMITTER IS IN OPERATION HAS A CHARGING EFFECT AND IN THIS MANNER TENDS TO INCREASE THE BATTERY VOLTAGE. THIS EFFECT IS MORE NOTICEABLE AS THE BATTERIES AGE AND THEIR INTERNAL RESISTANCE INCREASES.

ANOTHER METHOD OF OBTAINING A GRID BIAS VOLTAGE IS TO USE THE GRID LEAK METHOD AS HAS ALREADY BEEN EXPLAINED RELATIVE TO OSCILLATORS. THIS METHOD IS BOTH ECONOMICAL AS REGARDS THE SAVING IN COST OF BATTERIES AND IN ADDITION OFFERS THE DESIRABLE FEATURE OF REGULATING THE BIAS VOLTAGE IN ACCORDANCE WITH THE AMOUNT OF EXITING ENERGY AVAILABLE AND IN THIS WAY MOST EFFICIENT AMPLIFIER OPERATION IS REALIZED UNDER VARYING CONDITIONS OF OPERATION. THIS SAME METHOD ALSO OFFERS A DISADVANTAGE, HOWEVER, IN THAT IN CASE EXITATION SHOULD CEASE FOR SOME REASON OR OTHER, NO BIAS VOLTAGE WILL BE PRODUCED AND THE RESULTING INCREASE IN PLATE CURRENT MAY DAMAGE THE TUBE.

QUITE OFTEN, A COMBINATION OF GRID LEAK AND BATTERY BIAS IS USED AND IN WHICH CASE SUFFICIENT BATTERY VOLTAGE IS EMPLOYED TO SAFEGUARD THE TUBE IN CASE OF A LACK OF EXITATION AND THE ADDITIONAL BIAS VOLTAGE IS FURNISHED BY THE LEAK. UNDER SUCH CONDITIONS, THE BATTERY VOLTAGE AND THE VOLTAGE DROP PRODUCED ACROSS THE LEAK RESISTOR BY THE FLOW OF GRID CURRENT ARE EFFECTIVELY CONNECTED IN SERIES, THEREFORE, THE ACTUAL OR EFFECTIVE BIAS VOLTAGE WILL BE EQUAL TO THE SUM OF THE BATTERY VOLTAGE PLUS THE VOLT DROP ACROSS THE LEAK RESISTOR.

THE BIAS VOLTAGE MAY ALSO BE OBTAINED FROM THE TRANSMITTER'S POWER PACK OR ELSE FROM A BIAS RESISTOR WHICH IS INCLUDED IN THE CATHODE CIRCUIT OF THE TUBE THE SAME AS IN RECEIVERS. CIRCUIT DIAGRAMS WHICH ARE YET TO BE SHOWN YOU WILL ILLUSTRATE THESE DIFFERENT BIASING METHODS CLEARLY.

TUNING FREQUENCY MULTIPLIERS

IN THE TUNING OF FREQUENCY MULTIPLIERS, THE GENERAL PROCEDURE IS

MUCH THE SAME AS THAT OF TUNING STRAIGHT AMPLIFIERS AND IS DONE IN THE FOLLOWING MANNER:

FIRST THE PLATE VOLTAGE SOURCE IS DISCONNECTED FROM THE FREQUENCY MULTIPLIER TUBE AND THE GRID CIRCUIT IS THEN ADJUSTED FOR MAXIMUM GRID CURRENT IN THE SAME WAY AS ALREADY DESCRIBED RELATIVE TO STRAIGHT AMPLIFIERS. THE PLATE VOLTAGE IS THEN APPLIED TO THIS TUBE AND THE PLATE TANK CIRCUIT IS ADJUSTED SO AS TO RESONATE AT THE SECOND HARMONIC FREQUENCY AND WHICH IS INDICATED BY THE DIP IN PLATE CURRENT THE SAME AS WHEN TUNING A STRAIGHT AMPLIFIER TO RESONANCE WITH THE FUNDAMENTAL. IN THE CASE OF THE FREQUENCY MULTIPLIER, HOWEVER, THIS DIP IS NOT QUITE SO PRONOUNCED AS WHEN TUNING A STRAIGHT AMPLIFIER.

WITH THESE ADJUSTMENTS PROPERLY MADE, THE LOAD MAY BE CONNECTED AND THE OUTPUT COUPLING AND LOAD CIRCUITS ADJUSTED FOR MAXIMUM OUTPUT, IN KEEPING WITH THE PLATE CURRENT RATING OF THE TUBE. GENERALLY, IT IS ADVISABLE THAT THIS PLATE CURRENT BE SLIGHTLY LOWER THAN THAT FOR WHICH THE TUBE IS RATED, ESPECIALLY IF THE PLATE OF THE TUBE HAS A TENDENCY TO BECOME RED — THIS IS DUE TO THE INEFFICIENCY AT WHICH A FREQUENCY MULTIPLIER TUBE OPERATES. WITH ALL OF THESE ADJUSTMENTS TAKEN CARE OF, A LITTLE EXPERIMENTING CAN BE DONE AS REGARDS VARYING THE BIAS VOLTAGE OF THE FREQUENCY MULTIPLIER TUBE UNTIL MAXIMUM OUTPUT IS OBTAINED.

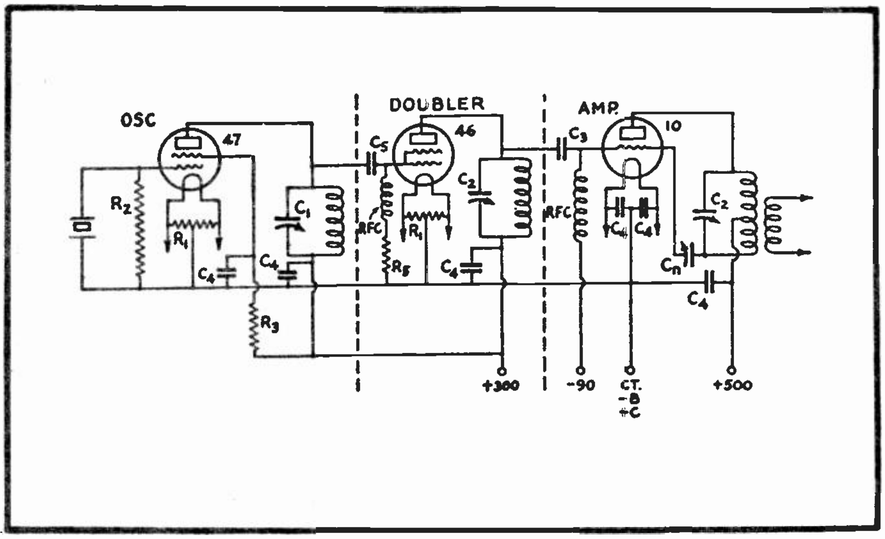

FIG. 7
Low-Power Three-Tube Transmitter.

THE TRI-TET PRINCIPLE

IN FIG. 6 YOU ARE SHOWN A CIRCUIT DIAGRAM WHICH IS SO ARRANGED THAT A SINGLE TUBE CAN FUNCTION SIMULTANEOUSLY AS A CRYSTAL CONTROLLED OSCILLATOR AND AS A STRAIGHT AMPLIFIER OR A FREQUENCY MULTIPLIER. AS SUCH, THE TRANSMITTER CAN BE OPERATED AT TWO DIFFERENT FREQUENCIES EVEN THOUGH ONLY A SINGLE CRYSTAL IS EMPLOYED. THE TUBE USED IN THIS PARTICULAR CASE IS A TYPE 59 RECEIVER POWER TUBE, HOWEVER, THE SAME PRINCIPLE CAN ALSO BE EMPLOYED WITH SOME REGULAR TRANSMITTING TYPE TUBES SO THAT GREATER POWER OUTPUTS CAN BE REALIZED.

HERE THE CRYSTAL, R.F. CHOKE, AND LEAK RESISTOR R_1 ARE CONNECTED ACROSS THE GRID CIRCUIT OF THE TUBE WHILE THE TUNING CIRCUIT CONSISTING OF L_1 AND C_1 ARE CONNECTED IN THE CATHODE CIRCUIT OF THE SAME TUBE. THE

VALUES OF L_1 AND C_1 ARE SO CHOSEN THAT THIS CIRCUIT WILL RESONATE AT THE FREQUENCY OF THE CRYSTAL.

THE TUNING CIRCUIT CONSISTING OF L_2 AND C_2 IS INSTALLED IN THE PLATE CIRCUIT OF THE SAME TUBE AND ITS VALUES ARE SO CHOSEN THAT THIS CIRCUIT WILL ALSO BE TUNED TO RESONANCE WITH THE CRYSTAL FREQUENCY. UNDER THESE CONDITIONS, THIS PORTION OF THE CIRCUIT WILL FUNCTION AS A STRAIGHT AMPLIFIER.

IN ORDER TO FURNISH AN OUTPUT FREQUENCY OF TWICE THAT OF THE CRYSTAL, IT IS ONLY NECESSARY TO CHANGE THE VALUES OF L_2 AND C_2 SO THAT THIS TUNING CIRCUIT WILL RESONATE AT THE SECOND HARMONIC OF THE FUNDAMENTAL. THE TRANSMITTER WILL THEREFORE FUNCTION AS A "TRI-TET".

COMPLETE TRANSMITTER CIRCUITS

SO FAR, WE HAVE ONLY CONSIDERED THE INDIVIDUAL SECTIONS OF MULTI-TUBE TRANSMITTERS, THEREFORE, THE NEXT STEP FOR US TO TAKE IS TO LOOK AT SOME TYPICAL TRANSMITTER CIRCUITS AS A WHOLE AND IN WHICH THESE DIFFERENT SECTIONS HAVE ALL BEEN COMBINED TO FORM A COMPLETE TRANSMITTER UNIT. THE POWER PACKS AND KEY CIRCUITS ARE NOT BEING CONSIDERED AT THE PRESENT TIME, SINCE THEY ARE FULLY EXPLAINED IN LATER LESSONS.

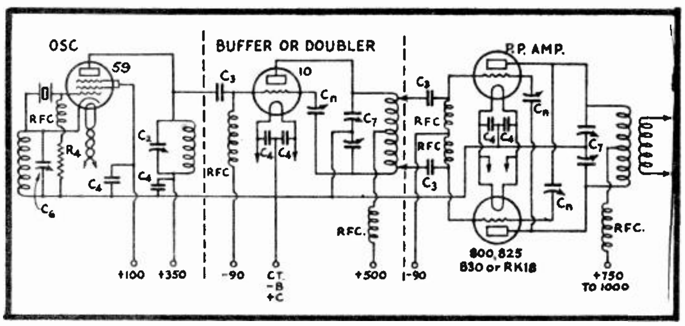

FIG. 8
Transmitter With Push-Pull Power Amplifier.

IN FIG. 7, FOR INSTANCE, YOU ARE SHOWN THE CIRCUIT DIAGRAM OF A TRANSMITTER IN WHICH THREE TUBES ARE EMPLOYED. THIS IS A TRANSMITTER OF COMPARATIVELY LOW POWER OUTPUT AND CALLS FOR A POWER PACK WHICH OFFERS A MAXIMUM "B" VOLTAGE OF ONLY 500 VOLTS. THE TUBES USED IN THIS TRANSMITTER, YOU WILL OBSERVE, ARE A TYPE 47 AS A CRYSTAL CONTROLLED OSCILLATOR, A 46 AS A FREQUENCY DOUBLER AND BUFFER AND A TYPE 10 AS THE FINAL AMPLIFIER.

WHEN WORKING "STRAIGHT", THE TUNING CIRCUITS OF ALL THREE TUBES ARE TUNED TO THE SAME FREQUENCY, THAT IS, TO THE FREQUENCY OF THE CRYSTAL. WHEN "DOUBLING", THE TUNING CIRCUIT OF THE OSCILLATOR IS STILL TUNED TO RESONANCE WITH THE CRYSTAL FREQUENCY BUT THE TUNING CIRCUITS OF THE DOUBLER AND AMPLIFIER ARE BOTH TUNED TO RESONANCE WITH THE SECOND HARMONIC OF THE OSCILLATOR FREQUENCY.

A STILL DIFFERENT CIRCUIT DESIGN APPEARS IN FIG. 8. HERE A TYPE 59 TUBE IS USED IN A TRI-TET OSCILLATOR CIRCUIT AND WHICH IS FOLLOWED BY A BUFFER OR DOUBLER STAGE IN WHICH A TYPE 10 TUBE IS EMPLOYED. THE POWER AMPLIFIER CONTAINS TWO TUBES CONNECTED IN PUSH-PULL AND WHICH MAY BE OF THE TYPE 800, 825, 830 OR RK18 TRANSMITTER TUBES. EACH OF THESE FOUR TUBE TYPES HAS A POWER OUTPUT RATING OF 50 WATTS AND THEREFORE AN ARRANGEMENT AS THIS WILL PROVIDE A TRANSMITTER OF HIGHER POWER OUTPUT THAN WILL THE CIRCUIT OF FIG. 7.

WHEN THE TRANSMITTER OF FIG. 8 IS OPERATED "STRAIGHT", ALL TUNING

CIRCUITS ARE TUNED TO RESONANCE WITH THE CRYSTAL FREQUENCY BUT WHEN "DOUBLING", THE PLATE CIRCUIT OF THE OSCILLATOR, DOUBLER TUBE AND FINAL AMPLIFIER STAGE ARE ALL TUNED TO THE SECOND HARMONIC OF THE CRYSTAL FREQUENCY.

IN FIG. 9 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF A TRANSMITTER IN WHICH A 47 TUBE IS USED IN THE CRYSTAL CONTROLLED OSCILLATOR CIRCUIT, A 50 WATT 800, 825, 830 OR RK18 IN THE BUFFER OR DOUBLER STAGE AND A 100 WATT 860 TUBE IN THE FINAL STAGE. THIS TRANSMITTER CAN BE OPERATED ON THREE DIFFERENT FREQUENCIES AND USING BUT A SINGLE CRYSTAL BY CARRYING OUT THE FOLLOWING PLAN:

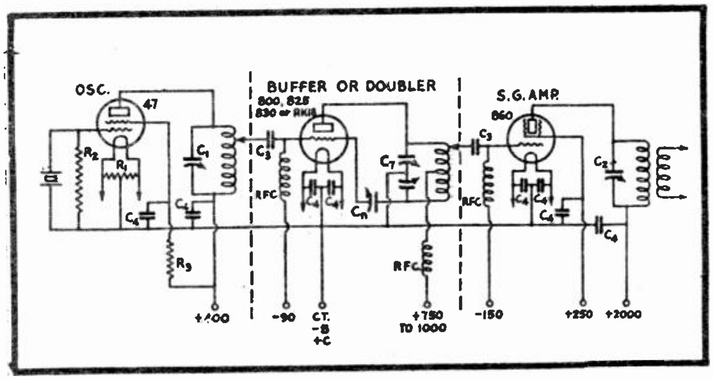

FIG. 9
Application of Screen Grid Tube as Final Amplifier.

WHEN OPERATED STRAIGHT, ALL TUNING CIRCUITS ARE TUNED TO THE FREQUENCY OF THE CRYSTAL. FOR THE SECOND BAND, THE FIRST AMPLIFIER STAGE CAN BE OPERATED AS A DOUBLER BY BEING TUNED TO THE SECOND HARMONIC AND IN WHICH CASE THE FINAL STAGE WOULD ALSO BE TUNED TO THE SECOND HARMONIC. FOR OPERATING ON THE THIRD BAND, THE FINAL AMPLIFIER STAGE IS ALSO OPERATED AS A DOUBLER SO THAT IT WILL AMPLIFY THE SECOND HARMONIC AS APPLIED TO ITS INPUT CIRCUIT FROM THE PRECEDING DOUBLER STAGE.

THE VALUES FOR THE DIFFERENT PARTS WHICH ARE USED IN THE CIRCUITS ILLUSTRATED IN FIGS. 7, 8 AND 9 ARE LISTED FOR YOU IN TABLE I.

TABLE I

C_1 = .00025 MFD. VARIABLE CONDENSER
C_2 = .0001 MFD. VARIABLE CONDENSER
C_3 = .0001 MFD. FIXED MICA CONDENSER
C_4 = .002 MFD. FIXED MICA CONDENSER
C_5 = .00005 MFD. FIXED MICA CONDENSER
C_6 = .00035 MFD. VARIABLE CONDENSER
C_7 = .0001 MFD. SPLIT-STATOR CONDENSER (BOTH SECTIONS IN SERIES).
C_n = NEUTRALIZING CONDENSER WHOSE CAPACITY AT MID-POSITION IS APPROXIMATELY EQUAL TO THE GRID-PLATE CAPACITY OF THE TUBE WITH WHICH IT IS BEING USED.
R_1 = 20 OHMS, CENTER-TAPPED.
R_2 = 10,000 OHMS
R_3 = 50,000 OHMS
R_4 = 100,000 OHMS
R_5 = 5000 OHMS.

DETAILED SPECIFICATIONS REGARDING THE TUNED COILS APPEAR IN A LATER LESSON.

DUMMY ANTENNAS

While preliminary adjustments are being made on a transmitter, it is advisable to use a DUMMY ANTENNA instead of the regular radiating antenna. In this way, the transmitter will not produce any interference while it is being adjusted.

A variety of dummy antenna circuits are available and in Fig. 10 you are shown three of them. For instance, at "A" of Fig. 10 you are shown a dummy antenna circuit which consists of the coil L and the variable condenser C which are connected in series with a resistor and a radio frequency ammeter. This constitutes a tuning circuit and whose constants are so chosen that this circuit can be tuned to the same frequency as furnished by the output of the transmitter. Therefore, if this dummy antenna circuit is coupled to the output tank circuit of the transmitter, it will

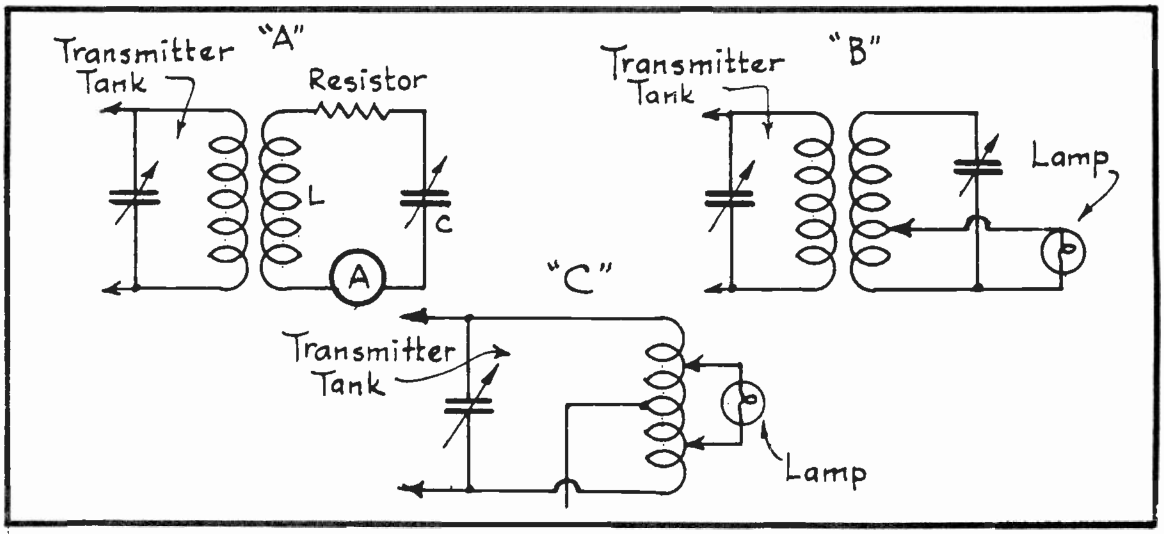

FIG. 10
Typical Dummy Antenna Circuits.

serve as a load in which the output energy of the transmitter can be dissipated just as though a regular antenna were used only that no appreciable radiation of this energy will occur. The value of this resistor is so chosen that the power which is dissipated by it is approximately equivalent to the output power of the transmitter in question.

If the resistor thus used is of the non-inductive type and its resistance value known, then by observing the current flow indicated by the radio frequency ammeter, the approximate power output can be determined by applying the formula $W = I^2R$. However, at high frequencies, the skin-effect becomes a most noticeable factor and for this reason the output power when measured in this manner is not altogether accurate.

Incandescent lamps are also used considerably in dummy antenna systems, and illustrations "B" and "C" of Fig. 10 illustrate this method. When using lamps in this manner, a lamp should be chosen whose watt rating is approximately the same as the power output of the transmitter, for in this way the lamp will be permitted to operate at about its normal brilliancy when the system is in operation.

A PAIR OF LEADS ARE USED WITH WHICH TO CONNECT THE LAMP EITHER TO THE TUNED ABSORPTION CIRCUIT AS AT "B" OF FIG. 10 OR DIRECTLY TO THE TRANSMITTER TANK AS AT "C". THE NUMBER OF COIL TURNS ACROSS WHICH THE LAMP IS TO BE CONNECTED SHOULD BE VARIED, AS SHOULD ALSO THE TUNING OF THE DUMMY ANTENNA CIRCUIT AND ITS COUPLING WITH THE TRANSMITTER, UNTIL THE GREATEST OUTPUT IS OBTAINED FOR A GIVEN PLATE INPUT. THIS GREATEST OUTPUT IS INDICATED BY THE MAXIMUM BRILLIANCE AT WHICH THE LAMP LIGHTS.

IN THE NEXT LESSON, YOU ARE GOING TO BE TOLD ABOUT THE DIFFERENT TYPES OF ANTENNA SYSTEMS WHICH ARE BEING USED IN CONJUNCTION WITH MODERN TRANSMITTERS. YOU WILL ALSO HAVE THE OPPORTUNITY AT THIS TIME OF BECOMING ACQUAINTED WITH THE FORMULAS FOR DESIGNING SUCH ANTENNA SYSTEMS, THE VARIOUS METHODS OF COUPLING THE ANTENNA SYSTEMS TO TRANSMITTERS AND THE CORRECT PROCEDURE FOR ADJUSTING THESE CIRCUITS SO THAT THE MAXIMUM SIGNAL ENERGY AS SUPPLIED AT THE OUTPUT OF THE TRANSMITTER CAN BE RADIATED INTO SPACE.

NO DOUBT YOU REALIZE BY THIS TIME THAT THE SAME SYSTEMATIC METHOD IS BEING EMPLOYED IN PRESENTING THE SUBJECT OF TRANSMITTERS TO YOU AS HAS BEEN USED THROUGHOUT THE ENTIRE PERIOD OF YOUR TRAINING UP TO THE PRESENT TIME. THIS PREVENTS EVEN THE SLIGHTEST DETAILS FROM PASSING YOU BY UNOTICED AND MAKES YOUR STUDIES MOST COMPLETE AS WELL AS UNDERSTANDABLE.

BY ACQUIRING A THOROUGH KNOWLEDGE OF ALL THE BASIC TRANSMITTER SYSTEMS AS THEY ARE NOW BEING BROUGHT TO YOU, YOU WILL FIND THE MORE COMPLEX TRANSMITTER CIRCUITS AS INCLUDED IN THE MORE ADVANCED LESSONS OF THIS SERIES TO BE READILY MASTERED. ALSO REMEMBER THAT EVEN THOUGH NOTHING AS YET HAS BEEN MENTIONED REGARDING RADIO-TELEPHONE OR BROADCAST TRANSMITTERS, YET ALL OF THE INFORMATION WHICH IS BEING GIVEN YOU NOW APPLIES EQUALLY WELL TO EVERY TYPE OF TRANSMITTER IN USE.

Ans Jan 21, 1942

Examination Questions

LESSON NO. T - 8

Every man who believes in himself, no matter who he be, stands on a higher level than the wobbler.

1. – EXPLAIN IN DETAIL HOW YOU WOULD PROCEED TO TUNE AN R.F. AMPLIFIER STAGE OF A TRANSMITTER.

2. – MAKE A DIAGRAM WHICH ILLUSTRATES HOW YOU CAN DETERMINE BY MEANS OF A D.C. MILLIAMMETER THE DEGREE OF EXITATION WHICH IS BEING DELIVERED TO THE GRID CIRCUIT OF AN R.F. AMPLIFIER IN A TRANSMITTER.

3. – DESCRIBE THE DIFFERENT METHODS WHEREBY THE COUPLING BETWEEN THE DIFFERENT STAGES OF A TRANSMITTER MAY BE VARIED.

4. – WHY IS IT SO IMPORTANT THAT THE PLATE TANK CIRCUIT OF AN AMPLIFIER IN A TRANSMITTER BE TUNED APPROXIMATELY TO RESONANCE BEFORE APPLYING THE PLATE VOLTAGE TO THE TUBE WHICH IS USED IN THIS STAGE?

5. – WHAT IS A FREQUENCY MULTIPLIER OR HARMONIC GENERATOR AS USED IN TRANSMITTERS?

6. – EXPLAIN IN DETAIL HOW YOU WOULD PROCEED TO TUNE A FREQUENCY-DOUBLER STAGE IN A TRANSMITTER, ASSUMING THAT THE INPUT FREQUENCY FOR THIS SAME STAGE IS 4000 Kc.

7. – DESCRIBE THE DIFFERENT METHODS WHICH MAY BE USED TO FURNISH THE GRID BIAS VOLTAGE FOR THE R.F. AMPLIFIER TUBES OF A TRANSMITTER.

8. – WHAT ARE THE ESSENTIAL DIFFERENCES IN THE DESIGN OF A STRAIGHT R.F. AMPLIFIER AND A FREQUENCY MULTIPLIER?

9. – DRAW A DIAGRAM OF A "TRI-TET" CIRCUIT AND EXPLAIN HOW IT OPERATES AND ALSO HOW YOU WOULD ADJUST IT SO THAT ITS OUTPUT FREQUENCY WILL BE TWICE THE FREQUENCY FOR WHICH THE CRYSTAL IS GROUND.

10. – DRAW A CIRCUIT DIAGRAM OF A PRACTICAL DUMMY ANTENNA; EXPLAIN THE REASON FOR ITS USE AND ALSO THE METHOD OF USING IT IN ACTUAL PRACTICE.

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RADIO - TELEVISION

Practical Training

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Established 1905

Los Angeles, California

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Transmitters

LESSON NO. 9

TRANSMITTING ANTENNAS

THE ANTENNA IS A MOST IMPORTANT PART OF THE TRANSMITTING EQUIPMENT AND MUST BE CORRECTLY DESIGNED AND CONSTRUCTED IN ORDER FOR THE TRANSMITTER TO PERFORM AT ITS BEST. IT IS THEREFORE ESSENTIAL THAT YOU BE THOROUGHLY INFORMED OF ALL THE DIFFERENT ANTENNA SYSTEMS OF STANDARD DESIGN WHICH ARE USED IN PRACTICE AND THE METHOD OF CORRECTLY ADJUSTING THEM FOR MAXIMUM EFFICIENCY.

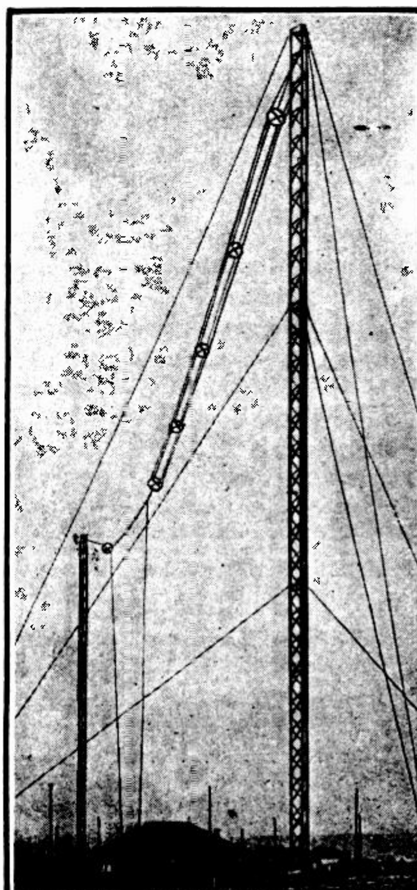

FIG. 1
Antenna of a High-Power Short-Wave Station.

THERE ARE TWO BASIC TYPES OF ANTENNAS WHICH ARE USED WITH TRANSMITTERS AND THEY ARE KNOWN AS THE MARCONI ANTENNA AND THE HERTZ ANTENNA. THOSE ANTENNAS WHICH EMPLOY THE GROUND AS A PART OF THE SYSTEM ARE CLASSIFIED AS MARCONI ANTENNAS, WHEREAS THOSE ANTENNAS WHICH OPERATE ENTIRELY INDEPENDENTLY OF THE GROUND ARE CLASSIFIED AS HERTZ ANTENNAS.

MARCONI ANTENNA SYSTEMS

IN FIG. 2 YOU ARE SHOWN THE THREE FUNDAMENTAL FORMS IN WHICH THE MARCONI ANTENNA SYSTEMS ARE CONSTRUCTED. AT THE LEFT OF FIG. 2, FOR INSTANCE, YOU ARE SHOWN THE VERTICAL TYPE MARCONI ANTENNA AND IN WHICH CASE THE RADIATING PORTION OF THE ANTENNA WIRE IS SUSPENDED VERTICALLY — ONE OF ITS ENDS BEING INSULATED AND THE OTHER END BEING GROUNDED THROUGH THE ANTENNA CIRCUIT OF THE TRANSMITTER. AN INVERTED "L" TRANSMITTER ANTENNA APPEARS AT THE CENTER OF FIG. 2 AND THIS SYSTEM YOU WILL READILY OBSERVE IS THE SAME AS THE RECEIVING TYPE INVERTED "L",

ONLY THAT THE TRANSMITTER IS INSERTED IN THE FEEDER-WIRE RATHER THAN THE RECEIVER. FINALLY AT THE RIGHT OF FIG.2 YOU WILL SEE AN INVERTED "L" ANTENNA WITH WHICH A COUNTERPOISE IS USED INSTEAD OF THE GROUND CONNECTION AND IN THIS CASE THE TRANSMITTER IS CONNECTED TO THE FEEDER BETWEEN THE HORIZONTAL OR FLAT-TOP PORTION OF THE ANTENNA AND THE COUNTERPOISE. IN ADDITION TO THESE BASIC DESIGNS OF THE MARCONI SYSTEM, YOU WILL ALSO FIND MODIFICATIONS USED SUCH AS THE "T" TYPE ANTENNA ETC. BUT WHICH HAVE THE SAME GENERAL APPEARANCE AS ANTENNAS OF CORRESPONDING DESIGN AS USED WITH RECEIVERS AND WHICH WERE ALREADY DESCRIBED TO YOU IN PREVIOUS LESSONS. IT IS EQUALLY TRUE THAT INSTEAD OF USING ONLY A SINGLE FLAT-TOP CONDUCTOR, YOU WILL ALSO FIND CASES WHERE SEVERAL SUCH WIRES ARE RUN PARALLEL TO EACHOTHER AND TOGETHER CONNECTED TO THE FEEDER OF THE SYSTEM.

HERTZ ANTENNA SYSTEMS

IN FIG. 3 YOU ARE SHOWN THREE FUNDAMENTAL FORMS OF HERTZ ANTENNAS

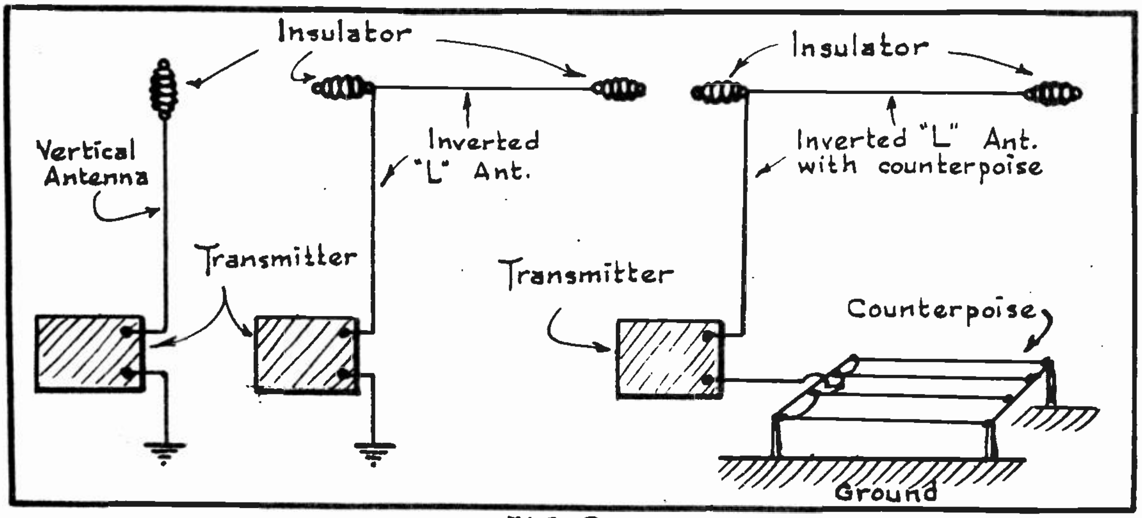

FIG. 2

Three Fundamental Forms of Marconi Type Antennas.

WHICH ARE COMMONLY USED. FOR EXAMPLE, AT THE LEFT OF FIG.3 WE AGAIN HAVE THE VERTICAL ANTENNA ONLY THAT IN THIS CASE IT IS COMPLETELY INSULATED FROM GROUND AND THE TRANSMITTER FEEDS INTO THE SYSTEM AS HERE SHOWN. AT THE CENTER OF FIG. 3 ONE FORM OF HORIZONTAL ANTENNA IS SHOWN AND WITH WHICH NO GROUND CONNECTION IS USED. THE UNGROUNDED ANTENNA AT THE RIGHT OF FIG.3 IS ALSO OF THE HORIZONTAL TYPE AND IN GENERAL APPEARANCE RESEMBLES THE DOUBLET ANTENNA AS USED WITH SHORT-WAVE RECEIVERS.

YOU WILL ALSO FIND VARIOUS MODIFICATIONS USED AS REGARDS THE HERTZ ANTENNA SYSTEMS BUT BY HAVING THESE FUNDAMENTAL PRINCIPLES IN MIND, YOU ARE NOW PREPARED TO ENTER A MORE DETAILED STUDY OF THESE DIFFERENT SYSTEMS. OUR FIRST STEP IN THIS DIRECTION WILL BE TO INVESTIGATE THE THEORY OF RADIATION A LITTLE MORE THOROUGHLY.

RADIATION

TRANSMITTING ANTENNA SYSTEMS FORM AN OSCILLATORY CIRCUIT IN THE SAME MANNER AS HAS ALREADY BEEN PREVIOUSLY EXPLAINED RELATIVE TO RECEIVER ANTENNAS AND THEREFORE BY PROPERLY COUPLING THE ANTENNA SYSTEM TO THE

OUTPUT OF A TRANSMITTER, THE HIGH FREQUENCY ENERGY WHICH IS GENERATED AND AMPLIFIED BY THE TRANSMITTER CAN CAUSE CURRENTS OF RADIO FREQUENCY TO FLOW IN THE ANTENNA CIRCUIT.

FROM YOUR PREVIOUS STUDIES, YOU WILL RECALL THAT WHENEVER AN ELECTRIC RIC CURRENT FLOWS THROUGH A CONDUCTOR, ELECTROMAGNETIC LINES OF FORCE WILL ENCIRCLE THE CONDUCTOR AND THIS IS ALSO THE CASE IN OUR ANTENNA SYSTEM AS ILLUSTRATED AT THE LEFT OF FIG.4. THEN SINCE THIS ANTENNA CURRENT IS CHANGING ITS DIRECTION OF FLOW AT A VERY HIGH FREQUENCY, THE RESULTING MAGNETIC FIELD WILL BUILD UP AND COLLAPSE AT A TREMENDOUS SPEED.

WHENEVER A CONDUCTOR IS CARRYING A CURRENT AT A RATHER LOW FREQUENCY SUCH AS A 60 CYCLE CURRENT, FOR EXAMPLE, THEN ALL OF THE ENERGY WHICH IS STORED IN THE MAGNETIC FIELD AROUND THE CONDUCTOR IS RETURNED TO THE CONDUCTOR AS THE FIELD COLLAPSES. HOWEVER, WHEN A CONDUCTOR IS CARRYING A CURRENT OF VERY HIGH FREQUENCY THEN THIS CONDITION IS NO LONGER TRUE FOR UNDER SUCH CIRCUMSTANCES NOT ALL OF THE ENERGY STORED IN THE MAGNETIC FIELD IS RETURNED TO THE CONDUCTOR. INSTEAD, SOME OF IT ESCAPES IN THE

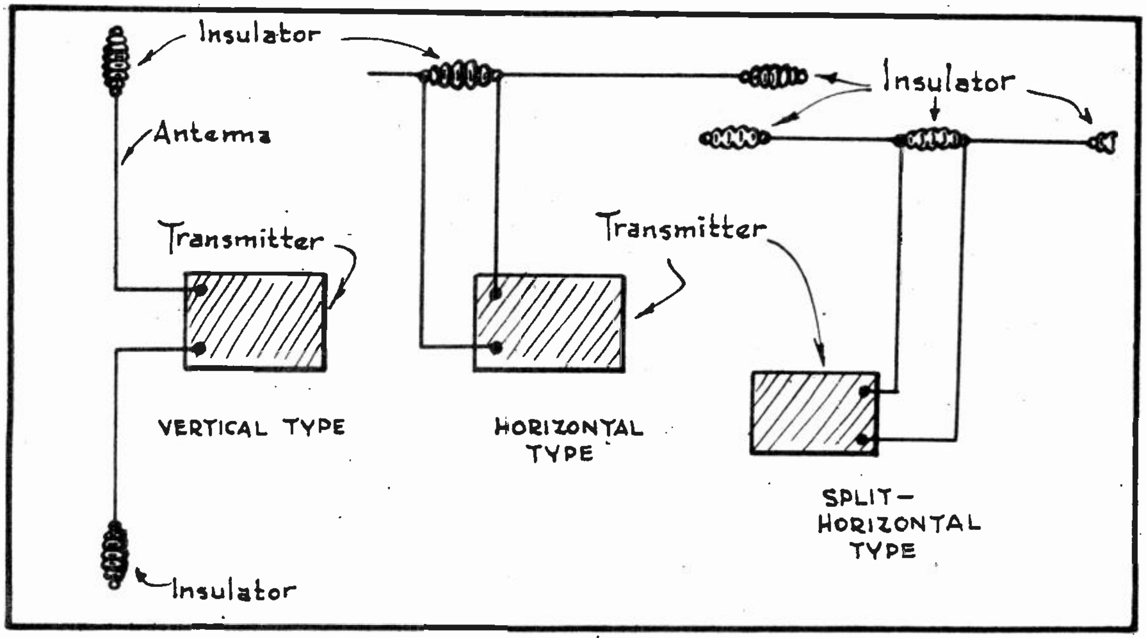

FIG. 3
Three Fundamental Types of Hertz Antenna.

FORM OF MAGNETIC WAVES AND WE THEN SAY THAT ENERGY HAS BEEN "RADIATED".

IN ADDITION TO THE FORMATION OF ELECTROMAGNETIC LINES OF FORCE AROUND AN ANTENNA SYSTEM, IT IS EQUALLY TRUE THAT ELECTROSTATIC LINES OF FORCE ARE ALSO PRODUCED AS ILLUSTRATED AT THE RIGHT OF FIG.4. THIS CAN BE BETTER VISUALIZED BY CONSIDERING THE HORIZONTAL FLAT-TOP AS ONE PLATE OF A CONDENSER AND THE GROUND AS THE OTHER PLATE. THE AIR SPACE BETWEEN THEM SERVES AS THE DIELECTRIC OF THE CONDENSER. BY CONSIDERING THIS ARRANGEMENT IN THIS MANNER, IT CAN READILY BE SEEN THAT THE HIGH FREQUENCY VOLTAGE OUTPUT OF THE TRANSMITTER WILL CONTINUALLY MAINTAIN A POTENTIAL DIFFERENCE BETWEEN THE AERIAL AND GROUND. THAT IS, SOMETIMES THE VOLTAGE OF THE AERIAL WILL BE GREATER THAN THAT OF GROUND AND SOMETIMES IT WILL BE LESS. IN EFFECT, WE HAVE A CONDENSER WHICH IS BEING

CHARGED FIRST IN ONE DIRECTION AND THEN IN ANOTHER.

WHENEVER A CONDENSER IS CHARGED, ELECTROSTATIC LINES OF FORCE WILL EXTEND THROUGH THE DIELECTRIC FROM ONE PLATE TO THE OTHER AND THUS FORM AN ELECTROSTIC FIELD. IN THIS SAME MANNER, AN ELECTROSTATIC FIELD IS PRODUCED IN THE ANTENNA SYSTEM AS PICTURED AT THE RIGHT OF FIG.4 AND IT IS CONTINUALLY VARYING IN INTENSITY AND POLARITY IN ACCORDANCE WITH THE RADIO FREQUENCY ENERGY WHICH IS FED TO THE ANTENNA FROM THE TRANSMITTER. THUS YOU WILL NOW SEE THAT BOTH AN ELECTROMAGNETIC FIELD AND AN ELECTROSTATIC FIELD ARE ESTABLISHED AROUND THE ANTENNA. IT IS CUSTOMARY TO SPEAK OF THE ELECTROMAGNETIC FIELD SIMPLY AS THE "MAGNETIC FIELD" AND THE ELECTROSTATIC FIELD AS THE "ELECTRIC FIELD". THESE TWO FIELDS TOGETHER CONSTITUTE THE ELECTROMAGNETIC WAVES.

VOLTAGE AND CURRENT DISTRIBUTION OF ANTENNAS

AN ANTENNA WHICH HAS NO "LUMPED" INDUCTANCE OR CAPACITY BUT DEPENDS

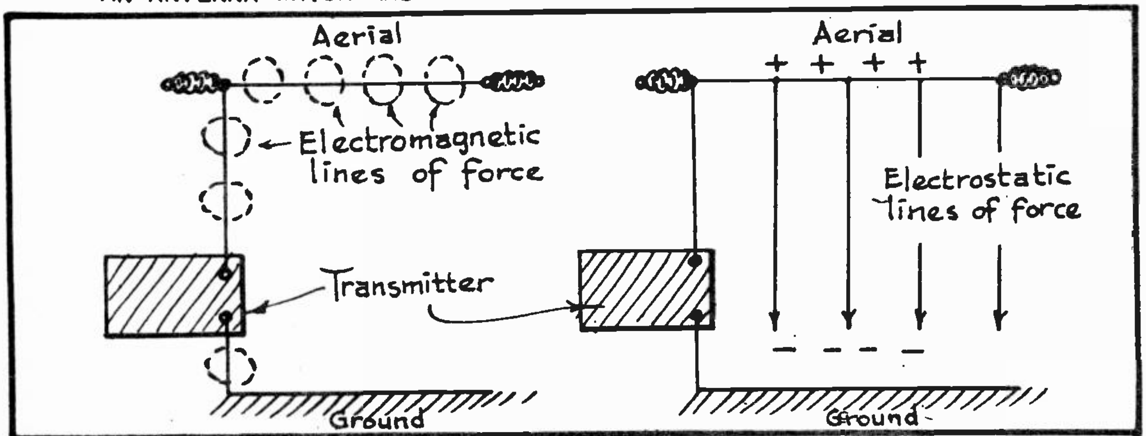

FIG. 4

Establishing Electromagnetic and Electrostatic Fields.

RATHER ON ITS DISTRIBUTED INDUCTANCE AND CAPACITY IS GENERALLY SPOKEN OF AS A "LINEAR OSCILLATORY CIRCUIT". A PECULIARITY OF SUCH A LINEAR CIRCUIT IS THAT WHEN IT IS EXITED AT ITS RESONANT FREQUENCY, THE CURRENT OR VOLTAGE AS MEASURED THROUGHOUT ITS LENGTH WILL HAVE DIFFERENT VALUES AT DIFFERENT POINTS. FOR EXAMPLE, IF THE WIRE HAPPENS TO BE SUSPENDED IN FREE SPACE BETWEEN INSULATORS AND WITH BOTH ENDS OPEN CIRCUITED AS IN THE HERTZ, THEN WHEN IT IS EXITED AT ITS RESONANT FREQUENCY, THE CURRENT WILL BE MAXIMUM AT THE CENTER AND ZERO AT THE ENDS AS ILLUSTRATED BY THE CURRENT CURVE IN FIG.5. IT IS ALSO OF INTEREST TO NOTE AT THIS TIME THAT AN ANTENNA OF THIS TYPE HAS A NATURAL TENDENCY TO RADIATE WAVES WHOSE WAVELENGTH IS EQUAL TO TWICE THAT OF THE LENGTH OF THE ANTENNA AND THE ANTENNA IS THEREFORE LOGICALLY NAMED A "HALF-WAVE ANTENNA",

THE VOLTAGE DISTRIBUTION IN THIS SAME ANTENNA OF FIG.5 IS JUST OPPOSITE TO THAT OF THE CURRENT DISTRIBUTION. IN OTHER WORDS, THE VOLTAGE WILL BE MAXIMUM AT THE ENDS AND ZERO AT THE CENTER AS SHOWN BY THE VOLTAGE CURVE IN FIG. 5. THE POINTS AT WHICH THE CURRENT OR VOLTAGE REACHES A MAXIMUM VALUE ARE CALLED ANTI-NODES OR LOOPS WHEREAS THE POINTS OF ZERO CURRENT ARE CALLED NODES.

THE REASON WHY THE CURRENT AND VOLTAGE VALUES DISTRIBUTE THEMSELVES

ACCORDING TO FIG. 5 IS DUE TO THE FACT THAT THE TRAVELLING WAVES ON THE WIRE ARE REFLECTED WHEN THEY REACH AN END. THE WAVES WHICH ARE REFLECTED FROM AN END ARE KNOWN AS THE REFLECTED WAVES, WHEREAS THOSE TRAVELLING TOWARDS THE SAME END ARE KNOWN AS THE INCIDENT WAVES. IT IS THUS OBVIOUS THAT AS SUCCEEDING WAVES TRAVEL TOWARDS THE SAME END OF THE WIRE, THE INCIDENT WAVES MEET THE REFLECTED WAVES AND DUE TO THIS MEETING, THE CURRENTS ADD UP AT THE CENTER AND THE VOLTAGES CANCEL OUT AT THE CENTER. AS THE OPERATION OF THE SYSTEM CONTINUES WITH ITS REPEATED REACTION BETWEEN THE INCIDENT AND REFLECTED WAVES, THE EFFECT OF A "STANDING WAVE" IS PRODUCED IN THE SYSTEM.

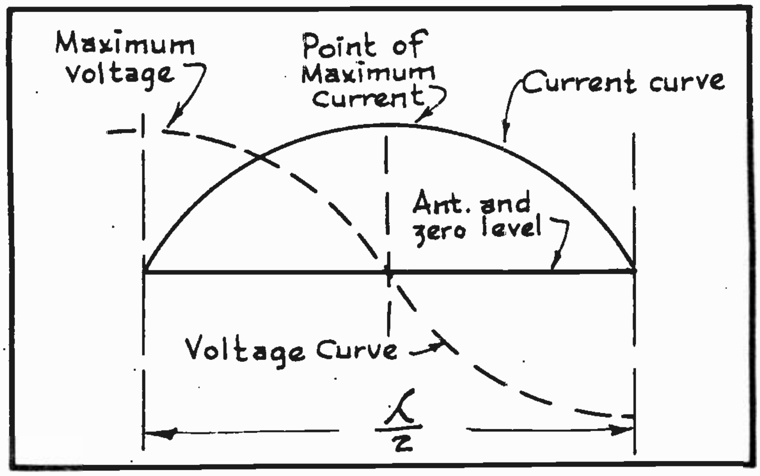

FIG. 5

Voltage and Current Distribution.

HARMONIC OPERATION OF ANTENNAS

THE VOLTAGE AND CURRENT DISTRIBUTION AS PICTURED IN FIG. 5 ASSUMES THAT THE ANTENNA IS BEING OPERATED AT ITS FUNDAMENTAL FREQUENCY. HOWEVER, IT IS ALSO POSSIBLE FOR AN ANTENNA TO OPERATE AT HARMONICS OF THE FUNDAMENTAL. IN FIG. 6, FOR EXAMPLE, WE HAVE THE SAME ANTENNA SYSTEM AS WAS USED RELATIVE TO FIG. 5 ONLY THAT IT IS NOW BEING OPERATED AT ITS SECOND HARMONIC INSTEAD OF AT ITS FUNDAMENTAL. WE THUS FIND THAT WHILE THERE WAS ONLY ONE POINT OF MAXIMUM CURRENT WITH FUNDAMENTAL OPERATION, THERE ARE TWO SUCH POINTS WHEN OPERATING AT THE SECOND HARMONIC.

IN FIG. 7 YOU ARE SHOWN THE CONDITIONS AS THEY EXIST WHEN OPERATING THE SAME ANTENNA AT THE THIRD HARMONIC. AT THIS TIME THERE ARE THREE POINTS OF MAXIMUM CURRENT. IT IS THUS CLEAR THAT THE NUMBER OF POINTS OF MAXIMUM CURRENT AND MAXIMUM VOLTAGE ARE IN ACCORDANCE WITH THE ORDER OF THE HARMONIC AT WHICH THE SYSTEM IS BEING OPERATED.

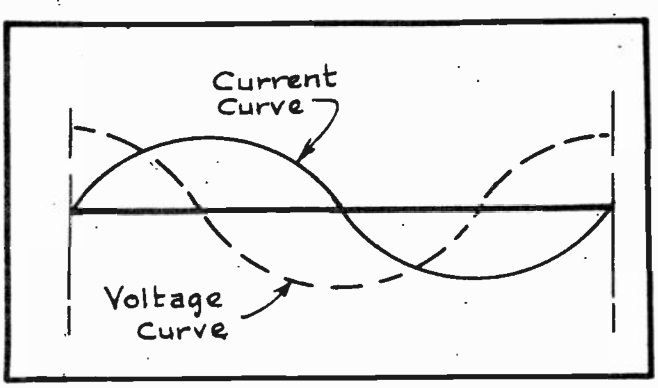

FIG. 6

Operation at Second Harmonic.

IT IS INTERESTING, AS WELL AS IMPORTANT, TO NOTE THAT A HERTZ ANTENNA MAY BE OPERATED AT THE FUNDAMENTAL FREQUENCY OR A HARMONIC FREQUENCY WHICH IS EITHER ODD OR EVEN. THE MARCONI ANTENNA, ON THE OTHER HAND, CAN BE OPERATED ONLY AT ITS FUNDAMENTAL OR HARMONICS THAT ARE ODD MULTIPLES OF THE FUNDAMENTAL FREQUENCY.

HAVING ADDED THIS AMOUNT

OF INFORMATION TO YOUR INCREASING KNOWLEDGE OF TRANSMITTER ANTENNAS, YOU ARE NOW PREPARED TO LEARN SOMETHING ABOUT "RADIATION RESISTANCE" AND THE PROCEDURE TO BE FOLLOWED IN THE DESIGN OF ANTENNA SYSTEMS.

RADIATION RESISTANCE

ALTHOUGH RADIATION WILL OCCUR FROM ANY CONDUCTOR THROUGH WHICH A HIGH-FREQUENCY CURRENT IS FLOWING, YET THE RADIATION IS GREATEST WHEN THE ANTENNA IS RESONATED TO THE FREQUENCY OF THE CURRENT. THE ENERGY WHICH IS ACTUALLY RADIATED BY AN ANTENNA IS EQUIVALENT TO THE ENERGY DISSIPATED WHEN CURRENT FLOWS THROUGH A RESISTANCE AND IN THE CASE OF ANTENNAS, THIS EQUIVALENT RESISTANCE IS KNOWN AS THE RADIATION RESISTANCE. IN REALLITY, THE RADIATION RESISTANCE IS A FICTITIOUS QUANTITY IN THAT IT IS EQUAL IN VALUE TO AN IMAGINARY RESISTANCE WHICH WHEN INSERTED IN SERIES WITH THE ANTENNA WILL CONSUME THE SAME AMOUNT OF POWER AS IS ACTUALLY RADIATED.

THE AVERAGE RADIATION RESISTANCE OF A HERTZ ANTENNA WHEN OPERATING AT ITS FUNDAMENTAL FREQUENCY IS APPROXIMATELY 70 OHMS AND FOR A MARCONI ANTENNA WHEN OPERATING AT ITS FUNDAMENTAL FREQUENCY IT IS APPROXIMATELY 35 OHMS.

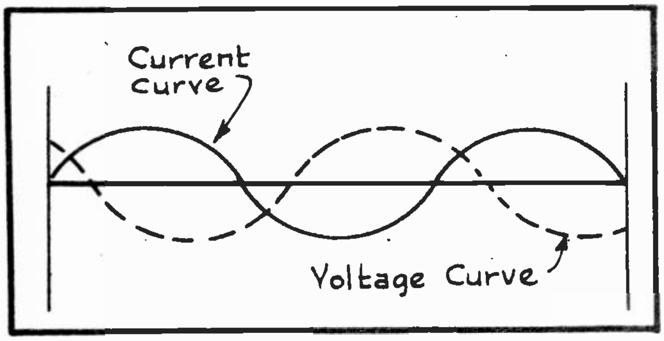

FIG. 7
Operation at Third Harmonic.

THE APPROXIMATE ANTENNA POWER IN WATTS CAN BE CALCULATED BY MULTIPLYING ITS ASSUMED RADIATION RESISTANCE EXPRESSED IN OHMS BY THE SQUARE OF THE MAXIMUM CURRENT (THAT IS, THE CURRENT AT THE CENTER OF A FUNDAMENTAL HERTZ ANTENNA AND THIS CURRENT VALUE SHOULD BE EXPRESSED IN AMPERES.)

SO MUCH FOR THE THEORY REGARDING ANTENNAS. NOW LET US PROCEED WITH THE CONSTRUCTIONAL DETAILS CONCERNING THESE SYSTEMS.

CALCULATING LENGTH OF HERTZ ANTENNAS

THEORETICALLY, THE NATURAL WAVELENGTH OF A FREELY SUSPENDED WIRE AS USED BY THE HERTZ SYSTEM IS EQUAL TO TWICE THE ACTUAL LENGTH OF THE WIRE. IN ACTUAL PRACTICE, HOWEVER, THE NATURAL WAVELENGTH OF THE WIRE WILL BE SOMEWHAT GREATER THAN ITS PHYSICAL LENGTH. THIS IS PRIMARILY DUE TO THE FACT THAT THE WIRE IS NOT ACTUALLY ISOLATED IN SPACE BUT IS IN PROXIMITY TO OTHER BODIES SUCH AS INSULATORS, ANTENNA MASTS, GUY WIRES ETC. AND ALL OF WHICH TEND TO INCREASE THE DISTRIBUTED CAPACITY TOGETHER WITH A RESULTING INCREASE IN THE WAVELENGTH OF THE SYSTEM.

FOR THE AVERAGE WELL CONSTRUCTED SYSTEM, THE NATURAL WAVELENGTH WILL BE BETWEEN 2.07 AND 2.1 TIMES THE PHYSICAL LENGTH OF THE WIRE. SOME HANDY FORMULAS FOR CALCULATING THE LENGTH OF THE RADIATING PORTION OF A HERTZ ANTENNA FOR ANY FREQUENCY DESIRED FOLLOW:

LENGTH IN FEET = 1.56 X DESIRED NATURAL WAVELENGTH EXPRESSED IN METERS.

LENGTH IN METERS = 0.475 X DESIRED NATURAL WAVELENGTH EXPRESSED IN METERS.

$$\text{LENGTH IN FEET} = \frac{468,000}{\text{FREQUENCY IN KC.}}$$

$$\text{LENGTH IN METERS} = \frac{142,500}{\text{FREQUENCY IN KC.}}$$

THE REQUIRED LENGTH OF WIRE REQUIRED SHOULD BE MEASURED ACCURATELY AND PREFERABLY WITH A GOOD STEEL TAPE, YARD STICK, OR METER STICK.

IT SHOULD ALSO BE REMEMBERED THAT THE HERTZ ANTENNA DOES NOT NECESSARILY HAVE TO BE CUT TO A LENGTH WHICH IS EQUAL TO HALF THE WAVELENGTH DESIRED. IT IS ALSO PERMISSIBLE TO HAVE THE ANTENNA LENGTH SO THAT IT WILL BE EQUAL TO A HALF WAVELENGTH MULTIPLIED BY ANY WHOLE NUMBER. HOWEVER, IT IS IMPORTANT TO NOTE THAT THE LENGTH OF THE ANTENNA ALWAYS MUST BE SUCH THAT IT WILL ACCOMMODATE A DEFINITE NUMBER OF HALF-WAVES. NO LESSER PORTION OF A WAVE SHOULD BE LEFT OVER.

THE FACT THAT THE ANTENNA CAN BE MADE TO OPERATE AT HARMONICS OF ITS FUNDAMENTAL IS QUITE ADVANTAGEOUS IN THAT THIS FEATURE MAKES IT POSSIBLE TO EFFICIENTLY OPERATE A GIVEN TRANSMITTER AND ANTENNA COMBINATION AT MORE THAN ONE FREQUENCY.

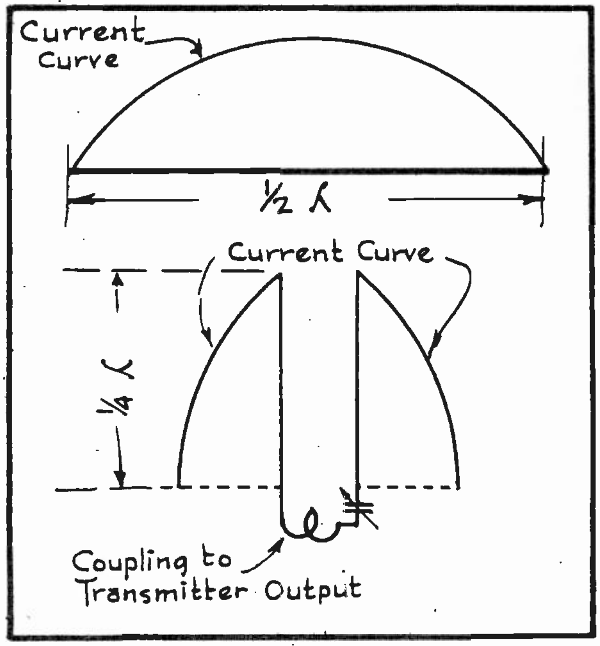

FIG. 8

A Quarter-Wave Feeder.

FEEDERS FOR THE HERTZ ANTENNA

HAVING DETERMINED THE LENGTH OF ANTENNA WIRE WHICH IS TO BE SUSPENDED HORIZONTALLY IN SPACE, OUR NEXT PROBLEM WILL BE TO TRANSFER THE SIGNAL ENERGY FROM THE TRANSMITTER TO THE RADIATING PART OF THE ANTENNA AND FOR THIS PURPOSE, WE USE A SYSTEM OF WIRES WHICH ARE KNOWN AS FEEDERS OR TRANSMISSION LINES. TWO GENERAL TYPES OF TRANSMISSION LINES ARE USED IN CONJUNCTION WITH HERTZ TYPE ANTENNAS AND THEY ARE CLASSIFIED AS TUNED OR RESONANCE LINES AND AS UNTUNED OR APERIODIC LINES.

THE TUNED TYPE OF TRANSMISSION LINE SHALL BE EXPLAINED FIRST.

TUNED TRANSMISSION LINES

THE THEORY OF A TUNED TRANSMISSION LINE FOR A HALF-WAVE ANTENNA IS ILLUSTRATED IN FIG.8. IN THE UPPER PORTION OF THIS ILLUSTRATION THE HALF-WAVE ANTENNA IS SHOWN TOGETHER WITH ITS CORRESPONDING CURRENT CURVE WHEN OPERATING AT THE FUNDAMENTAL. NOW IF WE SHOULD TAKE A SIMILAR WIRE

AND FOLD IT IN HALF SO THAT EACH HALF WOULD BE ¼ WAVE LENGTH LONG AS SHOWN IN THE LOWER ILLUSTRATION OF FIG.8 WE WOULD HAVE A QUARTER-WAVE TRANSMISSION LINE. UNDER THESE CONDITIONS, THE CURRENTS FLOWING IN EACH SIDE OF THE TWO-WIRE LINE WILL OPPOSE EACHOTHER AND THEREBY RESULTING IN A CANCELLATION OF THE FIELDS AROUND THE WIRES. FOR THIS REASON THE TRANSMISSION LINE WILL TAKE NO PART IN RADIATION AND SERVES ONLY TO CARRY THE ENERGY FROM THE TRANSMITTER TO THE RADIATING PORTION OF THE ANTENNA.

THE COUPLING COIL AND VARIABLE CONDENSER, WHICH SERVE BOTH AS A MEANS FOR TUNING THE SYSTEM AS WELL AS COUPLING THE ANTENNA TO THE TRANSMITTER, ARE CONNECTED AT THE POINT WHERE THE HALF-WAVE WIRE HAS BEEN FOLDED. FURTHERMORE, SINCE THE TRANSMITTER ENERGY IS FED INTO THE TRANSMISSION LINE AT A POINT WHERE THE LINE HAS BEEN "FOLDED" AND WHICH CORRESPONDS TO THE POINT OF MAXIMUM CURRENT, THIS PARTICULAR LINE IS SAID TO BE CURRENT FED.

WHEN CURRENT FEEDING IS USED IN THIS MANNER, SERIES TUNING SHOULD BE USED FOR THE TRANSMISSION LINE AND THIS IS ILLUSTRATED IN FIG.8 AND ALSO IN THE ILLUSTRATION AT THE LEFT OF FIG.9. IT IS THE MORE COMMON PRACTICE TO EMPLOY TWO TUNING CONDENSERS IN THE SERIES ARRANGEMENT AS SHOWN IN FIG.9. SERIES TUNING OF THE TRANSMISSION LINE HAS NO EFFECT ON THE CURRENT DISTRIBUTION IN THE SYSTEM.

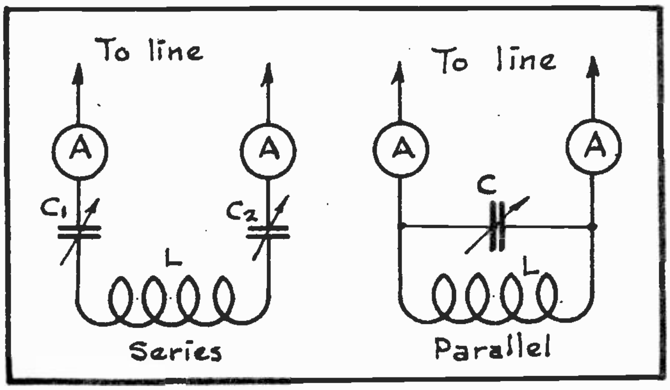

FIG. 9

Series and Parallel Feeder Tuning.

IN THE ANTENNA WHICH IS SHOWN IN THE UPPER PORTION OF FIG. 10 THREE HALF-WAVES ARE IMPOSED UPON IT AND UPON FOLDING THIS ANTENNA AT ITS MIDPOINT TO FORM A FEEDER OR TRANSMISSION LINE, WE HAVE AN ARRANGEMENT AS PICTURED IN THE LOWER SECTION OF FIG. 10. HERE WE FIND THAT UPON FOLDING THE WIRE AT ITS MIDPOINT, THE TWO OUTER HALF-WAVES ARE SIMPLY FOLDED BACK — ONE HALF-WAVE REMAINING FOR EACH OF THE FEEDER WIRES. THE THIRD HALF-WAVE WHICH APPEARS BETWEEN THE OUTER TWO AT THE TOP OF FIG. 10 IS REPLACED WITH A PARALLEL TUNING CIRCUIT WHICH IS TUNED TO THE FUNDAMENTAL OF ONE OF THESE HALF-WAVELENGTHS. THUS THE THREE HALF-WAVELENGTHS ARE STILL ACCOUNTED FOR IN THE TRANSMISSION LINE.

BY EMPLOYING THE PARALLEL TUNING CIRCUIT IN A TRANSMISSION LINE OF THIS TYPE, IT ACTS AS A PHASE REVERSER, THEREBY BRINGING THE CURRENTS IN THE TWO WIRES INTO PHASE-OPPOSITION SO THAT NO RADIATION CAN RESULT THRUOUT THE LENGTH OF THIS TRANSMISSION LINE. FROM A FURTHER STUDY OF THE TRANSMISSION LINE AS PICTURED IN THE LOWER SECTION OF FIG. 10, YOU WILL NOTICE THAT IF THE COIL OF THIS TUNING CIRCUIT IS COUPLED TO THE OUTPUT TANK OF A TRANSMITTER, THE R.F. ENERGY WILL BE FED INTO THE TRANSMISSION LINE AT A POINT OF ZERO CURRENT BUT WHICH AT THE SAME TIME CORRESPONDS TO A POINT OF MAXIMUM VOLTAGE AS YOU LEARNED FROM FIG.5. CONDITIONS BEING SUCH, WE THEN SAY THAT HERE IS A CASE WHERE WE HAVE VOLTAGE FEED TO THE TRANSMISSION LINE.

A HANDY RULE TO REMEMBER IS THAT IN OPEN-ENDED TRANSMISSION LINES WHERE THE LENGTH OF EACH TRANSMISSION WIRE IS AN ODD NUMBER OF QUARTER-WAVES LONG, CURRENT FEED IS REQUIRED IN CONJUNCTION WITH SERIES TUNING. ON THE OTHER HAND, IF THE LENGTH OF EACH WIRE OF THE TRANSMISSION LINE IS AN EVEN NUMBER OF QUARTER-WAVES LONG, THEN VOLTAGE FEED TOGETHER WITH PARALLEL TUNING IS REQUIRED.

THE TWO WIRES OF THE TRANSMISSION LINE SHOULD BOTH BE EQUAL IN LENGTH AND SHOULD BE RUN PARALLEL TO EACHOTHER THROUGHOUT THEIR LENGTH AND WITH A SEPARATION OF 3" TO 12" BETWEEN THEM. IT IS ALSO DESIRABLE THAT THE LENGTH OF THE TRANSMISSION LINE BE AN EXACT MULTIPLE OF A QUARTER WAVELENGTH, HOWEVER, EVEN IF THIS ISN'T EXACT, THE TUNING CIRCUIT IN THE LINE OFFERS A MEANS OF LOADING THE FEEDERS SO AS TO COMPENSATE FOR DIFFERENCES BETWEEN A QUARTER WAVELENGTH AND THE ACTUAL LENGTH OF THE WIRES.

HAVING CONSIDERED THE METHOD OF COUPLING THE ANTENNA TRANSMISSION LINE TO THE TRANSMITTER, OUR NEXT STEP WILL BE TO CONNECT THE OTHER END OF THIS TRANSMISSION LINE TO THE ANTENNA.

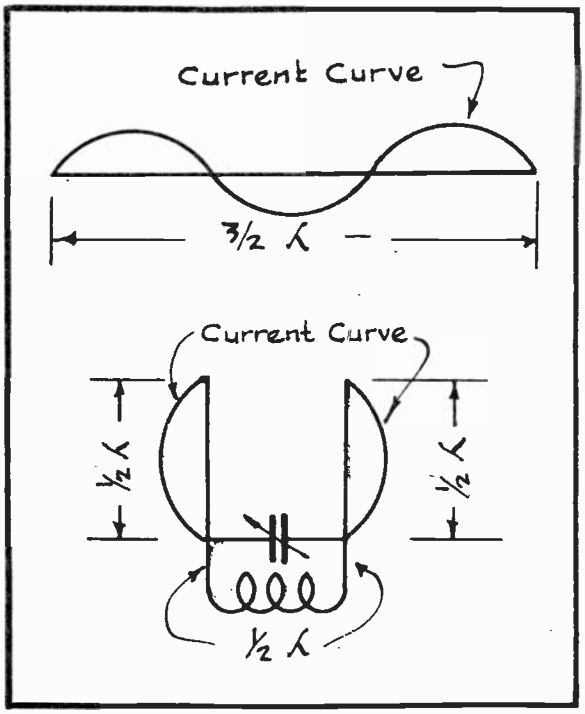

FIG. 10
Voltage-Feed Line.

THE ZEPPELIN ANTENNA

IN FIG. 11 YOU ARE SHOWN THE CONSTRUCTIONAL FEATURES OF ONE FORM OF HERTZ ANTENNA WHICH IS KNOWN AS A ZEPPELIN ANTENNA OR SIMPLY AS A "ZEPP" ANTENNA. THE CONSTRUCTIONAL DATA AS HERE FURNISHED WILL SET THE FUNDAMENTAL FREQUENCY OF THE ANTENNA AT 3550 KC. BUT WITH THE AID OF THE TUNING ARRANGEMENT WHICH IS ALSO PROVIDED, THIS SYSTEM CAN BE ADJUSTED FOR A FUNDAMENTAL FREQUENCY ANYWHERES BETWEEN 3500 AND 3600 KC. IN ADDITION THIS SAME ANTENNA CAN BE OPERATED AT ITS HARMONICS OF 7000 AND 14000 KC. AND IS THEREFORE SUITABLE FOR AMATEUR USE. THE TRANSMISSION LINE OF THIS ANTENNA IS BOTH SERIES TUNED AND PARALLEL TUNED — PARALLEL TUNING BEING MOST EFFECTIVE FOR 3500 KC. AND SERIES TUNING FOR THE 7000 AND 14,000 KC. BANDS. THE CONDENSERS C_1 AND C_2 MAY BE OF .00035 MFD. RATING. MORE DETAILS REGARDING THE ANTENNA-TRANSMITTER COUPLING METHODS ARE GIVEN IN A LATER LESSON.

SINCE THE ZEPPELIN ANTENNA IS OF THE HALF-WAVE TYPE, THERE IS ALWAYS A VOLTAGE LOOP AT ITS END AND SINCE THE TRANSMISSION LINE IS CONNECTED TO THE ANTENNA AT THIS POINT, THE ANTENNA IS SAID TO BE VOLTAGE FED. THE ANTENNA MAY BE ANY NUMBER OF HALF WAVES LONG AND THE LENGTH OF THE FEEDER IS USUALLY AN ODD MULTIPLE OF A QUARTER WAVELENGTH. SERIES TUNING IS RECOMMENDED WHEN THE FEEDERS HAVE A LENGTH BETWEEN ONE-QUARTER AND THREE-EIGHTS OF A WAVELENGTH WHEREAS FOR FEEDERS MUCH LESS THAN A QUARTER

WAVELENGTH LONG OR FOR LENGTHS FROM APPROXIMATELY THREE-EIGHTS UPTO ONE HALF WAVELENGTH, PARALLEL TUNING IS DESIRED.

A CENTER-FEED ANTENNA

THE ZEPPELIN ANTENNA, YOU WILL RECALL IS VOLTAGE FED, SO NOW LET US SEE HOW A "CURRENT FEED" ARRANGEMENT WOULD LOOK. ONE SUCH ARRANGEMENT IS ILLUSTRATED IN FIG. 12.

HERE THE ANTENNA IS ONE-HALF WAVELENGTH LONG AND THEREFORE THE CURRENT DISTRIBUTION WILL BE AS HERE SHOWN, THAT IS, WITH A CURRENT LOOP AT THE CENTER. THUS IF THIS ANTENNA IS TO BE CURRENT FED IT CAN BE CUT AT THE CENTER AND A FEEDER WIRE CONNECTED TO EACH OF THE RESULTING ANTENNA WIRES.

IN A SYSTEM OF THIS TYPE IT IS ALSO NECESSARY THAT THE LENGTH OF THE FEEDER WIRES BE SUCH THAT A CURRENT LOOP WILL ALSO OCCUR AT THEIR INPUT ENDS SO THAT THE PHASE RELATION THROUGHOUT THE SYSTEM MAY BE CORRECT. FOR THIS REASON, EACH WIRE OF THE FEEDER IS MADE ONE-HALF WAVELENGTH LONG. THIS ALSO PERMITS SERIES TUNING, WHEREAS IF THE FEEDERS SHOULD ONLY BE ONE-QUARTER WAVELENGTH LONG IT WOULD BE NECESSARY TO INSTALL A PHASE REVERSER IN THE FORM OF A PARALLEL TUNING CIRCUIT AT THEIR INPUT END.

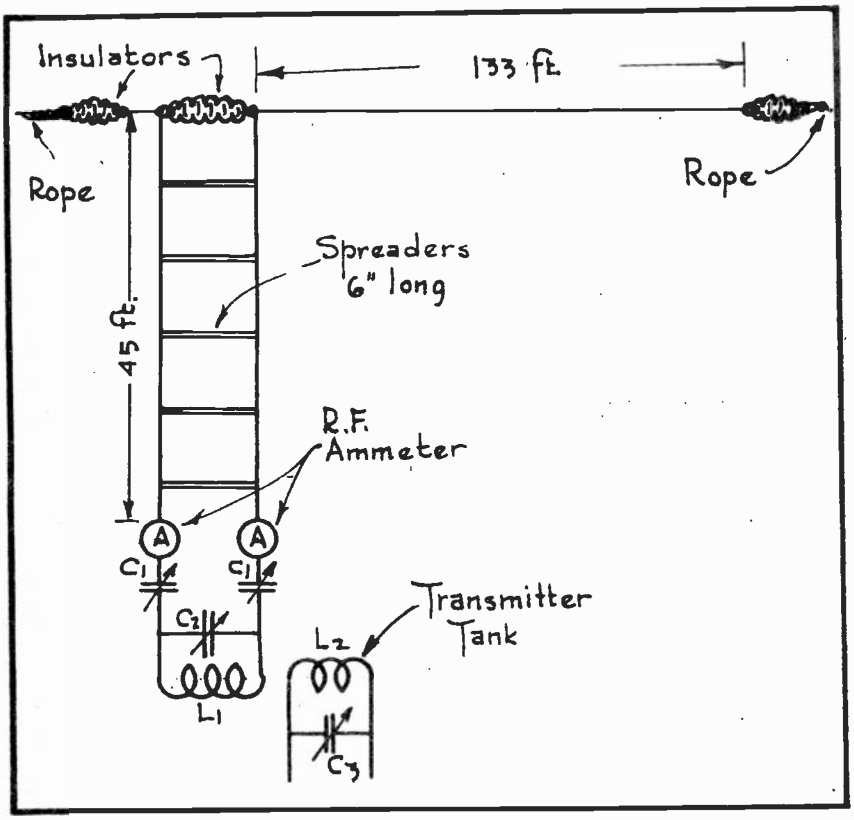

FIG. 13
The Zeppelin Antenna.

IN FIG. 13 YOU ARE SHOWN HOW THIS PRINCIPLE MAY BE EMPLOYED IN PRACTICE. THE PARTICULAR DESIGN HERE ILLUSTRATED IS INTENDED FOR AMATEUR USE AND HAS A FUNDAMENTAL FREQUENCY OF 7100 KC. IT MAY ALSO BE OPERATED AT ITS SECOND HARMONIC OR 14,200 KC. AND AT THE FOURTH HARMONIC OR 28,400 BOTH OF WHICH ARE IN AN AMATEUR BAND. A COMBINATION OF SERIES AND PARALLEL TUNING IS BEING USED IN THIS EXAMPLE, PARALLEL TUNING BEING EMPLOYED FOR THE 7100 KC. AND 28,400 KC. BANDS AND SERIES TUNING FOR THE 14,200 KC. BAND. IT MAY ALSO BE OPERATED ON THE 3500 KC. BAND WITH PARALLEL TUNING.

ALTHOUGH THE ANTENNA IN FIG. 13 IS A CENTER-FEED SYSTEM, YET THIS

DOES NOT NECESSARILY MEAN THAT IT IS CURRENT-FED. FOR INSTANCE, AT 7100 KC. WHERE THE ANTENNA IS A HALF-WAVE LONG, IT IS CURRENT FED BUT WHEN OPERATING AT 14,200 KC. AND HIGHER EVEN HARMONICS, IT IS VOLTAGE FED. IN THIS LATTER CASE THIS ANTENNA IN REALLITY BECOMES TWO ZEPPELIN ANTENNAS PLACED END TO END AND WHEN OPERATING AT 3500 KC., ONLY ONE HALF OF THE ANTENNA IS ACTUALLY USED.

TUNING THE ANTENNA SYSTEM

HAVING SO FAR CONSIDERED THE CONSTRUCTIONAL DETAILS OF TUNED TRANSMISSION LINES AS USED WITH ANTENNA SYSTEMS, OUR NEXT STEP WILL BE TO INVESTIGATE THE PROPER PROCEDURE OF TUNING THE ANTENNA WHEN PUTTING THE TRANSMITTER ON THE AIR. THE SYSTEMS ILLUSTRATED IN FIGS. 11 AND 12 SHALL BE USED AS AN EXAMPLE.

THE FIRST STEP IS TO PLACE THE TRANSMITTER IN OPERATION AND TO ADJUST IT THROUGHOUT FOR OPERATION AT THE DESIRED FREQUENCY. ASSUMING THAT SERIES TUNING IS TO BE EMPLOYED, SET THE ANTENNA'S PARALLEL TUNING CONDENSER AT ITS POSITION OF MINIMUM CAPACITY AND THE SERIES CONDENSERS AT THEIR POSITION OF MAXIMUM CAPACITY.

COUPLE THE ANTENNA COUPLING COIL TO THE TANK COIL IN THE OUTPUT CIRCUIT OF THE TRANSMITTER AND SIMULTANEOUSLY TURN BOTH SERIES CONDENSERS OUT OF MESH VERY SLOWLY, CAREFULLY WATCHING THE ANTENNA AMMETERS AS YOU DO SO. CONTINUE THIS ADJUSTMENT UNTIL THESE AMMETERS INDICATE MAXIMUM CURRENT AND AT WHICH TIME THE ANTENNA SYSTEM WILL BE TUNED TO RESONANCE WITH THE FREQUENCY FOR WHICH THE TRANSMITTER IS ADJUSTED. IF TWO POINTS OF MAXIMUM CURRENT ARE INDICATED BY THE AMMETERS, LOOSEN THE COUPLING SLIGHTLY BETWEEN THE ANTENNA COUPLING COIL AND THE TRANSMITTER TANK COIL.

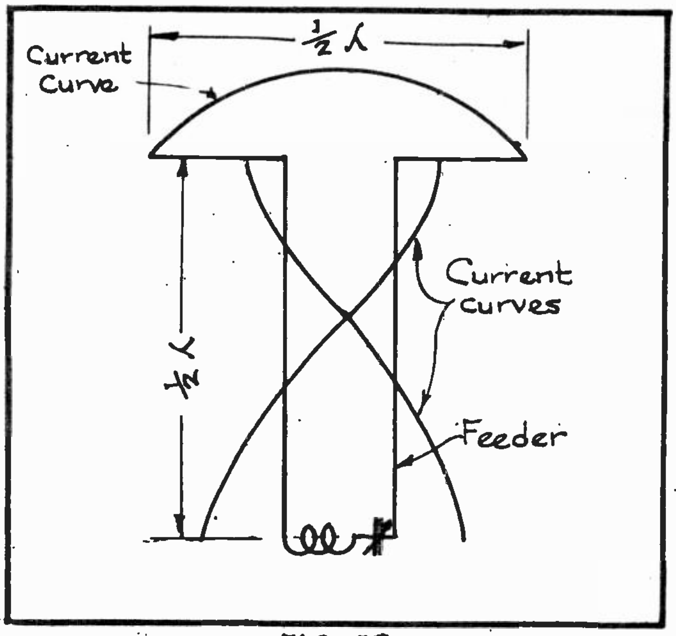

FIG. 12
A Current-Fed Antenna.

IN THE EVENT THAT PARALLEL TUNING OF THE ANTENNA'S TRANSMISSION LINE IS BEING EMPLOYED, THEN SET THE SERIES TUNING CONDENSERS, AS WELL AS THE PARALLEL TUNING CONDENSER AT THEIR POSITION OF MAXIMUM CAPACITY. THEN SLOWLY DECREASE THE CAPACITY OF THE PARALLEL CONDENSER UNTIL THE ANTENNA AMMETERS OFFER A MAXIMUM READING.

AS AN ADDITIONAL CHECK WHEN TUNING THE ANTENNA, YOU WILL FIND THAT THE PLATE CURRENT OF THE FINAL TUBE WILL INCREASE AS THE ANTENNA CIRCUIT IS TUNED NEARER TO RESONANCE.

UNTUNED TRANSMISSION LINES

In addition to the tuned transmission lines as so far described, transmission lines of the untuned type are also used. The untuned line offers the advantage that no standing waves appear upon it and it can therefore be made any length. However, the design and construction of the untuned line is much more critical than is that of the tuned line.

The main thing to be taken into consideration with respect to the untuned transmission line is that if it is terminated in an impedance which is equal to the characteristic impedance of the line or to the "surge impedance" as it is sometimes called, then no reflection will occur and no standing waves will be present on the line. Under these conditions, the transmission line can be made any length, no radiation will occur from the transmission line and practically all of the R.F. power which is fed into the line will be delivered to the antenna.

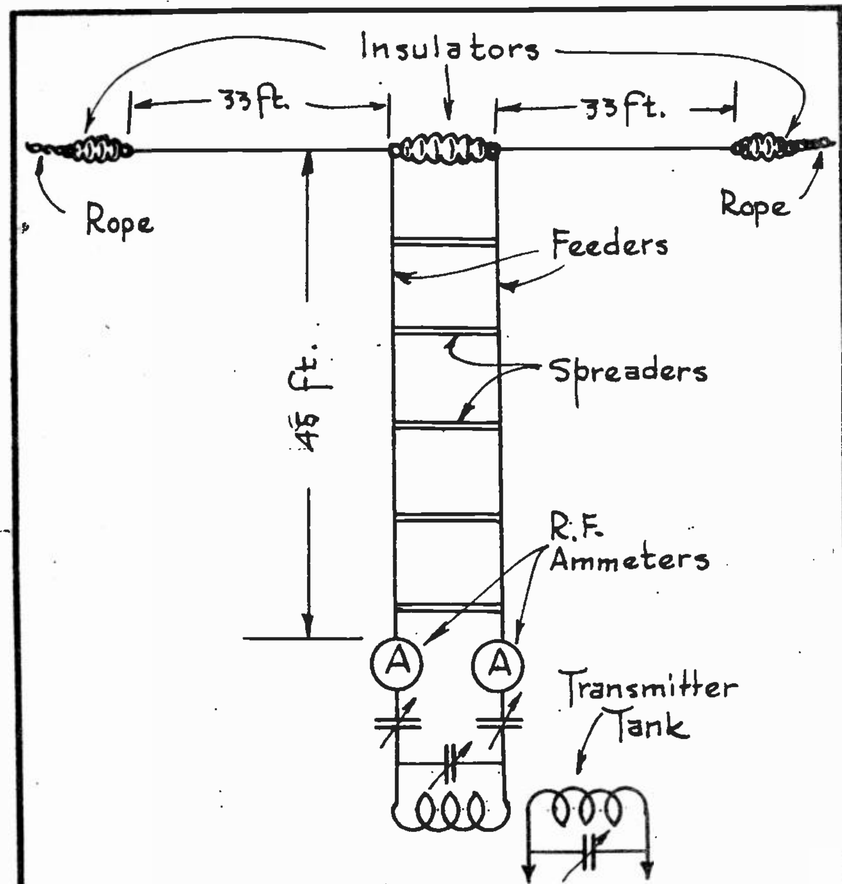

FIG. 13

A Typical Center-Feed Antenna System.

The surge or characteristic impedance of a two-wire transmission line is expressed by the following formula:

$$Z = 276 \log_{10} \frac{B}{A}$$

where Z = characteristic impedance; 276 is a constant; B = spacing between the wires in inches and A = the radius of the transmission line wire expressed in inches. A characteristic impedance of 600 ohms has through experiment been found to be most practical for this purpose.

In Fig. 14 you are shown how a 600 ohm untuned transmission line is used with a two-wire, matched-impedance antenna system. In this arrangement the transmission line itself may be of any length but the dimensions L-A-B and C are of utmost importance. Also observe in Fig. 14 that the transmission line spreads apart or is "fanned" at its upper end. This is done with the intention of having a gradually increasing impedance at

SPECIAL NOTICE

DURING THE PROCESS OF PRINTING TRANSMITTER LESSON #9 AN OMISSION OCCURRED ON PAGE 13.

FOLLOWING THE FORMULA $A(\text{METERS}) = \frac{150.00}{F} \times K_1$ ON THIS PAGE THE TEXT HERE GIVEN WAS OMITTED:

IN THESE FORMULAS ALSO, THE FREQUENCY F IS EXPRESSED IN KILOCYCLES AND THE VALUE FOR K_1 IS A CONSTANT WHICH VARIES WITH THE FREQUENCY IN THE FOLLOWING MANNER: FOR FREQUENCIES BELOW 3000 KC., $K_1 = 0.25$; FOR FREQUENCIES BETWEEN 3000 AND 28,000 KC., $K_1 = 0.24$ AND FOR FREQUENCIES ABOVE 28,000 KC., $K_1 = 0.23$.

THE DIMENSION "B" OF THE ANTENNA SYSTEM IS DETERMINED BY APPLYING EITHER ONE OF THE FOLLOWING FORMULAS:

$$B\ (\text{FEET}) = \frac{147{,}600}{F \text{ IN KC.}}$$

$$B\ (\text{METERS}) = \frac{45{,}000}{F \text{ IN KC.}}$$

THIS END OF THE LINE SO THAT ITS IMPEDANCE AT THE ANTENNA END WILL BE EQUAL TO THE IMPEDANCE OF SECTION "A" OF THE ANTENNA.

PROVIDED THAT THE CHARACTERISTIC IMPEDANCE OF THE TRANSMISSION LINE IS FIXED AT 600 OHMS, WE PROCEED TO WORK OUT THE DESIGN FOR THIS ANTENNA SYSTEM IN THE MANNER AS SHALL NOW BE EXPLAINED:

FIRST WE DETERMINE THE LENGTH OF THE ANTENNA BY APPLYING THE FOLLOWING FORMULA:

$$L\ (\text{FEET}) = \frac{492{,}000}{F} \times K \quad \text{OR} \quad L(\text{METERS}) = \frac{150{,}000}{F} \times K.$$

IN THIS FORMULA F = FUNDAMENTAL FREQUENCY OF THE ANTENNA SYSTEM EXPRESSED IN KILOCYCLES AND K IS A CONSTANT WHICH IS DEPENDENT UPON THE FREQUENCY IN THE FOLLOWING ORDER: FOR FREQUENCIES BELOW 3000 Kc., K = 0.96; FOR FREQUENCIES BETWEEN 3000 Kc. AND 28,000 Kc., K = 0.95 AND FOR FREQUENCIES ABOVE 28,000 Kc., K = 0.94.

THE NEXT STEP IS TO DETERMINE THE DIMENSION "A" OF FIG. 14 AND FOR THIS, EITHER OF THE FOLLOWING TWO FORMULAS CAN BE APPLIED:

$$A(\text{FEET}) = \frac{492{,}000}{F} \times K_1$$

$$A(\text{METERS}) = \frac{150{,}000}{F} \times K_1$$

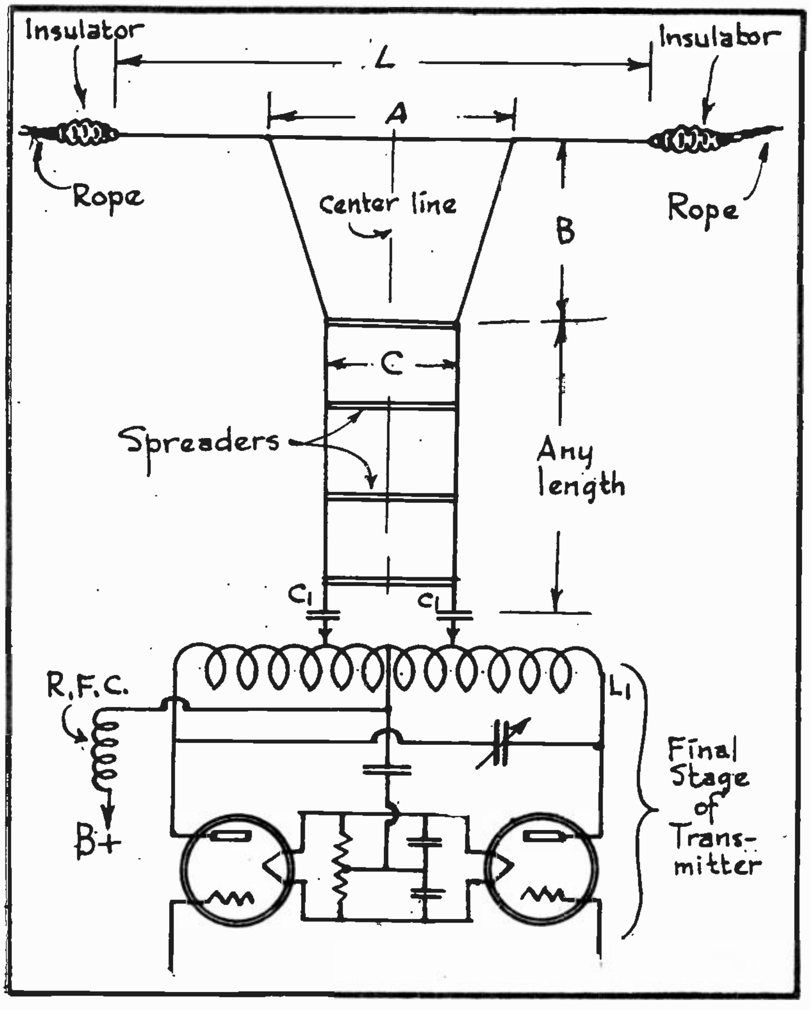

FIG. 14

Two-Wire Matched-Impedance Antenna.

THE FINAL STEP IS TO DETERMINE THE DIMENSION "C" OF THE SYSTEM, THAT IS, THE SPACING TO BE ALLOWED BETWEEN THE FEEDER WIRES AND FOR THIS WE USE THE FORMULA C = 75 × D, WHERE C = THE DISTANCE BETWEEN THE WIRES; D = THE DIAMETER OF THE WIRE AND THE NUMBER 75 IS A CONSTANT. IF "D" IS EXPRESSED IN INCHES, THEN C WILL ALSO BE EXPRESSED IN INCHES, WHEREAS IF "D" IS EXPRESSED IN MILLIMETERS, THEN C WILL ALSO BE EXPRESSED IN MILLIMETERS. IN THIS SYSTEM, IT IS ESPECIALLY NECESSARY THAT THE SPACING BETWEEN THE TWO WIRES OF THE TRANSMISSION LINE

BE KEPT CONSTANT THROUGHOUT THEIR ENTIRE LENGTH AND THAT THEY ALSO BE KEPT TAUT. IT IS ALSO IMPORTANT THAT SECTION "B" OF THE LINE BE RUN STRAIGHT AWAY FROM THE ANTENNA AND THE TWO HALVES OF DIMENSION "A" SHOULD BE EQUIDISTANT FROM THE EXACT CENTER OF THE ANTENNA'S FLAT TOP.

FIG. 14 ALSO SHOWS YOU HOW THE UNTUNED TRANSMISSION LINE MAY BE COUPLED TO THE TRANSMITTER'S PLATE CIRCUIT TANK THROUGH THE FIXED CONDENSERS C_1. THESE TWO CONDENSERS C_1 MAY EACH HAVE A VALUE OF .002 MFD. AND THE TWO WIRES OF THE LINE SHOULD BE CLIPPED ON THE TRANSMITTER TANK COIL AN EQUAL NUMBER OF TURNS FROM EACH SIDE OF ITS CENTER. STARTING FROM THE CENTER OF THE COIL, THESE CLIPS CAN TOGETHER BE MOVED OUTWARD ONE TURN AT A TIME UNTIL THE TUBES ARE DRAWING THEIR NORMAL PLATE CURRENT.

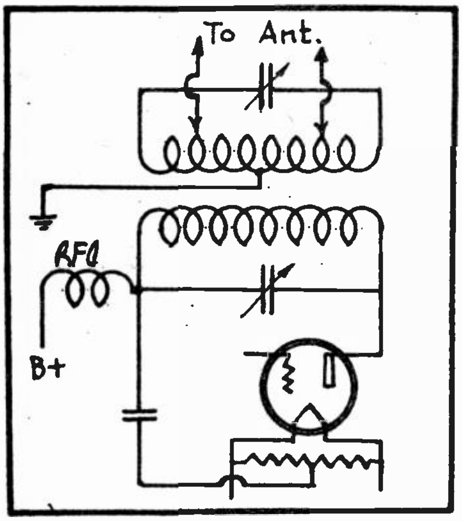

FIG. 15
Untuned line Coupled to Single-Tube Output.

IF ONLY A SINGLE TUBE IS USED IN THE FINAL STAGE OF THE TRANSMITTER, THEN IT CAN BE COUPLED TO THE TRANSMISSION LINE AS ILLUSTRATED IN FIG. 15.

SINGLE-WIRE FEED

IN FIG. 16 YOU ARE SHOWN A SINGLE-WIRE ANTENNA FEED AND IN WHICH CASE THE TRANSMISSION LINE CONSISTS OF ONLY A SINGLE WIRE INSTEAD OF TWO WIRES. IN A SYSTEM AS THIS, THE LENGTH OF THE ANTENNA IS DETERMINED AS ALREADY PREVIOUSLY DESCRIBED, THAT IS, BY EMPLOYING THE FORMULA $L(\text{FEET}) = \frac{492{,}000}{F} \times K$.

THE DIMENSION "D" OR THE DISTANCE FROM THE CENTER OF THE ANTENNA TO THE POINT AT WHICH THE FEEDER IS TAPPED TO IT IS FOUND BY MULTIPLYING THE LENGTH L BY 0.14.

IN AN ANTENNA OF THIS TYPE THE FEEDER MUST RUN AT RIGHT ANGLES TO THE ANTENNA FOR A DISTANCE WHICH IS AT LEAST EQUAL TO 1/3 THE LENGTH OF THE ANTENNA AND SHARP BENDS SHOULD BE AVOIDED IN THE FEEDER THROUGHOUT ITS LENGTH.

INVERTED "L" ANTENNA

TO DETERMINE THE LENGTH OF AN INVERTED "L" ANTENNA FOR A TRANSMITTER IS A RATHER SIMPLE PROCEDURE IN THAT THE NATURAL WAVELENGTH OF THIS TYPE OF ANTENNA IS APPROXIMATELY 4.2 TIMES ITS ACTUAL LENGTH. THE LENGTH CONSIDERED IN THIS CASE IS THE TOTAL LENGTH FROM THE OPEN END OF THE ANTENNA TO THE GROUND CONNECTION OR COUNTERPOISE. FOR EXAMPLE, IF THE FREQUENCY OF A TRANSMITTER IS 1250 KC. AND WHICH IS EQUIVALENT TO 240 METERS; THEN THE TOTAL LENGTH OF THE ANTENNA SYSTEM SHOULD BE $\frac{240}{4.2} = 57.14$ METERS. EXPRESSED IN FEET, THIS LENGTH IS EQUAL TO $57.14 \times 3.28 = 187.42$ FT. APPROXIMATELY.

SINCE IT IS CUSTOMARY TO INCLUDE A TUNING CIRCUIT IN SERIES WITH THIS TYPE OF ANTENNA AS ILLUSTRATED IN YOUR FIRST LESSON OF THE TRANSMITT-

ER SERIES, THE LENGTH OF THE TOTAL ANTENNA NEED NOT BE CALCULATED TO AN EXTREME ACCURACY. THIS TUNING CIRCUIT WILL PERMIT ANY NECESSARY ADJUSTMENT FOR TUNING THE ANTENNA CIRCUIT TO RESONANCE IN THE EVENT THAT THE LENGTH ITSELF DOES NOT RESONATE TO THE FREQUENCY.

SUGGESTIONS FOR CONSTRUCTION

ALL ANTENNA ERECTION JOBS SHOULD BE SO PLANNED THAT THE ELECTRICAL JOINTS IN THE SYSTEM WILL BE KEPT DOWN TO A MINIMUM. THE SAME PRECAUTIONS SHOULD BE EXERCISED IN SUSPENDING THE ANTENNA WIRE IN AS CLEAR A SPACE AS POSSIBLE AS HAVE ALREADY BEEN EXPLAINED RELATIVE TO RECEIVER TYPE ANTENNAS AND BOTH ENDS OF THE ANTENNA WIRE SHOULD BE ANCHORED IN SUCH A MANNER THAT IT WILL BE PREVENTED FROM SWAYING IN THE WIND. IN THIS CASE ALSO, A PULLEY AND WEIGHT ARRANGEMENT ARE FREQUENTLY USED TO TAKE UP ANY SLACK IN THE SYSTEM. A #12 B&S GAUGE HARD-DRAWN ENAMELLED COPPER WIRE FOR BOTH THE ANTENNA AND TRANSMISSION LINES WILL MEET MOST INSTALLATIONS OF THE AVERAGE TYPE.

WHENEVER ANY JOINTS ARE NECESSARY, THEY SHOULD BE MECHANICALLY TIGHT AND THOROUGHLY SOLDERED. IN THE CASE OF TWO-WIRE TRANSMISSION LINES, THE SPREADERS MAY CONSIST OF WOODEN DOWELS WHICH HAVE BEEN BOILED IN PARAFFIN AND THEY CAN BE ATTACHED TO THE WIRES BY DRILLING SMALL HOLES THRU THE ENDS OF THE DOWELS AND THEN BINDING THEM TO THE WIRES OF THE LINE.

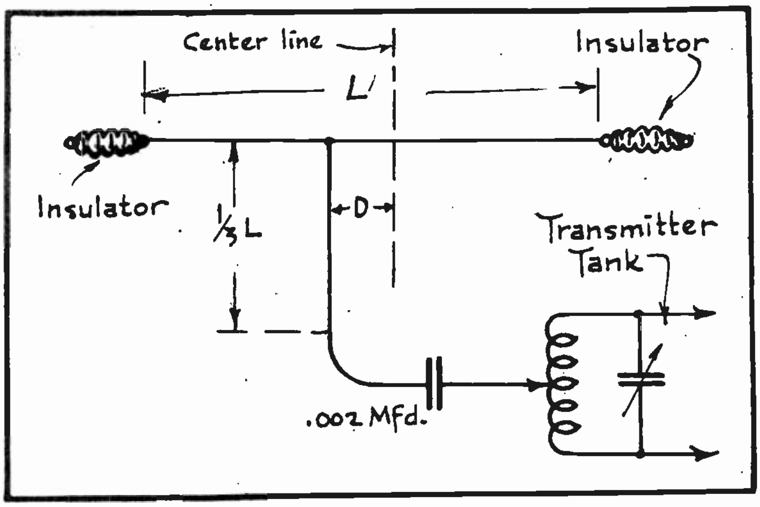

FIG. 16
Single-Wire Antenna Feed.

ONLY THE BEST INSULATORS SHOULD BE USED, PYREX ELECTRICAL-RESISTANT GLASS INSULATORS BEING PREFERRED, ALTHOUGH GLAZED PORCELAIN INSULATORS CAN ALSO BE USED. THESE INSULATORS ARE SIMILAR IN APPEARANCE TO THOSE USED WITH RECEIVING ANTENNAS ONLY THAT THEY ARE LARGER. TRANSMITTER INSULATORS OF 12" LENGTH ARE FREQUENTLY USED FOR TRANSMITTERS OF MODERATE POWER, WHEREAS STATIONS OF LESSER POWER USE SMALLER INSULATORS AND SOMETIMES TWO SMALL INSULATORS CONNECTED IN SERIES.

FOR HIGH FREQUENCY TRANSMITTERS, HERTZ ANTENNAS ARE USED MOST EXTENSIVELY ALTHOUGH MARCONI ANTENNAS ARE ALSO USED TO A CERTAIN EXTENT IN WORK OF THIS TYPE. LATER IN THE COURSE YOU WILL RECEIVE STILL MORE INSTRUCTIONS REGARDING ANTENNAS OF SPECIAL TYPES.

Due Jan 23, 1942

Examination Questions

LESSON NO. T-9

A business may be ever so successful, but it is never so sure—never secure, until it holds its old friends by Service and increases its circle of New Friends on the basis of Satisfaction.

1. — WHAT IS THE ESSENTIAL DIFFERENCE BETWEEN THE HERTZ TYPE ANTENNA AND THE MARCONI TYPE ANTENNA?

2. — EXPLAIN THE CURRENT AND VOLTAGE DISTRIBUTION ON A HERTZ ANTENNA WHILE IT IS BEING OPERATED AT ITS FUNDAMENTAL FREQUENCY.

3. — WHAT IS MEANT BY "RADIATION RESISTANCE"?

4. — IF YOU INTEND TO DESIGN AN INVERTED L (MARCONI ANTENNA) FOR A TRANSMITTER WHOSE OPERATING FREQUENCY IS 1500 KC., WHAT SHOULD BE THE TOTAL LENGTH OF THE ANTENNA?

5. — SHOULD YOU BE CALLED UPON TO CONSTRUCT A HERTZ ANTENNA FOR A TRANSMITTER OPERATING AT 6000 KC., HOW LONG WOULD YOU MAKE THE FLAT-TOP OF THE ANTENNA, THAT IS, THE RADIATING PART OF THE ANTENNA?

6. — WHAT EFFECT DOES A PARALLEL TUNING CIRCUIT IN AN ANTENNA FEEDER HAVE UPON THE CURRENT DISTRIBUTION IN THE SYSTEM?

7. — WHAT IS MEANT BY A "CURRENT-FED" ANTENNA TRANSMISSION LINE?

8. — WHAT IS MEANT BY A "VOLTAGE-FED" ANTENNA?

9. — EXPLAIN IN DETAIL HOW YOU WOULD PROCEED TO TUNE AN ANTENNA SYSTEM IN WHICH A TWO-WIRE TRANSMISSION LINE IS USED IN CONJUNCTION WITH SERIES TUNING.

10.— WHAT FACTS ARE TO BE CONSIDERED IN WORKING OUT THE DESIGN FOR AN UNTUNED, TWO-WIRE TRANSMISSION LINE FOR A HERTZ ANTENNA?

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Transmitters

LESSON NO. 10

POWER SUPPLY FOR TRANSMITTERS

IN ONE OF THE EARLY LESSONS OF THIS COURSE YOU WERE INSTRUCTED IN THE PRINCIPLES INVOLVED IN THE POWER SUPPLY CIRCUIT OF THE RECEIVING SET. THE SAME GENERAL PLAN IS USED IN LAYING OUT THE POWER SUPPLY SECTION OF THE TRANSMITTER, THE CHIEF DIFFERENCES BEING DUE TO THE LARGER CURRENT AND HIGHER VOLTAGE REQUIREMENTS OF THE LATTER. WHILE THE APPARATUS USED IS NOT AT ALL COMPLICATED, STILL THE OPERATION OF THE WHOLE TRANSMITTER DEPENDS UPON THE CARE AND PRECISION WITH WHICH THIS UNIT IS DESIGNED AND INSTALLED. NO TRANSMITTER CAN BE ANY BETTER THAN ITS POWER SUPPLY.

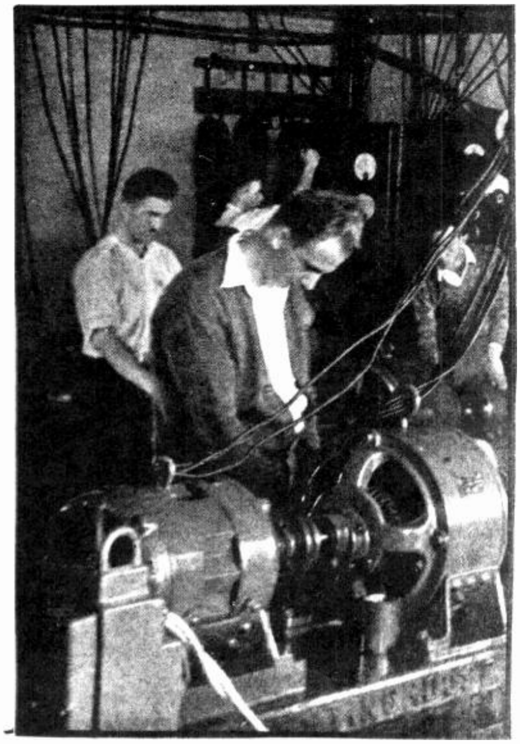


FIG. I

Section of National's Power Room.

POWER SUPPLY FROM A.C. SOURCE

WE SHALL FIRST CONSIDER THOSE SYSTEMS IN WHICH THE SOURCE OF ENERGY IS AN ALTERNATING CURRENT LINE, EITHER SINGLE PHASE, TWO PHASE, OR THREE PHASE. THERE ARE, IN EACH OF THESE SYSTEMS, FIVE MAJOR PARTS, NAMELY:

1. THE POWER TRANSFORMER WHICH STEPS THE LINE VOLTAGE UP TO A HIGHER VALUE.

2. THE FILAMENT TRANSFORMERS WHICH STEP THE LINE VOLTAGE DOWN TO THE PROPER VALUE. IN TRANSMITTERS, THE FILAMENT TRANSFORMERS ARE SELDOM COMBINED WITH THE HIGH VOLTAGE TRANSFORMER AS IN THE RECEIVING SET.

3. THE RECTIFIER WHICH CHANGES THE

HIGH AC VOLTAGE TO A PULSATING DC.

4. THE FILTER WHICH CHANGES THE PULSATING DC OUTPUT OF THE RECTIFIER TO A CONSTANT DC.

5. THE VOLTAGE DIVIDER WHICH PROVIDES VOLTAGES AS NEEDED BELOW THE HIGH DC OUTPUT OF THE FILTER SYSTEM.

YOUR LESSON #59 PRESENTED IN DETAIL THE DESIGN AND CONSTRUCTION OF POWER TRANSFORMERS SUCH AS ARE USED IN CONJUNCTION WITH THERMIONIC RECTIFIER TUBES TO PRODUCE THE HIGH DC POTENTIAL WHICH, AFTER BEING FILTERED, ENERGIZES THE PLATE AND OTHER "B" CIRCUITS OF THE TRANSMITTER.

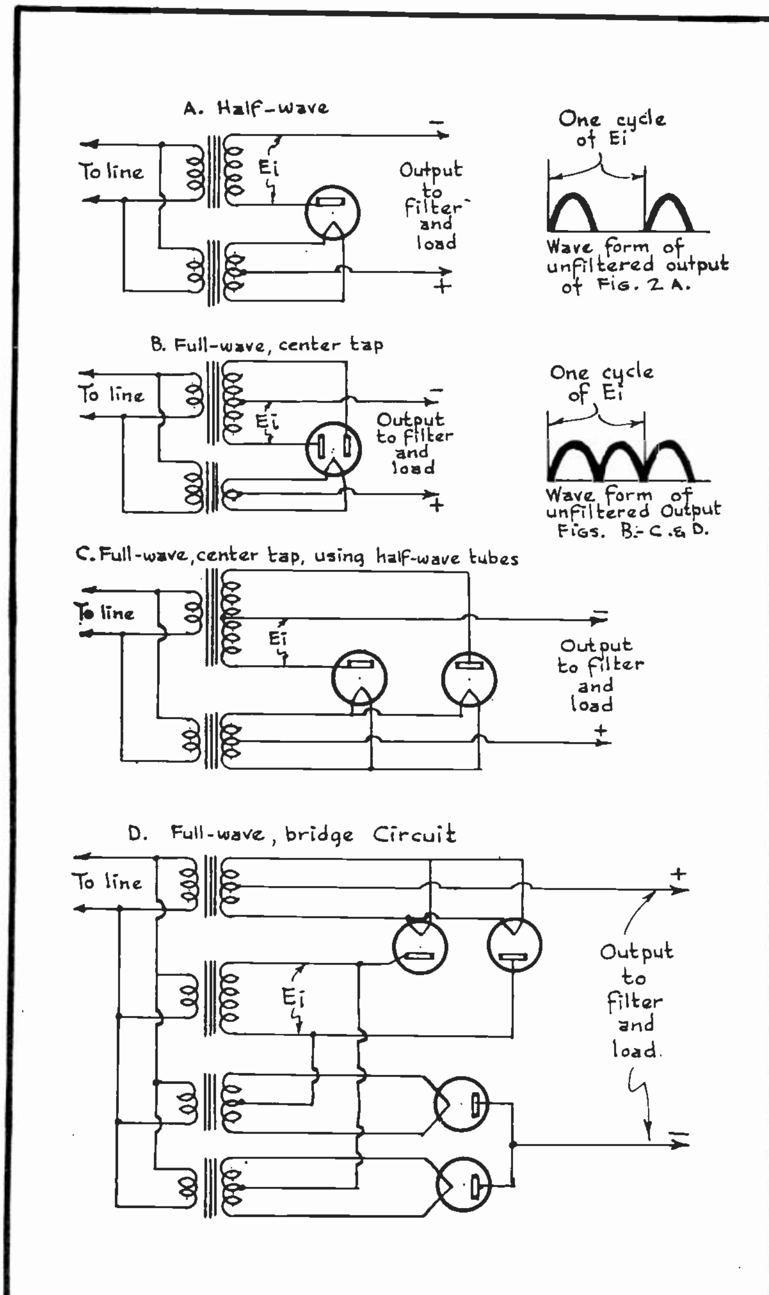


FIG. 2

Single-Phase Rectifier Circuits.

SINGLE-PHASE RECTIFIER CIRCUITS

THE CIRCUITS OF FIG. 2 IN THE PRESENT LESSON SHOWS YOU A NUMBER OF TYPICAL RECTIFYING SYSTEMS FOR A SINGLE-PHASE LINE. THE FIRST CIRCUIT (A) IS NOT OFTEN USED IN COMMERCIAL TRANSMITTERS BECAUSE OF THE DIFFICULTY OF FILTERING THE HALF-WAVE OUTPUT. HOWEVER, IT DOES HAVE ITS APPLICATION IN THE AMATEUR TRANSMITTER WHERE COST IS A LIMITING FACTOR. THE FAMILIAR CIRCUIT OF FIG. 2B IS USED EXTENSIVELY IN SUPPLYING THE SPEECH - INPUT AMPLIFIERS OF THE BROADCAST TRANSMITTER, BUT IS LIMITED TO THIS SERVICE BECAUSE THE FULL-WAVE RECTIFIER TUBES COMMERCIALLY AVAILABLE ARE NOT CAPABLE OF MEETING THE HIGH CURRENT AND VOLTAGE REQUIREMENTS OF THE OTHER SECTIONS OF THE TRANSMITT-

ER. (OF COURSE THIS LAYOUT CAN BE, AND OFTEN IS, USED IN LOW POWERED AMATEUR RIGS.)

THE HIGH VOLTAGE TUBES ARE ALL HALF-WAVE RECTIFIERS. TWO ARE CONNECTED AS IN FIG. 2C WHEN THE FULL-WAVE CENTER-TAP CIRCUIT IS TO BE USED WITH AN AC VOLTAGE PER PLATE OF OVER 500 VOLTS, EFFECTIVE VALUE, WHICH IS THE MAXIMUM RATING OF THE TYPE 83 FULL-WAVE RECTIFIER.

FOUR RECTIFIER TUBES ARE REQUIRED IN THE BRIDGE CIRCUIT OF FIG.2D, AND THREE SEPARATE FILAMENT TRANSFORMERS MUST BE PROVIDED. TO OFFSET THIS, HOWEVER, TWICE AS MUCH VOLTAGE CAN BE OBTAINED FROM THE BRIDGE CIRCUIT AS FROM THE CENTER-TAP SYSTEM WITHOUT EXCEEDING THE PEAK-INVERSE-VOLTAGE RATING OF THE TUBES. A CAREFUL INSPECTION OF THIS CIRCUIT WILL SHOW THAT IT IS THE FAMILIAR BRIDGE CIRCUIT OF FIG.7, LESSON NO.13, AND FIG.6, OF LESSON NO.50, WITH THE OXIDE RECTIFIERS REPLACED BY VACUUM TUBES.

VOLTAGE DOUBLER

WHEN A HIGH VOLTAGE IS NEEDED AND THE CURRENT DRAIN IS TO BE RATHER SMALL, A HALF-WAVE VOLTAGE DOUBLER RECTIFIER CAN BE USED TO ADVANTAGE. FIG. 3 SHOWS THIS SYSTEM.

A D.C. OUTPUT VOLTAGE NEARLY TWICE THE R.M.S. OR EFFECTIVE VOLTAGE OF THE TRANSFORMER IS PRODUCED BY ALTERNATELY CHARGING THE TWO CONDENSERS C1 AND C2 TO THE FULL VOLTAGE OF THE TRANSFORMER. SINCE THESE TWO CONDENSERS ARE IN SERIES SO FAR AS THE OUTPUT CIRCUIT IS CONCERNED, THE TOTAL VOLTAGE IS TWICE THE VOLTAGE ACROSS EITHER ONE. (SEE FIG. 12 OF LESSON #29.)

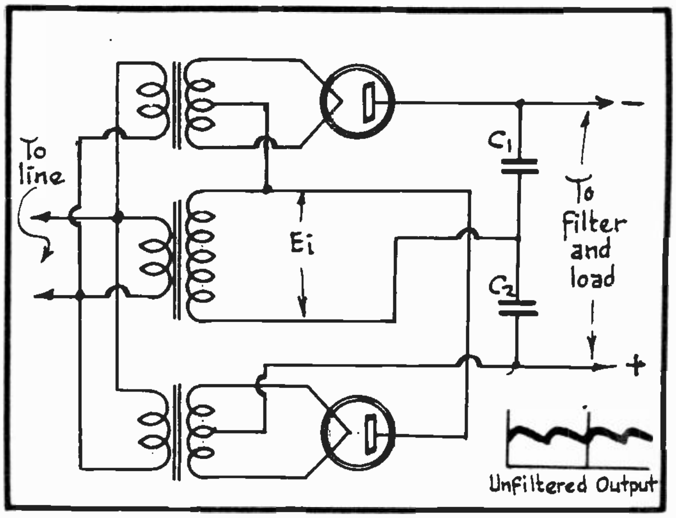


FIG. 3
Voltage Doubler.

POLYPHASE SYSTEMS

BECAUSE MOST OF THE ALTERNATING CURRENT DISTRIBUTION SYSTEMS IN COMMON USE ARE TWO AND THREE PHASE SYSTEMS, TWO AND THREE PHASE RECTIFIER CIRCUITS ARE OFTEN USED IN SUPPLYING THE TRANSMITTER WITH ITS PLATE CURRENT.

THE TWO-PHASE SYSTEM

A TWO-PHASE SYSTEM IS AN ALTERNATING-CURRENT SYSTEM ENERGIZED BY TWO SEPARATE E.M.F.'S WHICH ARE EQUAL IN VALUE BUT WHICH DIFFER IN PHASE BY NINETY ELECTRICAL DEGREES. A SINGLE ALTERNATING-CURRENT GENERATOR HAVING TWO SEPARATE WINDINGS IS USED TO ENERGIZE SUCH A SYSTEM. TRANSFORMERS IN SUCH A DISTRIBUTION SYSTEM MUST HAVE TWO WINDINGS ON BOTH PRIMARY AND SECONDARY WITH A SEPARATE MAGNETIC CIRCUIT FOR EACH "PHASE", AS THE E.M.F.'S ARE CALLED, OR ELSE TWO TRANSFORMERS MUST BE USED. THE GREEK

LETTER ϕ(PHI) IS FREQUENTLY USED TO DESIGNATE PHASE.

TWO-PHASE MOTORS ARE PROVIDED WITH TWO SETS OF COILS JUST AS ARE THE GENERATORS, AND WHEN A LAMP LOAD IS CARRIED BY A TWO-PHASE SYSTEM, THE LAMPS ARE DIVIDED INTO TWO "PHASE GROUPS", ONE BEING CONNECTED TO ONE PHASE AND THE OTHER GROUP BEING CONNECTED TO THE OTHER PHASE AS SHOWN IN FIG. 4.

WHEN THE TWO PHASES ARE INTERCONNECTED AS SHOWN IN FIG. 5, A TWO-PHASE, THREE-WIRE SYSTEM RESULTS. NOTE THAT THE VOLTAGE BETWEEN THE "OUTSIDE" WIRES IS 1.41 (OR THE SQUARE-ROOT OF TWO) TIMES THE PHASE-VOLTAGE. THIS IS THE RESULTANT VOLTAGE OBTAINED BY ADDING THE TWO PHASE-VOLTAGES AT A PHASE-DISPLACEMENT OF 90°. THE CURRENT IN THE COMMON OR NEUTRAL WIRE WILL BE 1.41 TIMES THE "LINE CURRENT" IN EITHER OUTSIDE WIRE.

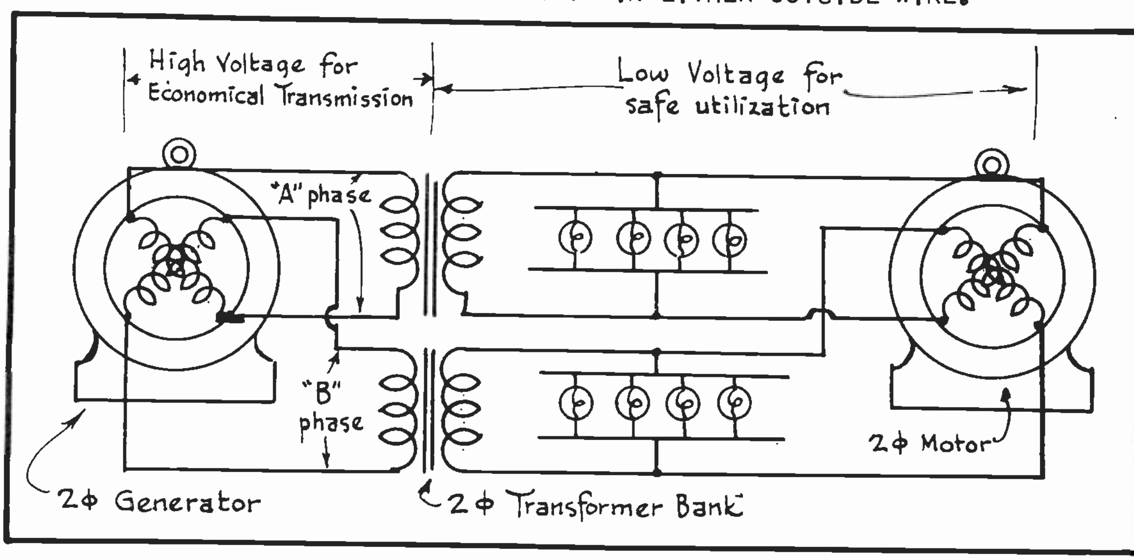


FIG. 4

A Two-Phase, Four-Wire System.

TWO METHODS OF REPRESENTING THE TWO PHASE SYSTEM GRAPHICALLY ARE SHOWN IN FIG. 6. THE DOTTED LINE OF THE VECTOR DIAGRAM SHOWS THE VOLTAGE BETWEEN THE OUTSIDE WIRES OF THE TWO-PHASE, THREE-WIRE SYSTEM AS THE VECTORIAL SUM OF THE TWO PHASE-VOLTAGES.

THE THREE-PHASE SYSTEM

A THREE-PHASE SYSTEM IS ENERGIZED BY THREE SEPARATE E.M.F.'S, EQUAL IN VOLTAGE BUT DIFFERING IN PHASE BY ONE-HUNDRED-TWENTY ELECTRICAL DEGREES. THIS IS GRAPHICALLY ILLUSTRATED IN FIG. 7.

THREE WIRES ONLY ARE REQUIRED TO CARRY THREE-PHASE ENERGY. THE PHASE WINDINGS OF THE GENERATOR ARE CONNECTED TO THE LINE WIRES EITHER IN STAR AS IN FIG. 8A, OR IN DELTA AS IN FIG. 8B. IN THE STAR-CONNECTED CIRCUIT THE LINE VOLTAGE E_L IS 1.73 (OR THE SQUARE ROOT OF THREE) TIMES THE PHASE VOLTAGE E_{PH}. WHEN A DELTA CONNECTION IS EMPLOYED, THE LINE VOLTAGE EQUALS THE PHASE VOLTAGE.

THREE-PHASE SYSTEMS ARE FAR MORE COMMON THAN SINGLE-OR TWO-PHASE

SYSTEMS FOR THE FOLLOWING REASONS: THE COST OF COPPER FOR THE THREE-PHASE DISTRIBUTION SYSTEM IS LESS; AN A.C. GENERATOR TAPPED FOR THREE-PHASE OUTPUT DELIVERS 50% MORE POWER THAN THE SAME GENERATOR TAPPED FOR SINGLE-PHASE OUTPUT, AND 6% MORE POWER THAN WHEN TAPPED FOR TWO-PHASE; AND IN ADDITION THREE-PHASE MOTORS ARE SELF-STARTING AND MORE ECONOMICAL THAN SINGLE-PHASE MOTORS. IN THE CASE OF THE RECTIFIER, THE OUTPUT OF

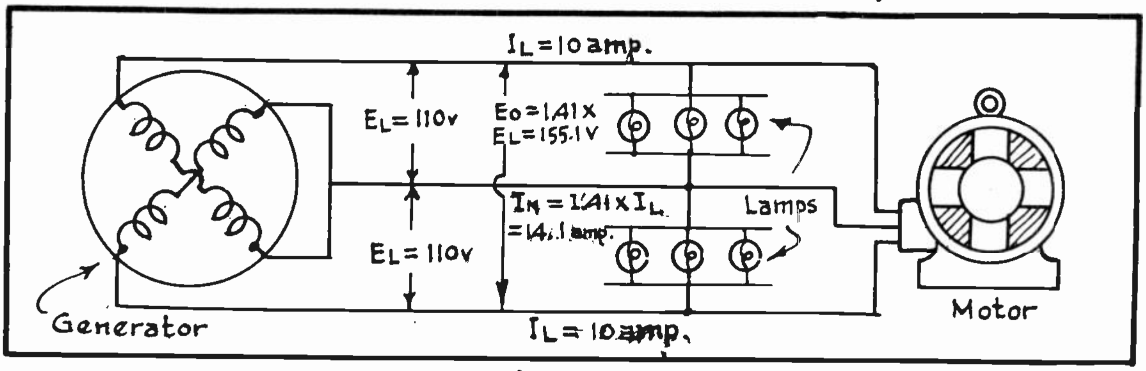


FIG. 5
Two-Phase, Three-Wire System.

THE THREE-PHASE RECTIFIER REQUIRES MUCH LESS FILTERING THAN EITHER SINGLE OR TWO-PHASE.

ANY PHASE OF A POLYPHASE LINE CAN BE USED TO ENERGIZE A SINGLE-PHASE LOAD.

THREE-PHASE CURRENT DISTRIBUTION

THE CURRENT DISTRIBUTION IN THE THREE-PHASE SYSTEM IS ESPECIALLY INTERESTING. TO BEGIN WITH WE FIND THAT IN THE STAR CONNECTION, THE CURRENT IN EACH LINE WIRE IS THE SAME AS THE CURRENT IN EACH PHASE COIL. THIS IS OBVIOUSLY TRUE BECAUSE EACH LINE IS CONNECTED TO A SINGLE COIL. IN THE DELTA CONNECTION, HOWEVER, BECAUSE EACH LINE IS FED BY TWO PHASE-COILS, THE LINE CURRENT IS THE VECTORIAL SUM OF THE TWO PHASE CURRENTS OR 1.73 TIMES THE PHASE CURRENT OF ONE COIL.

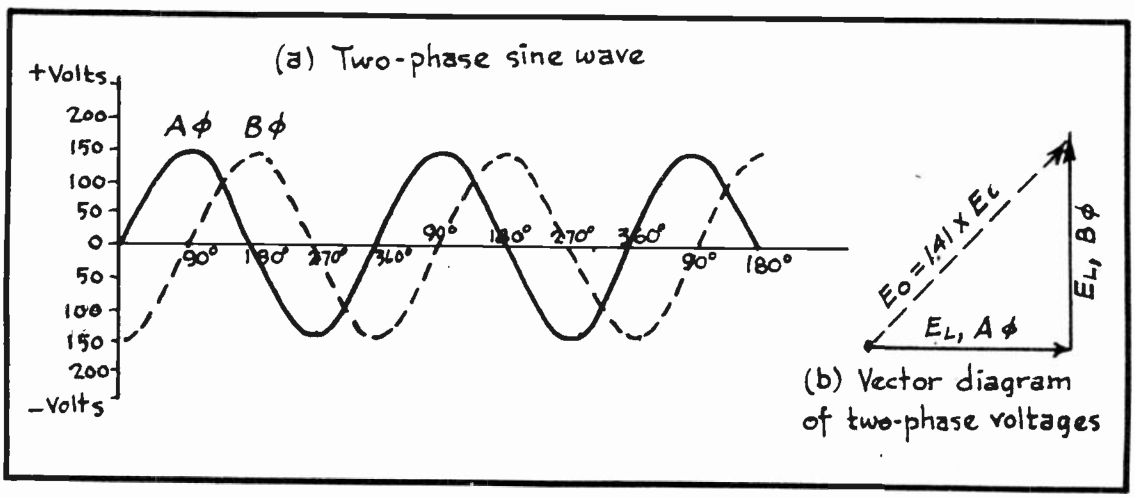


FIG. 6
Graphical Representation of Two Φ Systems.

THE FOUR TRANSFORMER CONNECTIONS IN GENERAL USE ON THREE PHASE LINES ARE: THE DELTA-DELTA (FIG. 9A), THE DELTA-STAR (FIG.9B) THE STAR-STAR (FIG.9C), AND THE STAR-DELTA (FIG.9D).

USUALLY THREE SEPARATE SINGLE PHASE TRANSFORMERS ARE EMPLOYED, BUT IN RECTIFIER CIRCUITS IT IS QUITE COMMON TO USE A SPECIALLY CONSTRUCTED THREE-PHASE TRANSFORMER. THE VOLTAGE TRANSFORMATION OBTAINED DEPENDS UPON THE CONNECTION USED, FOR EXAMPLE, IF E_p IS PRIMARY VOLTAGE, E_s IS SECONDARY VOLTAGE, AND N IS TURNS RATIO THEN:

IN DELTA-DELTA	E_s EQUALS E_p TIMES N
IN DELTA-STAR	E_s EQUALS E_p TIMES N TIMES 1.73
IN STAR-STAR	E_s EQUALS E_p TIMES N
IN STAR-DELTA	E_s EQUALS E_p TIMES N DIVIDED BY 1.73.

THUS WE HAVE A SIMPLE AND CONVENIENT MEANS FOR OBTAINING DIFFERENT OUTPUT VOLTAGES.

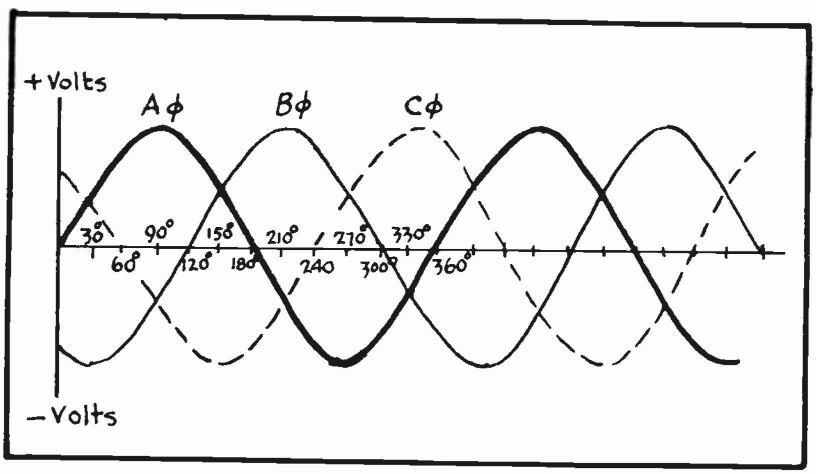


FIG. 7
Three-Phase Sine Wave.

TYPICAL TWO-PHASE CIRCUITS

ALTHOUGH TWO-PHASE CIRCUITS ARE SELDOM ENCOUNTERED, NEVERTHELESS, WE SHOW IN FIG. 10 SOME RECTIFIER HOOK-UPS WHICH ARE ENERGIZED BY THIS TYPE OF SYSTEM.

THREE-PHASE RECTIFIERS

THE THREE-PHASE RECTIFYING CIRCUITS AS USUALLY EMPLOYED USE A DELTA-STAR TRANSFORMER CONNECTION FOR OBTAINING THE HIGH VOLTAGE SUPPLY, AS SHOWN IN FIG. 11. THIS IS DONE PRIMARILY BECAUSE THE CENTER OF THE STAR-CONNECTED SECONDARY FORMS A CONVENIENT NEGATIVE LOAD TERMINAL. A PRIMARY DELTA CONNECTION IS USED BECAUSE BY SO DOING THE VOLTAGE TRANSFORMATION IS INCREASED BY 1.73. THE THREE-PHASE, HALF-WAVE CIRCUIT, YOU WILL SEE BY REFERRING BACK TO FIG. 2A, IS ESSENTIALLY THREE SINGLE-PHASE, HALF-WAVE RECTIFIERS WITH EACH LEG OF THE STAR SECONDARY FORMING ONE PHASE. NOTE THAT THE WAVE-FORM OF THE UNFILTERED OUTPUT MORE NEARLY APPROACHES A CONSTANT D.C. THAN THE OUTPUT OF ANY OF THE SINGLE-PHASE RECTIFIERS.

BY USING TWO THREE-PHASE, HALF-WAVE RECTIFIERS CONNECTED IN PARALLEL, AS SHOWN IN FIG. 12A, IT IS POSSIBLE TO OBTAIN AN OUTPUT WAVE WITH A VERY SMALL RIPPLE. THIS IS ACCOMPLISHED BY ARRANGING THE POLARITIES OF THE TWO STAR SECONDARIES SO THAT WHEN THE OUTPUT VOLTAGE OF ONE THREE-PHASE UNIT IS AT A MINIMUM, THE OUTPUT OF THE OTHER IS AT A MAXIMUM. THE INTERPHASE REACTOR, WHOSE CENTER TAP IS CONNECTED TO THE NEGATIVE OUTPUT TERMINAL, ACTS AS A BALANCE COIL WHICH ENABLES EACH THREE-PHASE UNIT TO OPERATE INDEPENDENTLY. THE THREE-PHASE, FULL-WAVE RECTIFIER CIRCUIT OF

FIG. 12B HAS THE ADVANTAGE THAT ONLY ONE THREE-PHASE SECONDARY IS REQUIRED, AND THE INTERPHASE REACTOR CAN BE DISPENSED WITH. TO PARTIALLY OFFSET THIS, FOUR SEPARATE FILAMENT SECONDARIES ARE REQUIRED. THE OUTPUT WAVE HAS THE SAME FORM AS THAT OF CIRCUIT 12A.

IN ALL OF THE PRECEDING CIRCUITS, IF MERCURY-VAPOR RECTIFIER TUBES ARE USED, SWITCHES SHOULD BE SO INSTALLED THAT THE FILAMENT TRANSFORMERS CAN BE CONNECTED TO THE LINE FROM 40 SECONDS TO ONE MINUTE BEFORE THE HIGH-VOLTAGE TRANSFORMERS ARE TURNED ON. THE FILAMENT SHOULD ALWAYS BE ALLOWED TO COME UP TO FULL OPERATING TEMPERATURE BEFORE THE PLATE VOLTAGE IS APPLIED.

A COMPARISON BETWEEN THESE RECTIFIER CIRCUITS, AS GIVEN BY TABLE I IS INTERESTING.

TABLE I

FIGURE	MAX. PERMISSIBLE INPUT VOLTS (E_i) EFFECTIVE VALUE	D.C. OUTPUT IGNORING DROP IN TUBE AND FILTER	MAX. PERMISSIBLE D.C. OUTPUT CURRENT
2B AND 2C	.353 M.P.I.V.	.85 E_i	.66 M.P.P.C.
2D	.7 M.P.I.V.	.85 E_i	.66 M.P.P.C.
3	1.14 M.P.I.V.	1.7 E_i	.33 M.P.P.C.
11	.41 M.P.I.V.	1.17 E_i	.84 M.P.P.C.
12A	.41 M.P.I.V.	1.17 E_i	2.00 M.P.P.C.
12B	.41 M.P.I.V.	2.34 E_i	1.00 M.P.P.C.

NOTE: M.P.I.V. = MAXIMUM PEAK INVERSE VOLTAGE AT RECTIFIER TUBE.
M.P.P.C. = MAXIMUM PERMISSIBLE PLATE CURRENT OF RECTIFIER TUBE.

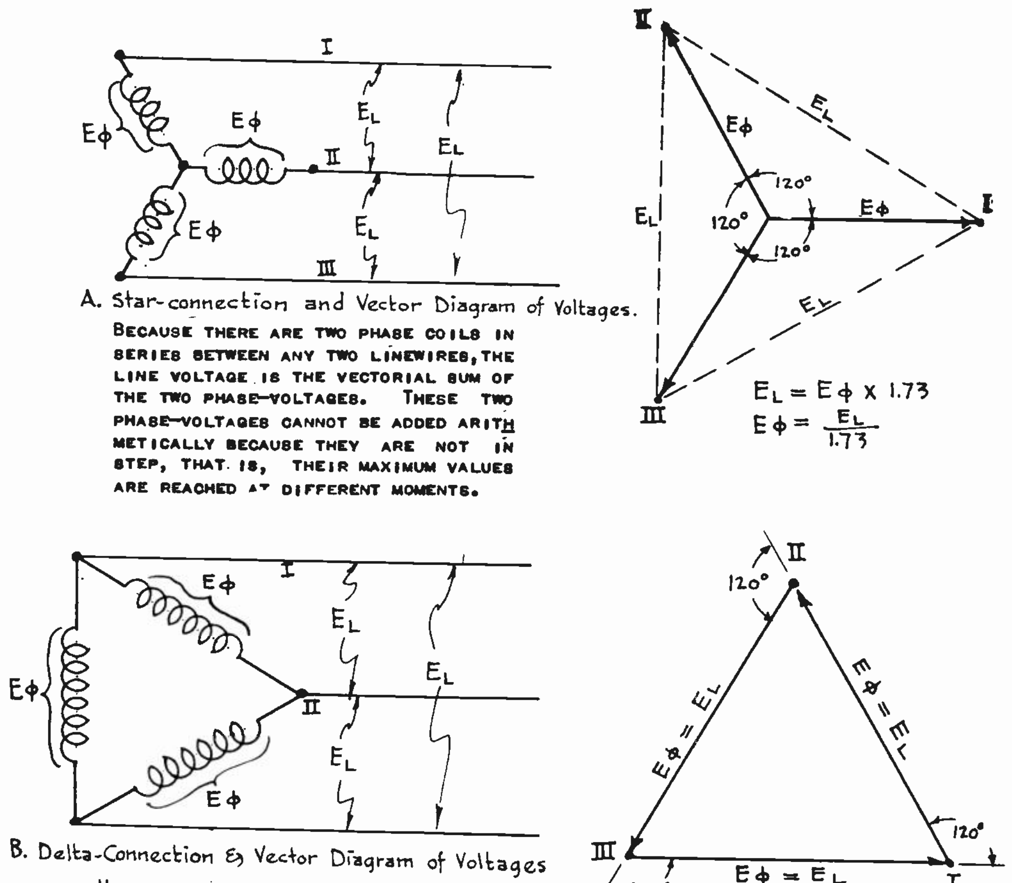
VOLTAGE REGULATION

ALTHOUGH THE EXPRESSION "VOLTAGE REGULATION" IS ALSO QUITE OFTEN USED IN CONNECTION WITH THE POWER PACK OF RECEIVERS YET IT IS STILL MORE FREQUENTLY EMPLOYED RELATIVE TO THE POWER SUPPLY OF TRANSMITTERS. THIS TERM IS USED TO INDICATE THE CHANGE IN TERMINAL VOLTAGE OF A PLATE-SUPPLY SYSTEM WITH DIFFERENT LOAD CURRENTS.

THE WINDINGS OF TRANSFORMERS, FILTER CHOKES ETC. AS USED IN POWER SUPPLY SYSTEMS ALL HAVE A CERTAIN AMOUNT OF RESISTANCE AND THEREFORE AS THE LOAD CURRENT THROUGH THESE WINDINGS INCREASES, THE VOLTAGE DROP ACROSS THEM WILL ALSO INCREASE AND CONSEQUENTLY THE OUTPUT TERMINAL VOLTAGE WILL DECREASE WITH ANY APPRECIABLE INCREASE IN LOAD CURRENT.

BESIDES THE OHMIC RESISTANCE OF THESE WINDINGS, OTHER FACTORS SUCH AS THE GENERAL BEHAVIOR OF THE FILTER UNDER OPERATING CONDITIONS ALSO AFFECT THE VOLTAGE REGULATION OF THE POWER SUPPLY SYSTEM. OBVIOUSLY, THE LESS VARIATION WHICH OCCURS WITH CHANGES IN LOAD CURRENT, THE BETTER WILL BE THE VOLTAGE REGULATION OF THE SYSTEM.

IT IS CUSTOMARY TO EXPRESS THE VOLTAGE REGULATION OF A POWER SUPPLY



A. Star-connection and Vector Diagram of Voltages.
BECAUSE THERE ARE TWO PHASE COILS IN SERIES BETWEEN ANY TWO LINEWIRES, THE LINE VOLTAGE IS THE VECTORIAL SUM OF THE TWO PHASE-VOLTAGES. THESE TWO PHASE-VOLTAGES CANNOT BE ADDED ARITHMETICALLY BECAUSE THEY ARE NOT IN STEP, THAT IS, THEIR MAXIMUM VALUES ARE REACHED AT DIFFERENT MOMENTS.

B. Delta-Connection & Vector Diagram of Voltages
HERE EACH PHASE COIL IS CONNECTED DIRECTLY BETWEEN A PAIR OF LINE WIRES, HENCE LINE-VOLTAGE EQUALS PHASE-VOLTAGE.

FIG. 8
Three-Phase, Three-Wire Systems.

SYSTEM AS A PERCENTAGE. GOOD PLATE VOLTAGE SUPPLIES WILL HAVE A REGULATION OF 10% OR LESS AND THIS FACTOR IS DETERMINED IN THE FOLLOWING MANNER: FIRST THE OUTPUT VOLTAGE OF THE PLATE POWER SUPPLY IS MEASURED AT NO LOAD, THAT IS, WITH NONE OF THE TRANSMITTER TUBES DRAWING ANY "B" CURRENT. THIS DONE, THE OUTPUT VOLTAGE OF THE PLATE POWER SUPPLY IS MEASURED AT NORMAL LOAD, THAT IS, WITH THE TRANSMITTER DRAWING ITS NORMAL

AMOUNT OF "B" CURRENT. WE THEN SUBTRACT THE "NORMAL LOAD" VOLTAGE FROM THE "NO LOAD" VOLTAGE AND DIVIDE THIS DIFFERENCE BY THE NO LOAD VOLTAGE. THIS RESULTING QUOTIENT WILL BE THE VOLTAGE REGULATION EXPRESSED AS A DECIMAL FRACTION.

TO MORE CLEARLY ILLUSTRATE THIS MATTER LET US CONSIDER THE FOLLOWING EXAMPLE: WE SHALL ASSUME THAT THE OUTPUT TERMINAL VOLTAGE OF A CERTAIN PLATE POWER SUPPLY IS 2000 VOLTS AT NO LOAD AND 1800 VOLTS AT NORMAL LOAD. THE CORRESPONDING VOLTAGE REGULATION OF THIS SYSTEM WILL THEN BE

$$\frac{2000 - 1800}{2000} = .1 = 10\%.$$

THE VOLTAGE REGULATION OF A TRANSMITTER'S POWER SUPPLY IS A VERY IMPORTANT ITEM AND THIS IS PARTICULARLY TRUE OF RADIO-TELEGRAPH TRANSMITTERS WHERE THE "B" CURRENT WHICH IS DRAWN IS BEING CONTINUALLY VARIED IN INTENSITY DURING THE PROCESS OF KEYING. WERE POOR REGULATION TO EXIST, THE "B" VOLTAGES AT THE TUBES WOULD BE SUBJECT TO CONSIDERABLE VARIATION WHEN KEYING.

FILTERS

THE FILTER CIRCUITS AS USED IN THE PLATE SUPPLY SYSTEM FOR TRANS-

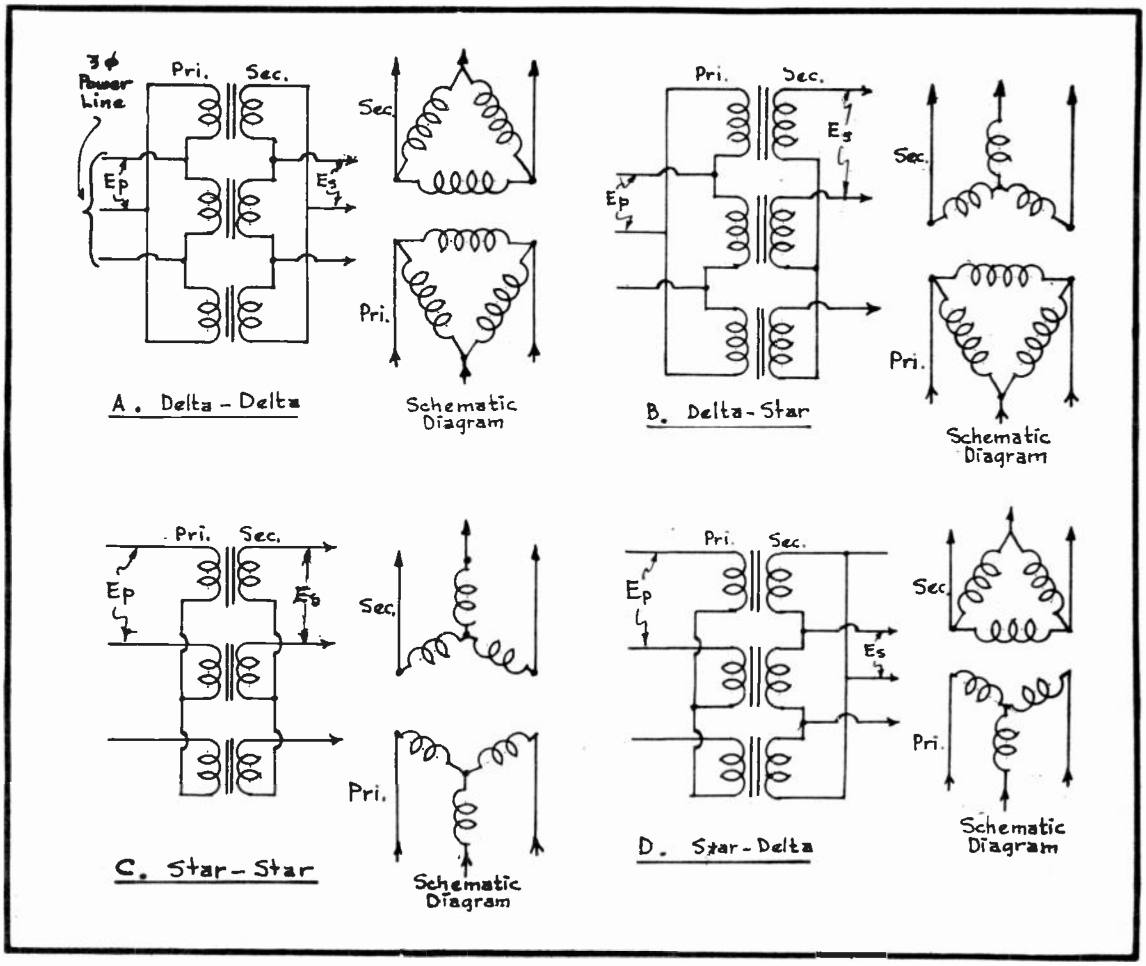


FIG. 9

Three-Phase Transformer Connections.

MITTERS FOLLOW THE SAME GENERAL DESIGN PRINCIPLES AS THOSE ALREADY DESCRIBED TO YOU RELATIVE TO RECEIVERS. THE ESSENTIAL DIFFERENCE BETWEEN THE RECEIVER AND TRANSMITTER FILTER LIES IN THE FACT THAT IN THE TRANSMITTER THE CONSTRUCTION OF THE FILTER MUST BE SUCH THAT THE SYSTEM CAN CARRY THE LARGER CURRENTS AND HANDLE THE HIGHER VOLTAGES SATISFACTORILY.

THE FILTER CONDENSERS AS USED WITH TRANSMITTERS MAY BE OF THE WET ELECTROLYTIC, DRY ELECTROLYTIC, PAPER, OR OIL IMPREGNATED PAPER TYPE. THE ELECTROLYTIC CONDENSERS OF BOTH TYPES HAVE A DISADVANTAGE IN THAT THEY ARE SELDOM CAPABLE OF WITHSTANDING D.C. VOLTAGES HIGHER THAN 500 VOLTS PEAK VALUE, HOWEVER, IT IS POSSIBLE TO CONNECT TWO OR MORE OF THESE CONDENSERS IN SERIES SO THAT THE SERIES COMBINATION MAY TAKE THE PLACE OF A SINGLE CONDENSER IN A CIRCUIT OF RATHER HIGH VOLTAGE. IT IS OF COURSE TO BE UNDERSTOOD THAT A SERIES CONDENSER ARRANGEMENT AS THIS WILL REDUCE

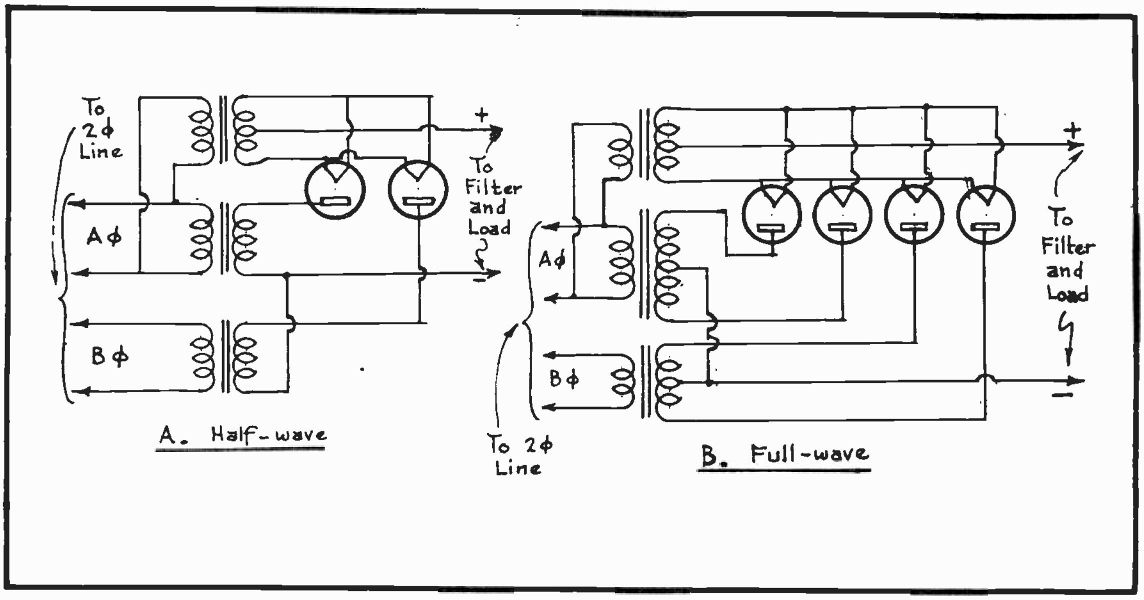


FIG. 10
Two-Phase Rectifier Circuit.

THE OVER-ALL CAPACITY OF THE ARRANGEMENT ACCORDINGLY.

IN FIG. 13 YOU ARE SHOWN A TYPICAL PAPER DIELECTRIC TYPE TRANSMITTING CONDENSER WHICH IS RATED FOR A CAPACITY OF 2 MFD. AND A D.C. WORKING VOLTAGE OF 2000 VOLTS. NOTICE HOW THE TERMINALS ARE SUPPORTED ON SPECIAL STAND-OFF INSULATORS SO THAT THE HIGH VOLTAGES CAN BE HANDLED PROPERLY. CONDENSERS AS THIS CAN BE OBTAINED TO WITHSTAND D.C. VOLTAGES AS HIGH AS 4000 VOLTS.

OIL IMPREGNATED PAPER DIELECTRIC CONDENSERS WILL STAND VOLTAGES STILL HIGHER THAN WILL THOSE OF THE PLAIN PAPER TYPE. THE OIL FREQUENTLY USED FOR THIS PURPOSE IS KNOWN AS PYRANOL AND IT HAS A HIGH DIELECTRIC STRENGTH AS WELL AS OTHER DESIRABLE PROPERTIES WHICH PERMIT THE CONSTRUCTION OF EFFICIENT CONDENSERS.

RIPPLE VOLTAGE

AS YOU WILL RECALL FROM YOUR PREVIOUS STUDIES CONCERNING FILTERS,

THE OUTPUT OF THE CONVENTIONAL FILTER IS NOT ABSOLUTELY UNIFORM IN VALUE BUT STILL HAS IMPOSED UPON IT A CERTAIN AMOUNT OF A.C. VOLTAGE AND WHICH IS GENERALLY REFERRED TO AS RIPPLE VOLTAGE. THE EXTENT OF RIPPLE WHICH IS PRESENT IN THE OUTPUT OF A FILTER IS GENERALLY EXPRESSED AS A PERCENTAGE AND WHICH IS EQUAL IN VALUE TO THE EFFECTIVE VALUE OF THE RIPPLE VOLTAGE DIVIDED BY THE D.C. VOLTAGE. THIS PERCENTAGE OF RIPPLE OFFERS A PRACTICAL MEANS OF COMPARING THE PERFORMANCE OF VARIOUS FILTER CIRCUITS. EXPERIENCE HAS SHOWN THAT A RIPPLE OF 5% OR LESS IS SATISFACTORY AND 1% IS DESIRABLE FOR A C.W. TRANSMITTER WHEREAS FOR RADIOTELEPHONY THE RIPPLE SHOULD NOT EXCEED 0.25% SO THAT THE HUM LEVEL WILL NOT BE OBJECTIONABLE.

OBVIOUSLY, THE PERCENT RIPPLE IS AFFECTED BY THE INDUCTANCE AND CAPACITIVE VALUES WHICH ARE USED IN THE FILTER CIRCUIT. FOR A SIMPLE SINGLE SECTION FILTER SUCH AS ILLUSTRATED AT "A" IN FIG. 15 AND WHICH IS GENERALLY SUFFICIENT IF A RIPPLE OF 5% CAN BE TOLERATED, THE FOLLOWING RELATION HOLDS GOOD:

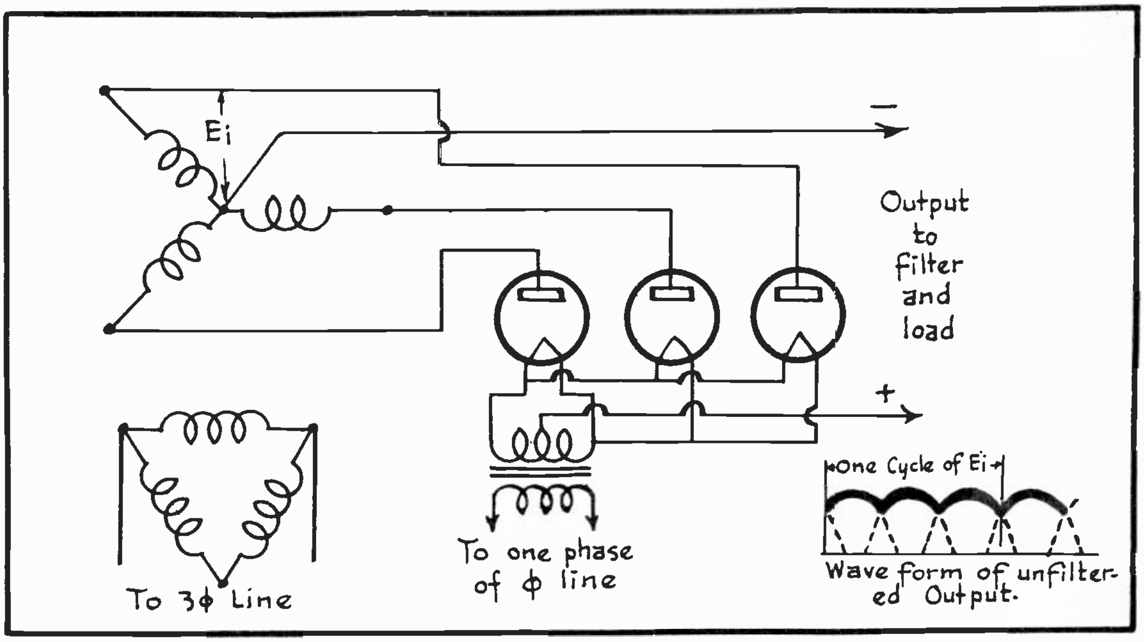


FIG. 11
Three-Phase, Half-Wave Rectifier.

$$\% \text{ RIPPLE} = \frac{100}{L\,C}$$ WHERE L IS EXPRESSED IN HENRYS AND C IN MFDS.

BY TRANSPOSITION, WE HAVE $LC = \frac{100}{\% \text{ RIPPLE}}$ AND FROM WHICH THE LC FACTOR CAN BE OBTAINED. THIS DONE, WE CAN SELECT A PRACTICAL CONDENSER RATING AND DETERMINE THE CORRESPONDING INDUCTANCE RATING FOR THE CHOKE OR VICE VERSA.

FOR A TWO SECTION FILTER SUCH AS THAT WHICH IS ILLUSTRATED AT "B" OF FIG. 15 THE RELATION BECOMES AS FOLLOWS: $\% \text{ RIPPLE} = \frac{650}{L_1 L_2 (C_1 + C_2)^2}$.

IN THIS CASE ALSO, A SUITABLE COMBINATION OF L_1; L_2; C_1 AND C_2 CAN BE DETERMINED TO SATISFY THE FORMULA.

IT IS ALSO WELL TO POINT OUT THIS TIME THAT FOR FILTER SYSTEMS WHICH OPERATE AT HIGH VOLTAGE A CHOKE INPUT FILTER IS PREFERABLE TO A CONDENSER INPUT FILTER. A CHOKE INPUT FILTER OFFERS AS ITS CHIEF CHARACTERISTICS GOOD VOLTAGE REGULATION AND A COMPARATIVELY LOW RECTIFIER TUBE PEAK CURRENT.

THE OPTIMUM VALUE FOR THE INPUT CHOKE INDUCTANCE OF THE FILTER IS

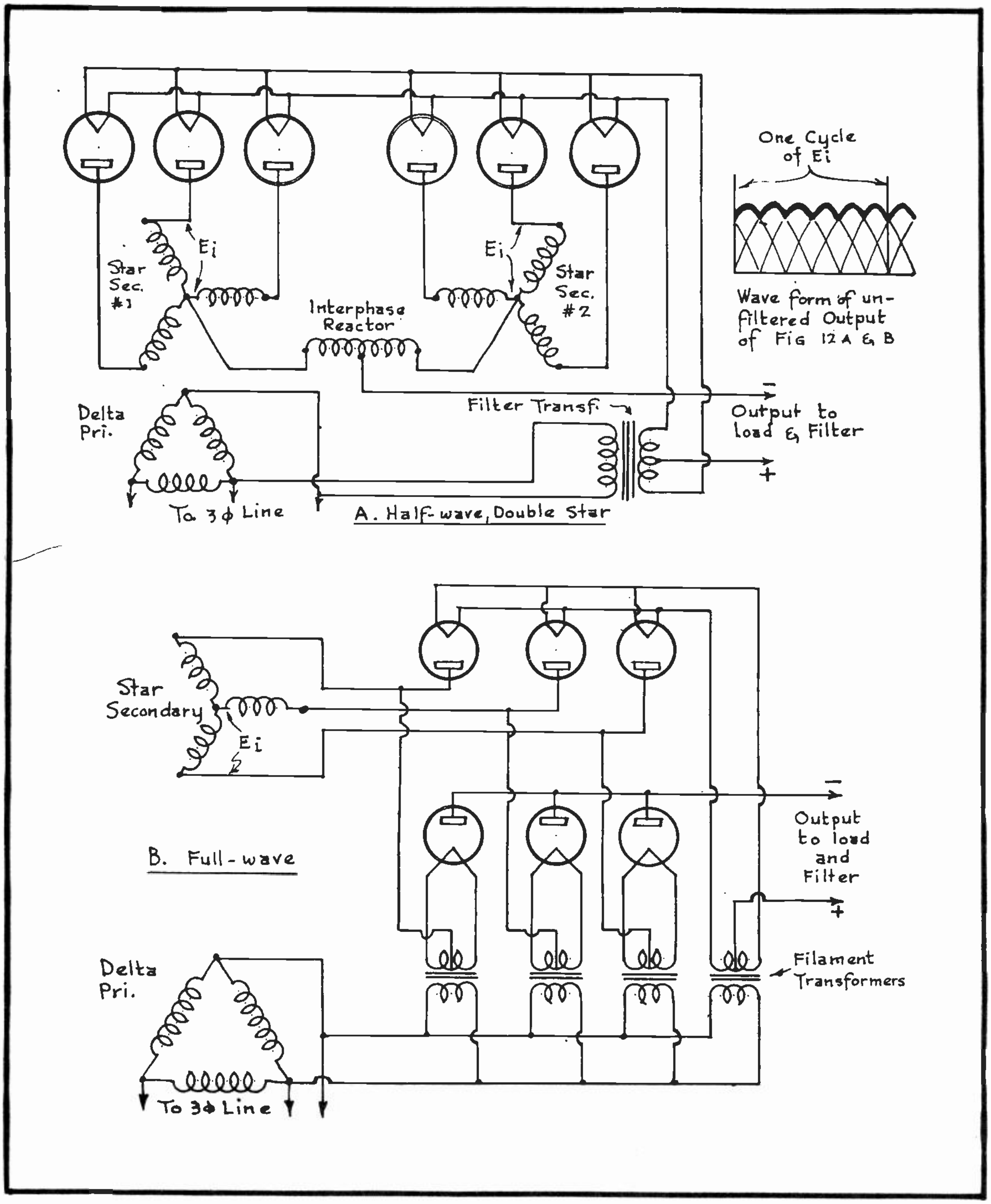


FIG. 12

Three-Phase Rectifier Circuits.

FOUND BY USING THE FOLLOWING FORMULA: $L_{opt.} = \frac{\text{FULL LOAD RESISTANCE}}{500}$ WHERE

L = INDUCTANCE OF CHOKE EXPRESSED IN HENRYS; THE FULL LOAD RESISTANCE IN OHMS IS EQUAL TO THE OUTPUT VOLTAGE DIVIDED BY THE TOTAL LOAD CURRENT IN AMPERES AND 500 IS A CONSTANT.

THE CRITICAL VALUE FOR THIS SAME INPUT CHOKE INDUCTANCE IS FOUND BY USING THE FORMULA:

$$L_{crit.} = \frac{\text{RESISTANCE OF BLEEDER IN OHMS.}}{1000}$$

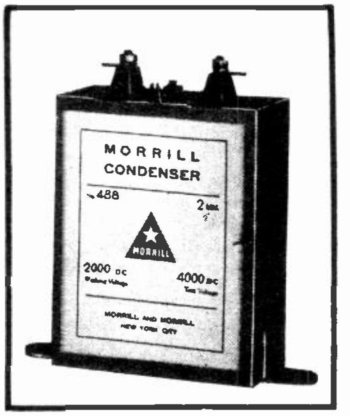


FIG. 13
A Transmitter Condenser.

BY INSPECTING THESE TWO FORMULAS, YOU WILL NOTE THAT TWO DIFFERENT CHOKE VALUES WILL BE OBTAINED, NAMELY THE OPTIMUM AND THE CRITICAL VALUES. ALTHOUGH A CHOKE HAVING THE CRITICAL INDUCTANCE CAN BE USED FOR THIS PURPOSE, YET IT WOULD BE STILL MORE PREFERABLE TO USE A "SWINGING CHOKE" WHOSE INDUCTANCE VALUE VARIES FROM NO LOAD TO FULL LOAD BETWEEN THE LIMITS ESTABLISHED BY THE OPTIMUM AND CRITICAL INDUCTANCE VALUES.

IN THE "B" POWER SUPPLY A BLEEDER RESISTOR IS DESIRABLE THE SAME AS IN RECEIVERS. IT IS A COMMON PRACTICE TO SELECT A BLEEDER RESISTANCE OF SUCH VALUE THAT IT WILL PASS A CURRENT OF ABOUT 10% OR LESS OF THE FULL LOAD CURRENT.

GENERATORS

SO FAR IN THIS LESSON YOU WERE ONLY SHOWN HOW AN EXISTING A.C. POWER SUPPLY CAN BE UTILIZED FOR OPERATING TRANSMITTERS BUT IN ADDITION TO THIS METHOD YOU WILL ALSO FIND GENERATORS AND MOTOR-GENERATORS USED EXTENSIVELY. IN LESSON #39 OF YOUR FOUNDATIONAL TRAINING YOU WERE ALREADY TOLD ABOUT THE OPERATING PRINCIPLES OF THE A.C. GENERATOR AND SO IF NECESSARY, IT IS ADVISABLE THAT YOU REVIEW LESSON #39 AT THIS TIME BEFORE CONTINUING WITH THE PRESENT LESSON REGARDING D.C. GENERATORS, MOTOR-GENERATOR SETS, CONVERTERS ETC.

FIG. 14
Oil-Filled Condensers

THE D.C. GENERATOR

BY TAKING THE SIMPLE A.C. GENERATOR WHICH WAS SHOWN YOU IN LESSON #39 AND MAKING SOME MINOR CHANGES, A D.C. GENERATOR CAN BE PRODUCED. FOR EXAMPLE, BY LOOKING AT FIG. 16 OF THE PRESENT LESSON YOU WILL SEE A LOOP PLACED IN A MAGNETIC FIELD BUT INSTEAD OF USING TWO COLLECTOR RINGS, WE ARE ONLY USING ONE AND EVEN THIS IS CUT IN HALF, SO THAT ITS ENDS ARE SEPARATED FROM EACHOTHER. WE DON'T REFER TO THIS AS A

COLLECTOR RING NOW BUT WE CALL IT A COMMUTATOR AND EACH HALF OR SECTION OF THE COMMUTATOR IN FIG. 16 IS REFERRED TO AS A COMMUTATOR SEGMENT.

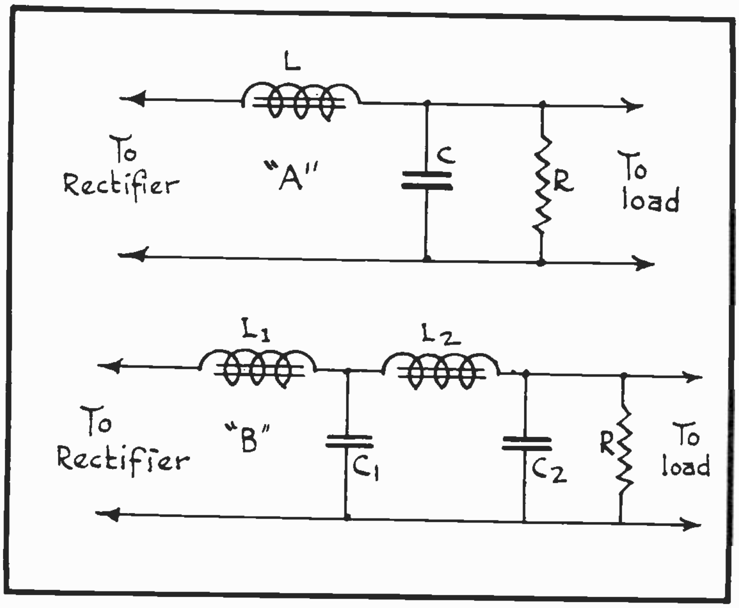


FIG. 15
Typical Filter Circuits.

SEGMENT A OF THIS COMMUTATOR IS CONNECTED TO THE END OF THE LOOP ON SIDE E AND SEGMENT B IS CONNECTED TO THE LOOP END ON SIDE F. NOW THEN, WITH THE LOOP BEING ROTATED IN THE DIRECTION AS INDICATED, BY SOME MECHANICAL FORCE, SIDE F WILL BE CUTTING LINES OF FORCE IN A DOWNWARD DIRECTION AND SIDE E WILL BE CUTTING THEM IN AN UPWARD DIRECTION, AND AS A RESULT, THE INDUCED OR GENERATED CURRENT WITHIN THE LOOP WILL FLOW FROM SIDE F TOWARDS AND INTO COMMUTATOR SEGMENT B. BRUSH D IS AT THIS TIME MAKING CONTACT WITH SEGMENT B AND SO THIS GENERATED CURRENT FLOWS THROUGH BRUSH D AND OVER THE EXTERNAL CIRCUIT. THIS SAME CURRENT THEN FLOWS FROM THE EXTERNAL CIRCUIT INTO BRUSH C, THROUGH WHICH IT ENTERS COMMUTATOR SEGMENT A AND SIDE E OF THE LOOP. SO HERE AGAIN WE HAVE A COMPLETE CIRCUIT WITH THE GENERATED CURRENT FLOWING OVER THE EXTERNAL CIRCUIT FROM BRUSH D TO BRUSH C, AND BRUSH D IS AT THIS TIME THE (+) BRUSH AND C IS THE (–) BRUSH. WITHIN THE LOOP, THE CURRENT IS FLOWING FROM SEGMENT A TOWARD SEGMENT B.

ACTION TAKING PLACE AFTER ROTATING THE D.C. GENERATOR LOOP 180°

AFTER THE LOOP HAS BEEN ROTATED A HALF REVOLUTION OR 180°, THE LOOP WILL COME TO THE POSITION AS PICTURED IN FIG. 17 AND HERE YOU WILL SEE THAT THE COMMUTATOR SEGMENTS, TOGETHER WITH THE LOOP, HAVE CHANGED THEIR POSITIONS WITH RESPECT TO THE BRUSHES. THAT IS, SEGMENT A IS MAKING CONTACT WITH BRUSH D, JUST THE OPPOSITE TO THE POSITIONS OCCUPIED IN FIG. 16.

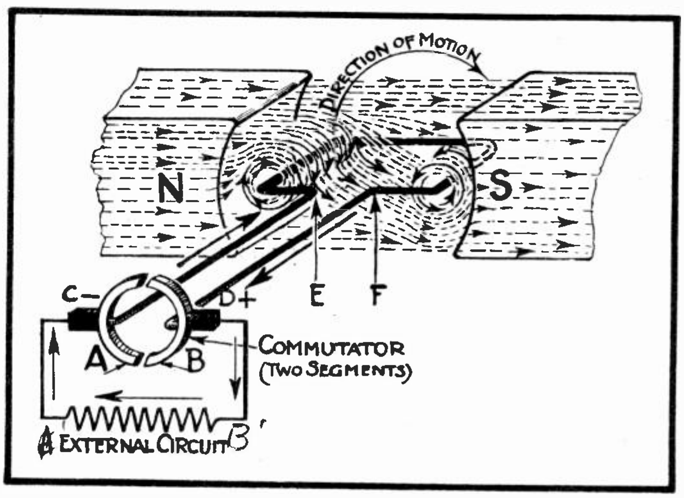


FIG. 16
The Simple D.C. Generator.

NOW IN FIG. 17, SIDE E OF THE LOOP WILL BE CUTTING LINES OF FORCE IN A DOWNWARD

DIRECTION, WHILE SIDE F IS CUTTING THEM IN AN UPWARD DIRECTION AND AS A RESULT, THE GENERATED CURRENT ON SIDE E WILL FLOW TOWARD AND INTO COMMUTATOR SEGMENT A, THENCE THROUGH BRUSH D OVER THE EXTERNAL CIRCUIT AND THROUGH BRUSH C INTO COMMUTATOR SEGMENT B AND THUS BACK INTO SIDE F OF THE COIL.

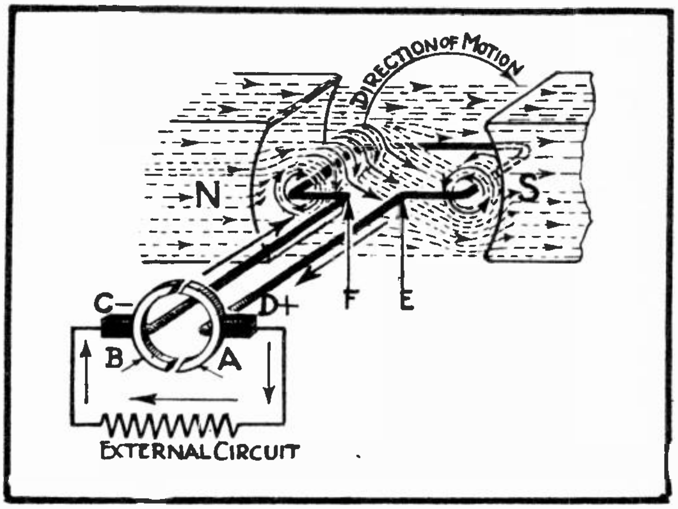


FIG. 17
Current Flow over External Circuit.

A DIRECT CURRENT SENT OVER THE EXTERNAL CIRCUIT

NOTICE ESPECIALLY IN FIG. 17 HOW THE GENERATED CURRENT FLOWS OVER THE EXTERNAL CIRCUIT FROM BRUSH D TO BRUSH C AND THIS, YOU WILL NOTICE, IS THE SAME DIRECTION THAT IT FLOWED IN FIG. 16. NOW TAKE A LOOK AT THE LOOP ITSELF IN FIG. 17 AND YOU WILL SEE THAT WITHIN THE LOOP, THE GENERATED CURRENT IS FLOWING FROM SEGMENT B TOWARD SEGMENT A AND THIS FLOW IS IN THE OPPOSITE DIRECTION TO WHICH THE CURRENT WAS FLOWING WITHIN THE LOOP IN FIG. 16. THIS SHOWS YOU THAT ALTHOUGH AN ALTERNATING CURRENT IS ACTUALLY GENERATED IN THE LOOP, YET THE COMMUTATOR ARRANGEMENT MAKES IT POSSIBLE TO SEND A DIRECT CURRENT OVER THE EXTERNAL CIRCUIT. THUS BRUSH D IS A POSITIVE AND BRUSH C IS A NEGATIVE BRUSH IN BOTH OF THESE ILLUSTRATIONS AND THEIR POLARITY NEVER REVERSES BUT REMAINS THE SAME.

BY USING BUT A SINGLE LOOP OR INDUCTOR IN EITHER A D.C. OR A.C. GENERATOR, IT IS EVIDENT THAT THE DELIVERED CURRENT WILL BE VERY IRREGULAR IN ITS FLOW, FOR THERE ARE PERIODS WHEN THE LOOP IS IN A STRAIGHT UP AND DOWN POSITION, AT WHICH INSTANT NO CURRENT IS GENERATED AT ALL. THEREFORE, TO OBTAIN A MORE UNIFORM AND USEABLE CURRENT OUTPUT FOR PRACTICAL PURPOSES, WE USE MANY INDUCTORS OR LOOPS, ARRANGING THEM ON AN IRON FORM OR CORE AND WE CALL THIS ENTIRE REVOLVING UNIT OF THE GENERATOR, THE ARMATURE. THEN IN ORDER TO GENERATE HIGHER VOLTAGES, WE USE COILS MADE UP OF SEVERAL TURNS OF WIRE INSTEAD OF THE LOOPS OF A SINGLE TURN.

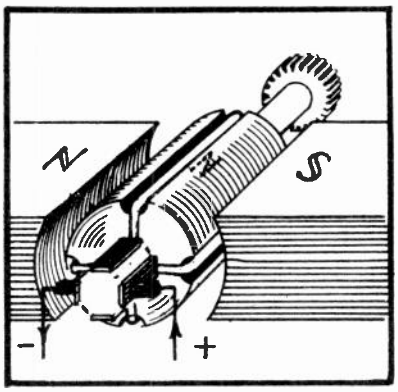


FIG. 18
Motor Details.

ELECTRIC MOTORS

WHILE YOU HAVE THESE GENERATOR PRINCIPLES WELL IN MIND LET US NEXT BECOME BETTER ACQUAINTED WITH ANOTHER IMPORTANT UNIT, WHOSE OPERATING PRINCIPLES ARE CLOSELY RELATED TO THE ELECTRICAL GENERATOR. THIS OTHER UNIT IS THE ELECTRIC MOTOR AND A D.C. MOTOR IS SHOWN IN SIMPLIFIED FORM BOTH IN FIGURES 18 AND 19. THE MOTOR'S PURPOSE IS TO CONVERT ELECTRICAL ENERGY OR POWER INTO MECHANICAL POWER.

IN FIGS. 18 AND 19 WE HAVE TWO MAGNETS,

WITH AN ARMATURE SUPPORTED BETWEEN THEM. THIS ARMATURE CONSISTS OF A LAMINATED IRON CORE, HAVING FOUR SLOTS CUT ALONG ITS LENGTH AND THE INDUCTORS OR WIRE LOOPS ARE FIRMLY HELD IN THESE SLOTS. THE ENDS OF THE LOOPS ARE CONNECTED TO THE SEGMENTS OF THE COMMUTATOR AS SHOWN. TWO BRUSHES ARE INSTALLED, SO AS TO MAKE CONTACT WITH TWO OPPOSITE COMMUTATOR SEGMENTS AND IN THIS WAY, THEY WILL CONNECT THE ENDS OF ONE OF THE ARMATURE LOOPS ACROSS THE EXTERNAL CIRCUIT OR POWER SUPPLY, WHICH IN THIS CASE HAPPENS TO BE A BATTERY.

WITH THE ARMATURE IN THE POSITION SHOWN IN FIG. 19, THE FLOW OF BATTERY CURRENT THROUGH THIS LOOP OR COIL WILL CAUSE IT TO ACT AS AN ELECTROMAGNET, WITH THE UPPER PORTION OF THE ARMATURE BECOMING A NORTH POLE AND THE LOWER PORTION A SOUTHPOLE, JUST AS SHOWN IN FIG. 19. THE VERTICAL LOOP IN FIG. 19 IS DEAD AT THIS TIME, AS NO CURRENT IS FLOWING THROUGH IT.

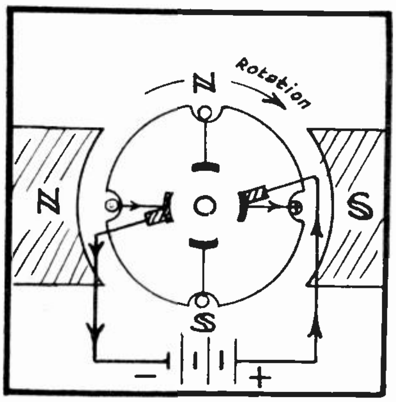


FIG. 19
Simple D.C. Motor

DUE TO THIS POLARIZATION OF THE ARMATURE, THE "S" FIELD MAGNET OF THE MOTOR WILL EXERT AN ATTRACTIVE FORCE UPON THE "N" SECTION OF THE ARMATURE, WHILE AT THIS SAME TIME, THE "N" FIELD MAGNET WILL EXERT AN ATTRACTIVE FORCE UPON THE "S" SECTION OF THE ARMATURE. FURTHERMORE, THE "N" FIELD MAGNET AND THE "N" SECTION OF THE ARMATURE TEND TO REPEL EACHOTHER AND THE SAME IS TRUE IN RESPECT TO THE "S" POLARITIES. IT THUS BECOMES OBVIOUS THAT THIS MAGNETIC REACTION WILL CAUSE THE ARMATURE TO ROTATE IN A CLOCKWISE DIRECTION AS INDICATED BY THE ARROW IN FIG. 19.

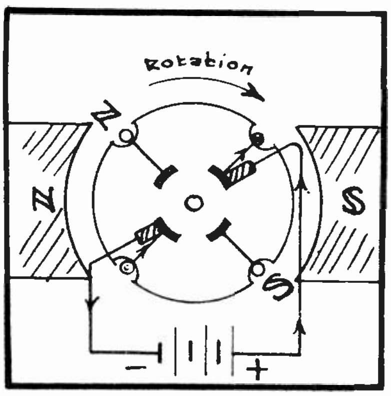


FIG. 20
Commutator Action.

WERE IT NOT FOR THE COMMUTATOR, WE WOULD FIND THAT AFTER THE ARMATURE HAS ROTATED ONE QUARTER REVOLUTION FROM THE POSITION PICTURED IN FIG. 19, THE NORTH SECTION OF THE ARMATURE WOULD COME DIRECTLY UNDER THE INFLUENCE OF THE "S" FIELD MAGNET AND THE SOUTH SECTION OF THE ARMATURE WOULD COME DIRECTLY NEXT TO THE "N" FIELD MAGNET. THE MAGNETIC ATTRACTION WOULD NOW BE SO STRONG AS TO HOLD THE ARMATURE STATIONARY.

TO PREVENT THIS UNDESIRABLE CONDITION, WE MAKE USE OF THE COMMUTATOR AND THE BRUSHES ARE PLACED IN SUCH A POSITION SO AS TO MAKE CONTACT WITH A DIFFERENT PAIR OF COMMUTATOR SEGMENTS BEFORE THE ARMATURE HAS COMPLETED ITS QUARTER REVOLUTION, FROM THE POSITION SHOWN IN FIG. 19. THIS IS CLEARLY SHOWN IN FIG. 20, WHERE YOU WILL NOTICE THAT THE COMMUTATOR SEGMENTS OF THE ARMATURE COIL BEGIN TO COME IN CONTACT WITH THE BRUSHES SOON ENOUGH, SO THAT THE NORTH AND SOUTH SECTIONS OF THE ARMATURE ARE STILL NEAR THE POLE PIECES AT THE INSTANT THAT THIS PARTICULAR ARMATURE COIL SETS UP ITS MAGNETIC FIELD. THIS MEANS THAT THE LIKE MAGNETIC POLES WILL EXERT A VIOLENT REPELLING FORCE TOWARD ONE ANOTHER AND BEFORE THE ARMATURE POLES COME DIRECTLY UNDER THE FACE OF THE FIELD MAGNETS OF OPPOSITE POLARITY, THE COMMUTATOR WILL ALREADY HAVE CAUSED CURRENT TO STOP FLOWING

THROUGH THE COIL IN QUESTION AND TO HAVE PERMITTED THE CURRENT TO NOW FLOW THROUGH THE ARMATURE COIL WHICH WAS FORMERLY DEAD.

THE NEW COIL WILL NOW BECOME THE WORKING COIL AND THUS ANOTHER ROTATIVE IMPULSE IS FURNISHED THE ARMATURE AND JUST BEFORE THESE NEW ARMATURE POLES COME DIRECTLY UNDER THE INFLUENCE OF FIELD MAGNETS OF OPPOSITE POLARITY, THE BRUSHES WILL AGAIN SEND CURRENT THROUGH ANOTHER PAIR OF COMMUTATOR SEGMENTS. THIS ACTION CONTINUES ON IN THIS WAY AND THE ARMATURE KEEPS ON REVOLVING CONSTANTLY AS LONG AS IT IS FURNISHED WITH AN ELECTRIC CURRENT.

THE ROTATION, AS PRODUCED BY ONLY TWO ARMATURE LOOPS, WILL NOT BE UNIFORM BUT THIS CONDITION CAN BE OVERCOME BY USING A GREATER NUMBER OF ARMATURE COILS AND COMMUTATOR SEGMENTS AND THIS YOU WILL FIND TO BE THE CASE IN COMMERCIAL ELECTRIC MOTORS.

MOTOR AND GENERATOR CONSTRUCTION

IN FIG. 21, YOU WILL SEE A PHOTOGRAPH OF A D.C. MOTOR, WITH A SECTION OF THE HOUSING CUT AWAY SO THAT ITS INNER PARTS ARE EXPOSED TO VIEW. NOTICE CAREFULLY IN THIS ILLUSTRATION HOW THE PARTS, WHICH WE HAVE BEEN DISCUSSING, APPEAR ON THE ACTUAL UNIT AND THAT THE FIELD MAGNETS OR POLES ARE ELECTROMAGNETS PROVIDED WITH A WINDING.

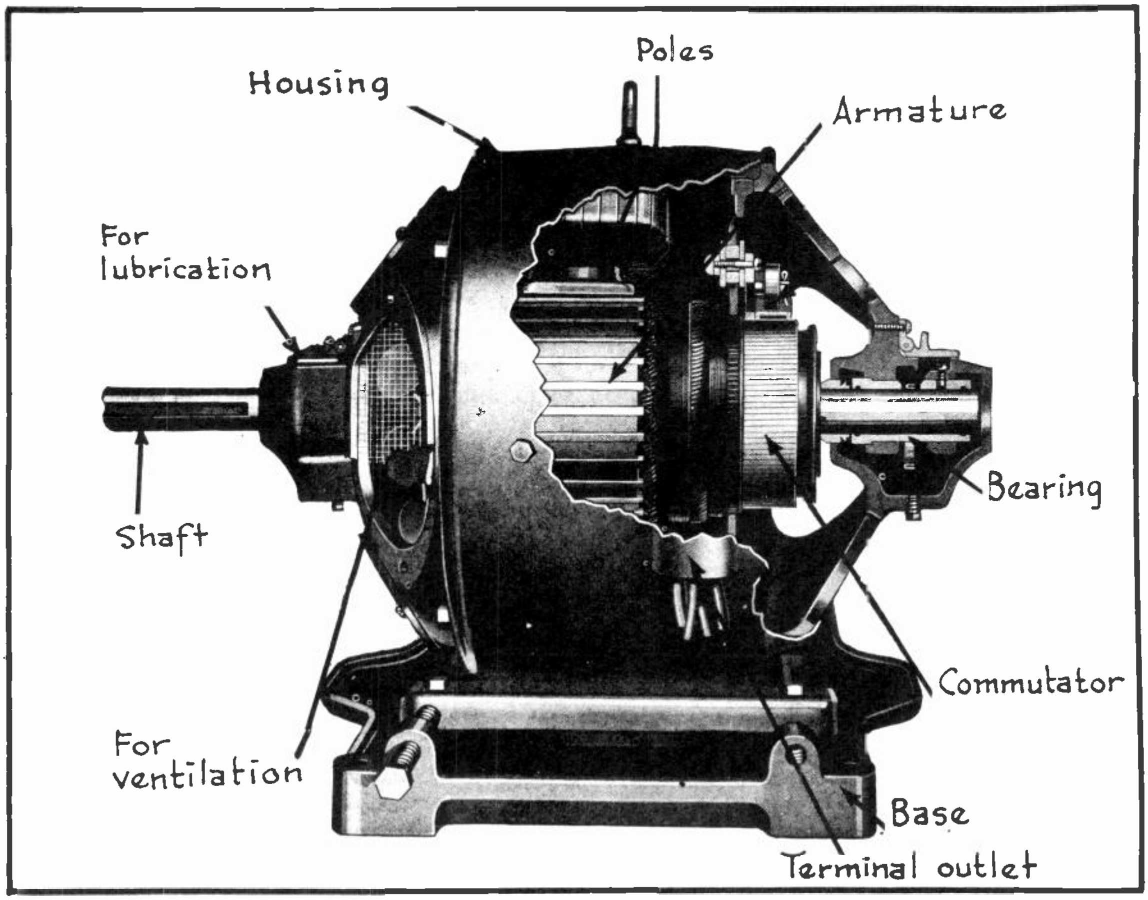


FIG. 21

A Direct Current Motor

Should you open up a direct current generator, you would find its internal construction to be practically the same as that of the motor shown in Fig. 21. In fact, by passing a direct current from some outside source through a D.C. generator, you would find that the generator armature would revolve the same as that of a motor. Then again, should you drive the armature of a motor by some mechanical means you would find that it would to a certain extent act as a generator of electric current.

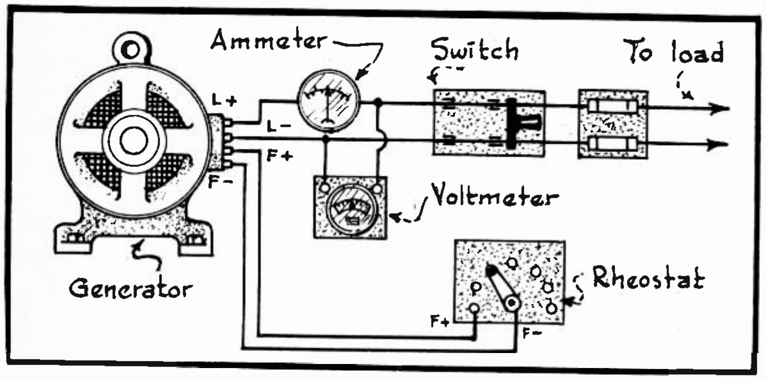


FIG. 22
Typical Generator Control Unit.

The motor, however, can generate but little current while on the other hand a plain generator when operated as a motor does not produce the required mechanical power in order to handle heavy loads as does the motor. Each, therefore, is especially designed to fulfill a definite purpose.

There are of course many types of electric motors and generators and to master all of the more complicated types, require special study. You are being trained as a RADIO SPECIALIST and not as a motor or generator expert. Consequently, there is no need for you to study motors, generators etc. in too great detail but you should be FAMILIAR with this type of equipment, which you may be called upon to use in your radio work.

OPERATING GENERATORS

The correct method of operating generators and motors is an important matter and one which you cannot afford to overlook. A typical control circuit for a generator is shown in Fig. 22 and the generator should be operated according to the methods outlined in the following pharagraphs.

To start the generator, be sure that the line switch is OPEN and that the rheostat control switch is turned to that position, which offers maximum resistance. This point is marked on the rheostat in a self-explaining manner.

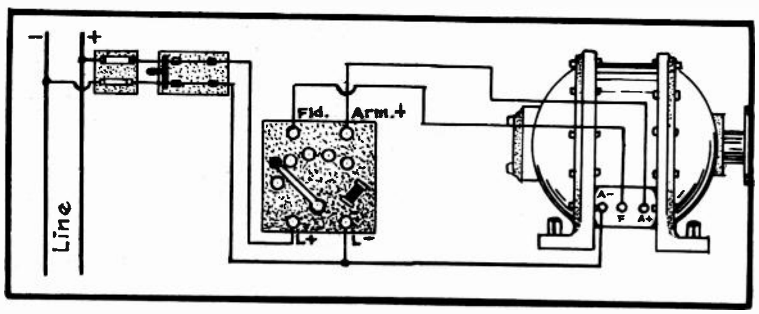


FIG. 23
Typical Motor Control

Now start the generator armature in motion by putting its driving unit into operation. This driving unit may be an electric motor, a gasoline engine, etc. As soon as the generator armature has come up to its full running speed, gradually turn the rheostat

CONTROL KNOB IN THE DIRECTION INDICATED THEREON, UNTIL THE VOLTAGE OF THE GENERATOR COMES UP TO ITS NORMAL VALUE. THIS DONE, CLOSE THE LINE SWITCH, CAREFULLY WATCHING THE VOLTMETER AND AMMETER DURING THIS PROCESS AND MAKE A FURTHER ADJUSTMENT OF THE RHEOSTAT IF NECESSARY, IN ORDER TO BRING THE GENERATOR TO THE REQUIRED OUTPUT.

IN A GREAT DEAL OF THE MODERN GENERATING EQUIPMENT, NO HAND OPERATED LINE SWITCH IS USED BETWEEN THE GENERATOR AND ITS LOAD. IN SUCH A CASE, THIS LINE SWITCH WILL BE REPLACED WITH AN AUTOMATICALLY OPERATING CIRCUIT BREAKER, WHICH AUTOMATICALLY CONNECTS THE GENERATOR TO THE LOAD AS SOON AS THE GENERATOR VOLTAGE COMES UP TO THE REQUIRED POINT.

IN ORDER TO SHUT DOWN THIS GENERATOR, COMMENCE BY TURNING THE RHEOSTAT CONTROL KNOB SO AS TO REDUCE THE GENERATOR OUTPUT. IF AN AUTOMATIC CIRCUIT BREAKER IS USED, IT WILL DISCONNECT THE GENERATOR FROM THE LOAD AT THE PROPER TIME BUT IF NONE IS USED, THEN YOU WILL HAVE TO INTERRUPT THE CIRCUIT WITH THE HAND OPERATED SWITCH BUT NOT UNTIL THE GENERATOR VOLTAGE IS QUITE LOW. ANY OTHER GENERATOR SWITCH, WHICH MIGHT BE USED, CAN NOW BE OPENED AND THE DRIVING MACHINE CAN THEN BE SHUT DOWN.

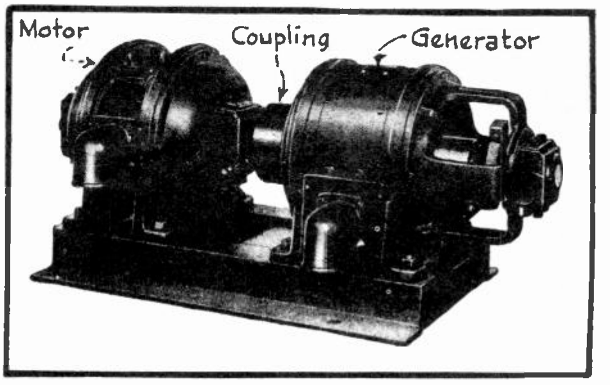


FIG. 24

A Motor Generator Set.

OPERATING MOTORS

ON MANY OF THE SMALLER ELECTRIC MOTORS, ALL THAT MUST BE DONE, IN ORDER TO START THEM, IS TO TURN "ON" A SWITCH. MANY OF THE LARGER MOTORS, HOWEVER, ARE EQUIPPED WITH A STARTING SWITCH OR CONTROL, WHICH ENABLES THE MOTOR TO PICK UP ITS LOAD WITHOUT DRAWING AN EXCESSIVE AND INJURIOUS STARTING CURRENT, AS WELL AS OFFERING A MEANS WHEREBY THE SPEED OF THE MOTOR CAN BE CONTROLLED.

A COMMONLY USED MOTOR CONTROL CIRCUIT IS SHOWN IN FIG. 23. TO START UP SUCH A MOTOR, FIRST SEE TO IT THAT THE CONTROL OF THE STARTING RHEOSTAT IS IN THE "OFF" POSITION AND THEN CLOSE THE MAIN OR LINE SWITCH. NOW GRADUALLY TURN THE RHEOSTAT CONTROL TOWARD THE HIGH OR RUNNING POSITION, PAUSING AT EACH CONTACT FOR A FEW SECONDS AND WAITING FOR THE MOTOR ARMATURE TO PICK UP SPEED OR ACCELERATE UNTIL THE HANDLE REACHES ITS LIMIT OF TRAVEL.

IN ORDER TO STOP THE MOTOR, ALL THAT IS NECESSARY IS TO OPEN THE LINE SWITCH. MOST OF THE STARTING RHEOSTATS ARE SO MADE AS TO CAUSE THE CONTROL ARM TO RETURN TO ITS "OFF" POSITION AUTOMATICALLY. NO ATTEMPT SHOULD BE MADE TO FORCE THE OPERATING ARM OF AN AUTOMATIC STARTING RHEOSTAT BACK TO ITS "OFF" POSITION.

THE MOTOR-GENERATOR

SO FAR, WE HAVE CONSIDERED THE MOTOR AND GENERATOR AS TWO SPEARATE UNITS BUT IN RADIO TRANSMITTING PRACTICE, YOU WILL GENERALLY FIND THE TWO USED TOGETHER IN A COMBINATION, WHICH WE REFER TO AS A MOTOR-GENERATOR. A

TYPICAL MOTOR-GENERATOR SET IS SHOWN IN FIG. 24 AND AS YOU WILL OBSERVE, IT CONSISTS OF A SEPARATE MOTOR AND GENERATOR MOUNTED ON THE SAME BASE, WHILE THEIR ARMATURE SHAFTS ARE COUPLED TOGETHER BY SOME SEMI-FLEXIBLE TYPE COUPLING DEVICE.

ALTHOUGH MOUNTED SO AS TO FORM A SINGLE UNIT, YET FROM AN ELECTRICAL STANDPOINT, THEY ARE ENTIRELY INDEPENDENT FROM EACHOTHER. THE MOST COMMON PRACTICE IS TO USE AN A.C. MOTOR, WHICH IS CONNECTED TO THE A.C. POWER LINES AND THIS MOTOR IN TURN SERVES AS THE DRIVING FORCE TO ROTATE THE GENERATOR ARMATURE. THE GENERATOR IS GENERALLY OF THE D.C. TYPE AND IN THIS WAY, A D.C. SUPPLY FOR THE TRANSMITTER CAN BE GENERATED READILY, EVEN THOUGH THE TRANSMITTER BE LOCATED IN A DISTRICT, WHOSE ONLY POWER SUPPLY IS OF THE A.C. VARIETY.

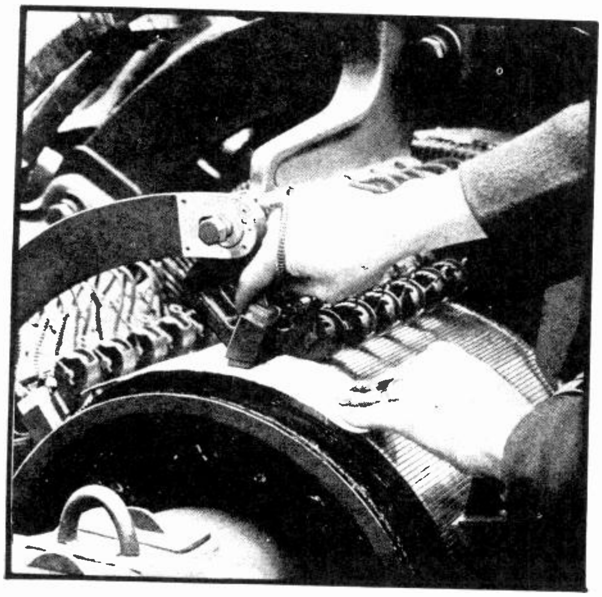


FIG. 25
Sanding the Commutator.

IT IS OF COURSE NOT ALWAYS ESSENTIAL TO USE THIS A.C.-D.C. COMBINATION AS JUST MENTIONED AND THIS SET WOULD STILL BE CLASSIFIED AS A MOTOR-GENERATOR, EVEN THOUGH THE MOTOR WERE OF THE A.C. TYPE DRIVING AN A.C. GENERATOR. THEN TOO, YOU WILL FIND CASES WHERE A SINGLE A.C. MOTOR IS DRIVING TWO OR THREE D.C. GENERATORS, ALL OF WHICH ARE MOUNTED ON A COMMON BASE AND WITH THE ARMATURE SHAFTS ALL CONNECTED END TO END WITH FLEXIBLE COUPLINGS. COMPOUND UNITS AS THIS WOULD STILL BE CLASSIFIED AS MOTOR-GENERATORS.

AS FAR AS THE CONTROL METHODS FOR OPERATING MOTOR-GENERATORS ARE CONCERNED, THEY ARE PRACTICALLY THE SAME AS THOSE OUTLINED FOR THE MOTORS AND GENERATORS SEPARATELY. THAT IS, THE MOTOR PORTION OF THE MOTOR GENERATOR SET IS TREATED AS THOUGH IT WERE AN INDEPENDENT MOTOR AND THE GENERATOR OR GENERATORS, WHICH ARE DRIVEN BY IT, ARE TREATED AS THOUGH THEY WERE INDEPENDENT — IN FACT, THEY ARE.

CARE OF MOTORS AND GENERATORS

ALTHOUGH THESE VARIOUS MOTORS AND GENERATORS MAY APPEAR TO YOU AS BEING RUGGED UNITS OF BRUTE STRENGTH WHEN COMPARED TO GENERAL RADIO EQUIPMENT, YET DON'T BY ANY MEANS OVERLOOK THE FACT THAT THESE MOTORS AND GENERATORS DEMAND AND SHOULD HAVE THE SAME CAREFUL ATTENTION AS THAT GIVEN TO ANY OTHER IMPORTANT PART OF THE TRANSMITTER. A FAILURE OF THEIR OPERATION MEANS THE FAILURE OF THE WHOLE TRANSMITTER.

SINCE MOTORS AND GENERATORS ARE SO MUCH ALIKE IN THEIR CONSTRUCTION, MANY OF THE MINOR TROUBLES WILL BE FOUND TO BE COMMON IN BOTH THESE CLOSELY ASSOCIATED UNITS.

PERIODIC LUBRICATION IS OF UTMOST IMPORTANCE IN ALL TYPES OF MACHINERY

AND MOTORS AND GENERATORS ARE NO EXCEPTIONS. SPECIAL OIL CHAMBERS OR WELLS ARE PROVIDED IN THE BEARING ENDS OF THE UNITS HOUSING AND IT IS ADVISABLE TO SEE THAT THESE ARE ADEQUATELY SUPPLIED WITH THE TYPE OF LUBRICANT RECOMMENDED BY THE MANUFACTURES, EACH TIME BEFORE THE UNIT IS PUT INTO OPERATION.

ANY OIL, WHICH MAY OVERFLOW FROM THE BEARINGS, SHOULD BE WIPED AWAY IMMEDIATELY AND NO DIRT OR DUST SHOULD BE PERMITTED TO ACCUMULATE ANY-WHERES UPON THE UNIT. COMPRESSED AIR OFFERS THE BEST MEANS WITH WHICH TO BLOW OUT DUST OR DIRT FROM A MOTOR OR GENERATOR.

AFTER MOTORS OR GENERATORS HAVE BEEN IN OPERATION FOR SOME TIME, THE COMMUTATOR GENERALLY BECOMES SOMEWHAT ROUGH AND BURNT-LOOKING AND CONTINUOUS SPARKING WILL BE NOTICED BETWEEN THE BRUSHES AND THE COMMUTA-TOR. TO REMEDY THIS CONDITION, HOLD THE ROUGH SIDE OF A PIECE OF #00 SAND PAPER AGAINST THE COMMUTATOR WHILE THE ARMATURE IS REVOLVING, AS SHOWN IN FIG. 25, AND THIS WILL SMOOTH DOWN SLIGHTLY ROUGH SUR FACES. EMERY CLOTH OR EMERY PAPER SHOULD NEVER BE USED FOR THIS PUR-POSE.

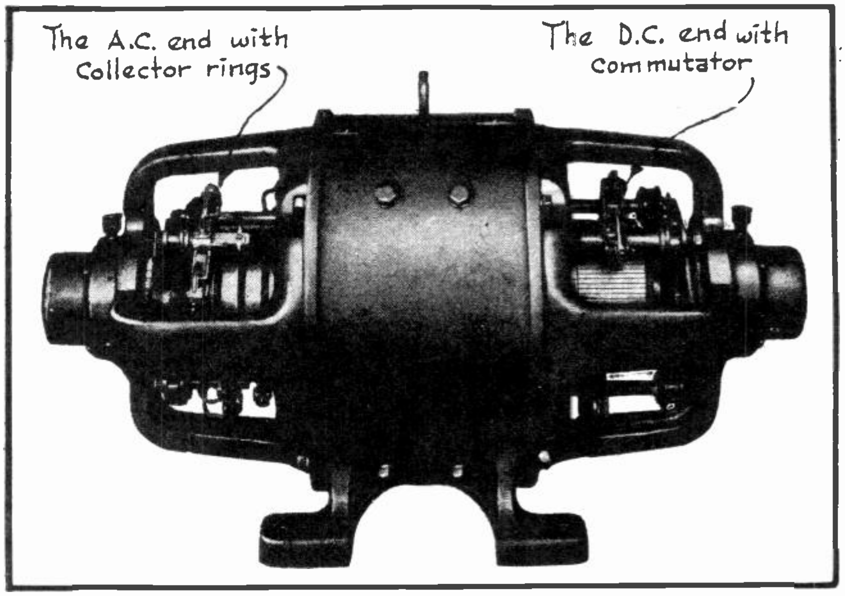


FIG. 26

A Synchronous Converter.
Showing the A.C. and D.C. Ends.

IN EXTREME CASES OF COMMUT-ATOR WEAR, SANDING WILL BE FOUND TO BE INSUFFICIENT AND IN SUCH A CASE, IT BECOMES NECESSARY TO DISMANTEL THE UNIT AND "MACHINE-DOWN" THE COMMU-TATOR IN A LATHE.

BRUSHES IN EITHER A MOTOR OR GENERATOR SHOULD FIT WELL IN THEIR HOLDERS. THIS FIT SHOULD NOT BE LOOSE ENOUGH SO AS TO PERMIT THE BRUSH TO BE JARRED ABOUT AND YET NOT TIGHT ENOUGH SO AS TO PREVENT THE BRUSH SPRINGS FROM EXERTING THEIR FULL FORCE TOWARD PRESSING THE BRUSHES A-GAINST THE COMMUTATOR. THE EDGE OF THE BRUSHES, WHICH RIDES ON THE COMMU-TATOR, SHOULD BE SMOOTH AND MAKING CONTACT ACROSS ITS ENTIRE SURFACE AGAINST THE COMMUTATOR. IN THE CASE OF STICKING BRUSHES, THIS MAY BE FOUND TO BE DUE TO GREASE AND DIRT HAVING ACCUMULATED BETWEEN THE BRUSH AND BRUSH HOLDER AND SHOULD THIS BE TRUE, THESE FOREIGN MATERIALS CAN BE RE-MOVED BY WASHING THE BRUSH AND HOLDER WITH GASOLINE WHILE THE MACHINE IS AT REST — DON'T USE KEROSENE.

IN DUE TIME, THE BRUSHES WILL DECREASE IN LENGTH BECAUSE OF WEAR AND IF THE BRUSHES ARE MATERIALLY SHORTENED BY THIS CAUSE, THEY SHOULD

BE REPLACED WITH NEW ONES OF THE SAME SIZE AND TYPE AS THOSE ORIGINALLY USED IN THE MACHINE AT THE TIME OF ITS CONSTRUCTION.

A GENERAL CHECK-UP SHOULD BE MADE NOW AND THEN, IN ORDER TO INSURE THAT ALL ELECTRICAL CONNECTIONS ARE SECURE AND IN FIRST CLASS CONDITION.

CONVERTERS

NOW ANOTHER POWER UNIT, WHICH IS USED IN RADIO WORK, IS THE ROTARY CONVERTER — SOMETIMES CALLED THE SYNCHRONOUS CONVERTER. THIS UNIT CONSISTS OF A SINGLE ARMATURE, HAVING A.C. COLLECTOR RINGS AT ONE END AND A D.C. COMMUTATOR AT THE OTHER END AND THE SAME ARMATURE WINDING IS USED FOR BOTH ENDS.

ITS PURPOSE IS TO MAKE USE OF AN ALTERNATING CURRENT POWER SUPPLY WHICH IS CONNECTED TO THE A.C. END OF THE UNIT AND THUS DRIVES THE ARMATURE AS AN A.C. MOTOR. THIS REVOLVING OF THE ARMATURE AT THE SAME TIME GENERATES AN ELECTRIC CURRENT AND BY MEANS OF THE COMMUTATOR AT THE OTHER END OF THE UNIT,A DIRECT CURRENT WILL BE DELIVERED FROM IT. IN OTHER WORDS, THE ROTARY CONVERTER IS MADE TO USE AN A.C. SUPPLY, IN ORDER TO PRODUCE A D.C. OUTPUT.

IN THIS RESPECT, THE ROTARY CONVERTER SERVES THE SAME PURPOSE AS A MOTOR-GENERATOR SET BUT FOR RADIO PURPOSES,THE MOTOR-GENERATOR SET IS MOST COMMONLY USED BECAUSE IT DOESN'T INTRODUCE THE A.C. LINE VOLTAGE VARYING CHARACTERISTICS INTO THE D.C. OUTPUT, AS IS THE CASE WITH A ROTARY CONVERTER.

INSTEAD OF SUPPLYING THE CONVERTER WITH AN A.C. SUPPLY IN ORDER TO PRODUCE A D.C. OUTPUT, IT IS EQUALLY TRUE THAT WE CAN HAVE A CONVERTER IN WHICH WE PROVIDE A D.C. SUPPLY AND RECEIVE AN A.C. OUTPUT IN RETURN. THE UNIT THEN BECOMES WHAT IS CORRECTLY CALLED AN INVERTED ROTARY OR SYNCHRONOUS CONVERTER AND ONE SUCH UNIT IS SHOWN YOU IN FIG.26.

IN GENERAL APPEARANCE AND CONSTRUCTION,THE ROTARY CONVERTER AND THE INVERTED ROTARY CONVERTER ARE THE SAME AND THE ONLY DIFFERENCE IS THAT THEIR OUTPUT AND INPUT CHARACTERISTICS ARE REVERSED. FIG.26 SHOWS YOU CLEARLY HOW THE A.C. COLLECTOR RINGS ARE MOUNTED ON ONE END OF THE ARMATURE, WHILE THE D.C. COMMUTATOR IS MOUNTED ON THE OTHER END.

THE INVERTED ROTARY CONVERTER IS ESPECIALLY ADAPTABLE IN SUCH LOCALITIES WHERE A D.C. POWER SUPPLY IS PROVIDED BUT WHERE A.C. RADIO EQUIPMENT HAS TO BE OPERATED. IN FACT, INVERTED ROTARY CONVERTERS ARE NOW BEING MARKETED AT A REASONABLE PRICE, WHICH WILL OPERATE AT 32, 115, OR 230 VOLTS D.C., IN ORDER TO PRODUCE AN OUTPUT OF 110 VOLTS-60 CYCLE A.C., WITH WHICH TO OPERATE RADIO EQUIPMENT.

THE GENERAL CARE, OPERATION AND INSPECTION OF CONVERTERS IS MUCH THE SAME AS OUTLINED FOR YOU IN OUR DISCUSSION OF MOTORS AND GENERATORS.

THE DYNAMOTOR

STILL ANOTHER POWER UNIT IS KNOWN AS THE DYNAMOTOR. THIS DEVICE IS

SIMILAR TO THE CONVERTER IN THAT IT USES A SINGLE ARMATURE, WITH A COMMUTATOR AT ONE END AND COLLECTOR RINGS AT THE OTHER END. THE A.C. AND D.C. PORTION OF THE UNIT MAKE USE OF THE SAME FIELD WINDING, THE SAME AS IN THE CONVERTER BUT THE BIG DIFFERENCE BETWEEN THE DYNAMOTOR AND CONVERTER IS THAT THE DYNAMOTOR HAS TWO SETS OF ARMATURE WINDINGS.

THESE TWO INDEPENDENT ARMATURE WINDINGS, HOWEVER, ARE WOUND TOGETHER IN THE SAME SLOTS BUT ARE THOROUGHLY INSULATED FROM EACHOTHER. ONE OF THE WINDINGS IS CONNECTED TO THE COLLECTOR RINGS, WHEREAS THE OTHER IS CONNECTED TO THE COMMUTATOR. DUE TO THE USE OF SEPARATE WINDINGS THERE IS LESS NEED FOR FILTERING THE D.C. OUTPUT BECAUSE THE A.C. LINE CHARACTERISTICS ARE NOT CARRIED OVER INTO THE D.C. OUTPUT, AS MUCH AS IS THE CASE WHERE THE SAME ARMATURE WINDING IS COMMON TO BOTH THE A.C. AND D.C. PARTS OF THE UNIT, AS FOUND IN THE CONVERTER. LESS INTERFERENCE IS ALSO EXPERIENCED WITH THE DYNAMOTOR THAN WITH THE CONVERTER.

THIS IS A VERY IMPORTANT LESSON AND A GREAT DEAL OF WORK HAS BEEN COVERED HEREIN. IT IS THEREFORE NECESSARY THAT YOU MASTER THIS LESSON THOROUGHLY AND IF NECESSARY TO STUDY IT EVEN A SECOND OR THIRD TIME.

THE DETAILS CONCERNING THE CONSTRUCTION AND OPERATING CHARACTERISTICS OF TRANSMITTER TYPE RECTIFIER TUBES, AS WELL AS THE PRACTICAL OPERATION OF POWER MACHINERY RELATING TO TRANSMITTERS, WILL BE THOROUGHLY EXPLAINED IN LATER LESSONS OF THIS TRANSMITTER SERIES.

IN THE LESSON IMMEDIATELY FOLLOWING, YOU ARE GOING TO HAVE THE OPPORTUNITY OF STUDYING ABOUT THE CONSTRUCTIONAL FEATURES AND CORRECT METHODS OF OPERATING RADIO-TELEGRAPH TRANSMITTERS IN THEIR COMPLETE FORM.

THIS COMING LESSON WILL ANSWER FOR YOU THE MANY QUESTIONS WHICH WOULD PERHAPS ARISE IN YOUR MIND IF YOU WERE PLACED BEFORE A RADIO-TELEGRAPH TRANSMITTER AND TOLD TO OPERATE IT. THIS BEING THE CASE, YOU CAN READILY SEE THAT THIS COMING LESSON IS NOT GOING TO BE ESPECIALLY INTERESTING BUT ALSO OF GREAT TECHNICAL VALUE.

Feb 11, 1942

Examination Questions

LESSON NO. T-10

GH "Its the easiest thing in the world for a man to deceive himself." 10

1. – NAME THE VARIOUS COMPONENTS WHICH CONSTITUTE THE POWER SUPPLY OF THE CONVENTIONAL TRANSMITTER AND EXPLAIN HOW THESE VARIOUS UNITS DIFFER FROM THE CORRESPONDING UNITS AS USED IN RADIO RECEIVERS.

2. – DRAW A CIRCUIT DIAGRAM OF A TWO-PHASE, THREE-WIRE ELECTRICAL SYSTEM AND DESCRIBE ITS ELECTRICAL CHARACTERISTICS, THAT IS, THE VOLTAGE AND CURRENT DISTRIBUTION ETC.

3. – WHAT IS AN OUTSTANDING ADVANTAGE OF USING A THREE-PHASE RECTIFIER SYSTEM FOR A TRANSMITTER?

4. – EXPLAIN WHAT IS MEANT BY THE VOLTAGE REGULATION OF A POWER SUPPLY AND DESCRIBE HOW IT MAY BE DETERMINED.

5. – HOW MAY THE PERCENT OF RIPPLE OF A POWER SUPPLY BE DETERMINED?

6. – DRAW A CIRCUIT DIAGRAM OF A RECTIFYING SYSTEM EMPLOYING A THREE-PHASE, FULL-WAVE ARRANGEMENT.

7. – ILLUSTRATE BY MEANS OF SCHEMATIC DIAGRAMS THE FOLLOWING THREE-PHASE TRANSFORMER CONNECTIONS:
(1) STAR-STAR CONNECTION; (2) DELTA-STAR CONNECTION;
(3) DELTA-DELTA CONNECTION; (4) STAR-DELTA CONNECTION.

8. – EXPLAIN THE OPERATING PRINCIPLES OF A D.C. GENERATOR AND ILLUSTRATE YOUR EXPLANATION BY MEANS OF A DIAGRAM.

9. – DRAW A CIRCUIT DIAGRAM OF A MOTOR CONTROL CIRCUIT AND EXPLAIN HOW YOU WOULD OPERATE THIS SYSTEM.

10. – DRAW A CIRCUIT DIAGRAM OF A GENERATOR CONTROL CIRCUIT AND EXPLAIN HOW YOU WOULD OPERATE THIS SYSTEM.

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RADIO - TELEVISION

Practical • J. A. ROSENKRANZ, Pres. • Training

NATIONAL SCHOOLS

Established 1905

Los Angeles, California

Transmitters

LESSON NO. T-11

RADIO TELEGRAPH TRANSMITTERS

UP TO THIS TIME IN YOUR TRANSMITTER STUDIES, YOU HAVE CENTERED YOUR ENTIRE ATTENTION UPON SPECIFIC SECTIONS OF RADIO TELEGRAPH TRANSMITTERS AND NOW THAT YOU ARE WELL ACQUAINTED WITH THESE VARIOUS PARTS, THE NEXT LOGICAL STEP WILL BE TO STUDY TRANSMITTERS OF THIS TYPE AS A WHOLE. WE SHALL NATURALLY START WITH THE MORE SIMPLE MULTI-TUBE TRANSMITTERS AND GRADUALLY ADVANCE THROUGH THE MORE COMPLEX EQUIPMENT.

A BATTERY OPERATED TRANSMITTER

IN FIG. 2 YOU ARE SHOWN A FRONT AND REAR VIEW OF AN EFFICIENT LOW-POWER BATTERY-OPERATED TRANSMITTER AND THE CIRCUIT DIAGRAM OF THIS SAME UNIT APPEARS IN FIG.3. THIS TRANSMITTER, YOU WILL OBSERVE, CONSISTS OF A PUSH-PULL, TUNED-GRID, TUNED-PLATE OSCILLATOR STAGE IN WHICH A PAIR OF TYPE 30 TUBES ARE EMPLOYED. THE POWER AMPLIFIER IS ALSO OF PUSH-PULL DESIGN AND USES A PAIR OF TYPE -33 TUBES.

COIL L_2 ACTS AS AN AUTO-TRANSFORMER AND FURNISHES SUFFICIENT STEP-UP OF R.F. VOLTAGE TO SWING THE PENTODE GRIDS FOR MAXIMUM EXCITATION. AT THE SAME TIME IT SERVES AS A COUPLING

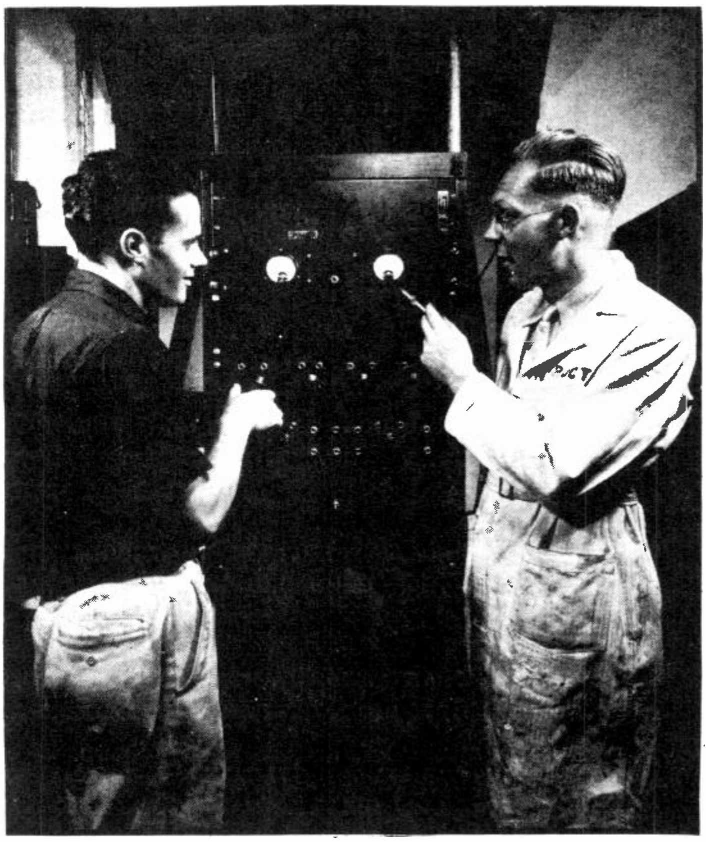
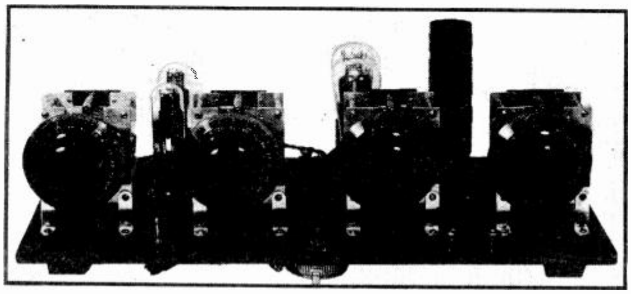


FIG. I
TUNING NATIONAL'S TRANSMITTER.

BETWEEN THE OSCILLATOR AND AMPLIFIER AND ALSO SERVES AS A PART OF THE TUNING SYSTEM IN THE PLATE CIRCUIT OF THE OSCILLATOR.



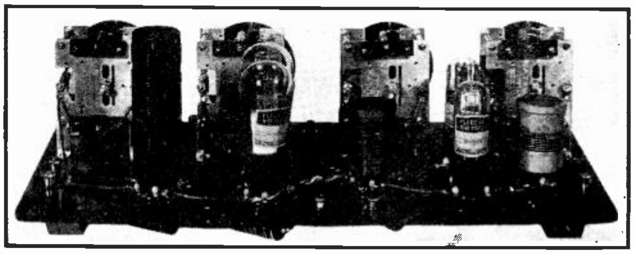


FIG. 2

Front and Back Views of a Battery-Operated Transmitter.

THE NEUTRALIZING CAPACITIES C_7 AND C_8 IN THE POWER AMPLIFIER CIRCUIT ARE MADE BY ATTACHING 4" LENGTHS OF RUBBER COVERED HOOK-UP WIRE TO EACH GRID AND PLATE SOCKET TERMINAL. EACH GRID WIRE IS TWISTED WITH THE PLATE WIRE OF THE OPPOSITE TUBE AND WHEN SUFFICIENT CAPACITY FOR NEUTRALIZATION HAS BEEN OBTAINED IN THIS MANNER, THE REMAINING WIRE IS CUT-OFF. IT IS IMPORTANT THAT THE OPEN ENDS OF THESE WIRES DO NOT MAKE CONTACT AS THIS WOULD SHORT CIRCUIT THE "B" AND "C" BATTERIES.

ALL OTHER CONSTRUCTIONAL FEATURES OF THIS TRANSMITTER WILL BE OBVIOUS UPON STUDYING FIGS. 2 AND 3 CAREFULLY. DATA CONCERNING THE ELECTRICAL VALUES OF THE VARIOUS PARTS USED IN THIS CIRCUIT FOLLOWS:

C_1–C_2–C_3–C_4 ——— 350 MMFD. VARIABLE CONDENSERS.
C_5–C_6–C_9–C_{10} ——— 200 MMFD. FIXED CONDENSERS.
R_1 ——— 10,000 OHM CARBON RESISTOR.
R_2 ——— 2 OHM RHEOSTAT
RFC ——— SHORT-WAVE TRANSMITTING TYPE R.F. CHOKES.
K ——— TELEGRAPH KEY.
SW ——— SWITCH

TABLE I

COIL SPECIFICATIONS					
BAND	L_1 TURNS	L_2 TURNS	X TURNS	L_3 TURNS	L_4 TURNS
1715 Kc	26	40	26	40	12
3500 Kc	14	30	14	30	10
7000 Kc	8	18	8	18	9
14000 Kc	4	10	4	10	7

COILS L_1 AND L_2 ARE BOTH WOUND ON TYPE R-39 NATIONAL COIL FORMS. L_1 IS CENTER-TAPPED AND L_2 IN ADDITION TO BEING CENTER TAPPED ALSO HAS TWO ADDITIONAL TAPS AS SPECIFIED IN TABLE I. THE AMPLIFIER PLATE COIL L_3 AND THE ANTENNA COUPLING COILS L_4 ARE WOUND ON THE SAME BAKELITE FORM WHICH IS 5" LONG AND WHOSE INSIDE DIAMETER IS SUCH AS TO FIT SNUGLY OVER A TUBE

Base to which it is cemented. All of the coils are wound with #20 B&S enameled wire. The coils for the 7000 and 14,000 Kc. bands are single spaced while all others are close-wound.

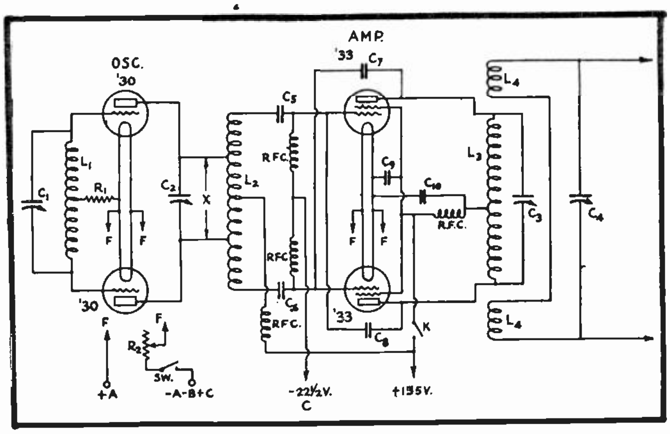


FIG. 3

Diagram of Battery-Operated Transmitter.

The coupling between coils L_3 and L_4 should be varied until the best results are obtained by experiment.

A MEDIUM POWER TRANSMITTER

The complete circuit diagram for an A.C.- operated oscillator- amplifier transmitter appears in Fig. 4. This transmitter is equipped with a type 59 tube operating as a tri-tet oscillator featuring crystal control, and a type 210 tube is used in the power amplifier stage. Separate power packs are used for the oscillator and amplifier stage.

The power pack for the oscillator needs only to furnish a "B" supply of about 15 ma. and therefore for this purpose an ordinary receiver type power supply can be used. This use of a separate power supply for the oscillator permits the oscillator to operate absolutely steady in that it is entirely unaffected by keying of the amplifier. The "B" voltages at the output of this power pack are adjusted for the voltages designated on the diagram by means of the sliding taps on the voltage divider.

The power pack for the amplifier here used must be capable of furnishing a "B" supply of 100 ma. at 450 volts. To meet this demand, this power transformer should develop 600 volts across each side of the center tap and two type-81 tubes or a single 5Z3 may be used as the rectifier. A separate transformer is used for furnishing the filament supply for the

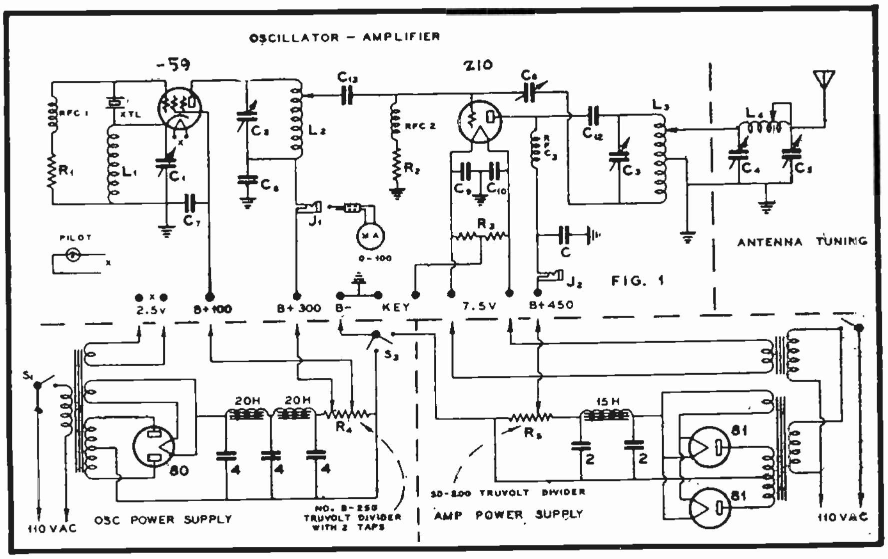


FIG. 4

The A.C. Operated Transmitter.

THE 210 TUBE. SWITCH S_3 IS PROVIDED SO THAT THE B- CIRCUITS CAN BE INTERRUPTED DURING PERIODS OF RECEPTION. IN THIS WAY THE TUBE FILAMENTS ARE PERMITTED TO REMAIN HOT AND THUS PERMIT THE TRANSMITTER TO COME INTO INSTANT OPERATION AS SOON AS THE "B" CIRCUIT IS COMPLETED.

THE PARTS VALUES FOR THE CIRCUIT OF FIG.4 ARE GIVEN TO YOU IN TABLE II.

TABLE II

$C_1-C_2-C_3$	140 MMFD VARIABLE CONDENSERS.
C_4	500 MMFD. " "
C_5	220 MMFD. " "
C_6	50 MMFD DOUBLE SPACED NEUTRALIZING CONDENSER
$C_7-C_8-C_9-C_{10}-C_{11}$	.005 MFD. 1000 VOLT MICA CONDENSERS
C_{12}	.005 MFD. 2500 VOLT MICA CONDENSER
C_{13}	.00025 MFD. 1000 VOLT MICA CONDENSER
R_1	50,000 OHM 2 WATT
R_2	10,000 OHM NON-INDUCTIVE 100 WATT
R_3	60 OHM WIRE-WOUND AND CENTER TAPPED
R_4	25,000 OHM DIVIDER WITH TWO SLIDER TAPS
R_5	20,000 OHM DIVIDER WITH TWO SLIDER TAPS
$RF_1 - RF_2$	8 MH. CHOKES
RF_3	5 MH. HEAVY DUTY CHOKES
J_1-J_2	SINGLE CLOSED CIRCUIT JACKS WITH ONE PHONE PLUG
0-100 MA	0-100 MILLIAMMETER
XTAL	CRYSTAL FOR FREQUENCIES BEING USED

THE COIL DATA FOR THIS SAME TRANSMITTER FOLLOWS:

FOR 40 METERS:

L_1	16 TURNS #20 D.C.C.
L_2	19 TURNS #20 D.C.C. TAPPED AT 14TH TURN
L_3	14 TURNS #14 BARE

FOR 80 METERS:

L_2	30 TURNS #20 D.C.C. TAPPED AT 20TH TURN
L_3	25 TURNS #14 BARE

FOR BOTH BANDS L_1 AND L_2 MAY BE WOUND ON 4 PRONG PLUG-IN FORMS OF 1 3/4" DIAMETER, WHEREAS FORMS OF 2½" DIAMETER AND WHICH ARE SUPPORTED BY STAND-OFF INSULATORS ARE TO BE USED FOR L_3 AND L_4. THE TURNS ARE SPACED EQUAL TO THE DIAMETER OF THE WIRE. L_4 SHOULD CONSIST OF 25 TURNS OF #14 BARE COPPER WIRE.

IN THE PARTICULAR TRANSMITTER WHICH IS ILLUSTRATED IN FIG.4, THE OSCILLATOR AND AMPLIFIER ARE BUILT AS ONE UNIT, THE ANTENNA TUNING ARRANGEMENT AS ANOTHER AND EACH OF THE POWER SUPPLIES IS AN INDIVIDUAL UNIT AND WIRED TO THE TRANSMITTER PROPER. THE JACK ARRANGEMENT PERMITS THE USE OF A SINGLE MILLIAMMETER FOR MEASURING THE PLATE CURRENT OF EITHER THE OSCILLATOR OR THE AMPLIFIER.

TUNING THE TRANSMITTER

THE TUNING OF THIS TRANSMITTER IS CARRIED OUT IN THE FOLLOWING MANNER:

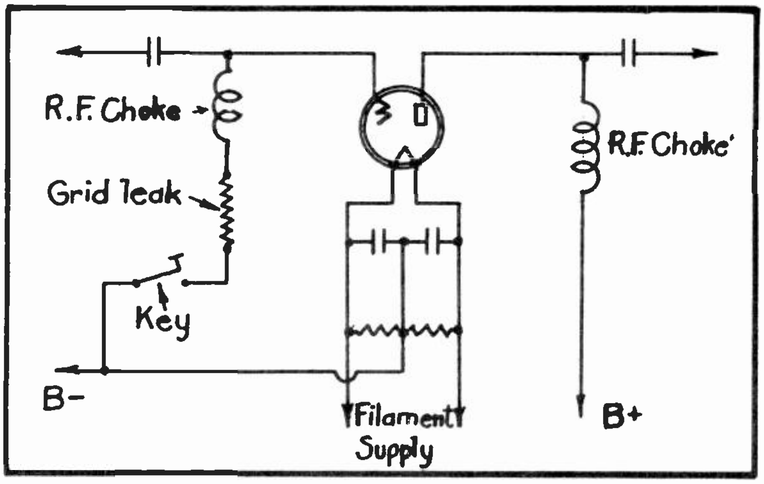


FIG. 5
Grid-leak Keying.

FOR OPERATION ON THE CRYSTAL FREQUENCY, USE THE CORRESPONDING COIL COMBINATION, SHORT OUT THE L_1 SOCKET, CONNECT THE MILLIAMMETER TO JACK J_1, TURN ON BOTH POWER PACKS, LEAVING THE TRANSMITTER KEY IN THE OPEN POSITION SO THAT NO CURRENT IS APPLIED TO THE PLATE OF THE POWER AMPLIFIER.

TURN C_6 AND C_3 TO ZERO. TUNE C_2 FOR MINIMUM PLATE CURRENT — A CRITICAL SPOT WILL BE FOUND BUT THE CONDENSER SHOULD BE SET FOR A LITTLE LOWER CAPACITY THAN THE MINIMUM REQUIRES. TOUCH A NEON TUBE TO THE TOP OF L_3 AND TUNE C_3 FOR MAXIMUM GLOW. NOW TURN IN C_6 SLOWLY (MAKING A SLIGHT READJUSTMENT ON C_2 TO KEEP THE OSCILLATOR STABLE) AND ROCK C_3 BACK AND FORTH UNTIL THE GLOW DISAPPEARS AND CANNOT BE OBTAINED WITH ANY SETTING OF C_3. THE AMPLIFIER TUBE IS THEN NEUTRALIZED.

SWITCH THE MILLIAMMETER TO J_2, PRESS THE KEY (WITH THE AERIAL OFF) AND TUNE C_3 SHARPLY FOR MINIMUM PLATE CURRENT.

IN ORDER TO "DOUBLE" THE CRYSTAL FREQUENCY, USE THE 40 METER COIL COMBINATION AND TUNE C_1 AND C_2 FOR MINIMUM PLATE CURRENT AS INDICATED WHEN THE MILLIAMMETER IS INSERTED IN JACK J_1. TUNE C_3 FOR MINIMUM PLATE CURRENT AS INDICATED WHEN THE MILLIAMMETER IS INSERTED IN JACK J_2.

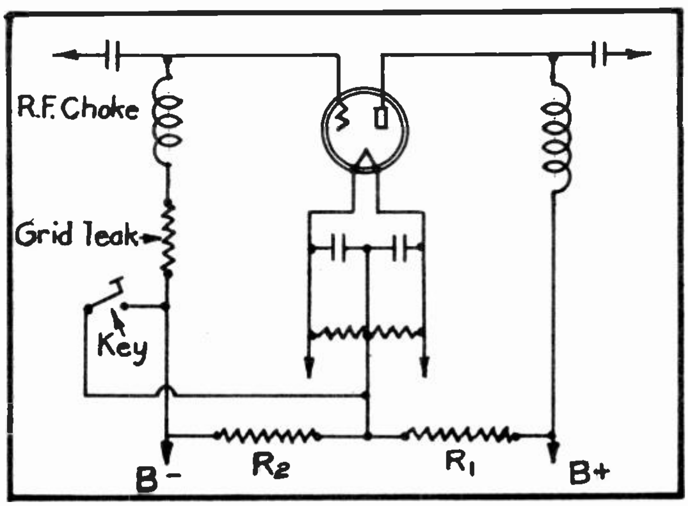


FIG. 6
Blocking Grid With Bias Voltage.

TO ADJUST THE ANTENNA COUPLING CIRCUIT MAKE THE CLIP CONNECTION TO L_3 EXPERIMENTALY AND THE TAP CONNECTION AT L_4 SHOULD BE MADE SO THAT APPROXIMATELY ONE-HALF OF THIS WINDING WILL BE USED. UPON ROTATING C_4 RAPIDLY, WITH C_5 ABOUT HALF IN, A DIP SHOULD BE NOTICED IN THE PLATE CURR-

ENT OF THE POWER AMPLIFIER TUBE. CONTINUE BY ADJUSTING C_5, JUGGLING IT AGAINST C_4 UNTIL THE AMPLIFIER TUBE IS SAFELY LOADED AND AN ANTENNA AMMETER OR FLASHLIGHT LAMP SHOWS A MAXIMUM INDICATION. A 2.5 VOLT PILOT LIGHT FURNISHES A GOOD BRILLIANT INDICATION WITH THE PLATE LOAD ABOUT 65 MA. AT 450 VOLTS.

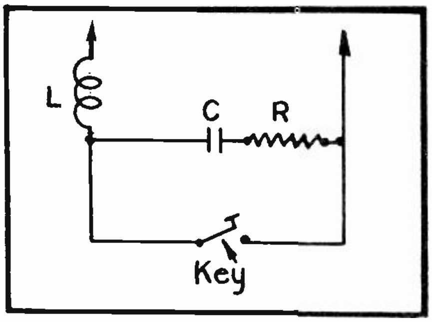


FIG. 7
A Key Filter.

METHODS OF KEYING

BEFORE WE GO INTO DETAILS CONCERNING THE MORE POWERFUL COMMERCIAL TRANSMITTERS THERE ARE SOME IMPORTANT FACTS WHICH WE MUST CONSIDER REGARDING SPECIAL TYPES OF KEYING CIRCUITS WHICH ARE EMPLOYED IN CODE TRANSMITTERS OF MORE ELABORATE DESIGN.

AS YOU WILL HAVE NOTICED FROM THE TRANSMITTER CIRCUITS WHICH WERE SHOWN YOU SO FAR, IT HAS BECOME THE GENERAL PRACTICE TO INCLUDE THE KEY IN THE TRANSMITTER CIRCUIT IN SUCH A MANNER THAT THE "B" CIRCUIT OF A TUBE IS SUCCESSIVELY COMPLETED AND INTERRUPTED IN ORDER TO FORM THE CHARACTERS OF THE CODE. SINCE YOU HAVE ALREADY HAD THE OPPORTUNITY OF INSPECTING MANY CIRCUITS OF THIS TYPE WE SHALL NOT SPEND ANY MORE TIME UPON THEM NOW.

GRID-LEAK KEYING

A SOMEWHAT DIFFERENT KEYING METHOD IS ILLUSTRATED IN FIG. 5. THIS METHOD PERMITS THE PLATE CIRCUIT OF THE TUBE TO BE COMPLETE AT ALL TIMES, AND THE KEY SIMPLY BREAKS THE D.C. GRID RETURN CIRCUIT.

WHEN THE KEY IS IN THE OPEN POSITION THE GRID RETURN CIRCUIT IS ALSO OPEN AND THIS CONDITION WILL CAUSE ELECTRONS TO ACCUMULATE ON THE GRID TO SUCH AN EXTENT THAT THE NEGATIVE CHARGE WILL BECOME GREAT ENOUGH TO BLOCK THE TUBE AND THEREBY PREVENT ANY FURTHER PASSAGE OF PLATE CURRENT THROUGH IT. WHEN USED, THIS METHOD IS MORE SUCCESSFUL WHEN KEYING THE GRID LEAK CIRCUIT OF A TUBE WHICH HAS A HIGH AMPLIFICATION RATHER THAN ONE HAVING A LOW AMPLIFICATION FACTOR. THE REASON FOR THIS IS THAT A LOWER BLOCKING VOLTAGE IS REQUIRED FOR A HIGH-MU TUBE THAN FOR A LOW-MU TUBE. IT IS ALSO IMPERATIVE THAT GOOD INSULATION BE USED IN THE KEY WHEN EMPLOYING THIS SYSTEM, OTHERWISE SOME OF THE ELECTRON CHARGE MAY LEAK OFF THE GRID AND THEREBY PERMIT SOME PLATE CURRENT TO FLOW EVEN THOUGH THE KEY BE OPEN. ANY SUCH RESULTING RADIATION WHICH OCCURS DURING SPACES IN KEYING IS CALLED A "BACK-WAVE" AND IS OF COURSE UNDESIRABLE.

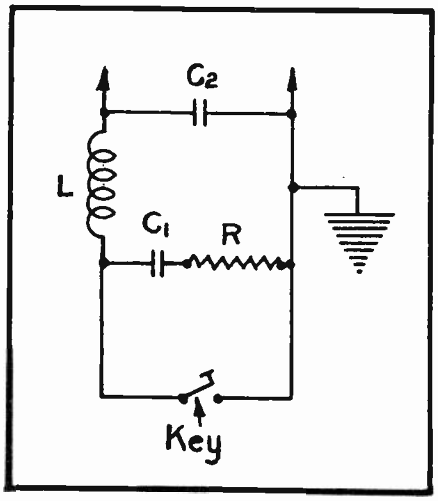


FIG. 8
Another Key Filter.

ANOTHER BLOCKED-GRID KEYING METHOD

IN FIG. 6 YOU ARE SHOWN A CIRCUIT WHICH ALSO HAS THE KEY INSTALLED IN THE

GRID RETURN CIRCUIT BUT INSTEAD OF DEPENDING UPON THE TUBE TO BLOCK ON ACCOUNT OF AN EXCESSIVE ELECTRON ACCUMULATION WHEN THE GRID RETURN CIRCUIT IS INTERRUPTED, THE CIRCUIT OF FIG. 6 ACTUALLY APPLIES A DEFINITE SURPLUS BIAS VOLTAGE TO THE TUBE'S GRID SO THAT THE TUBE IS ABSOLUTELY ASSURED OF BLOCKING.

BY STUDYING FIG. 6 CLOSELY, YOU WILL OBSERVE THAT THE BLOCKING BIAS IS OBTAINED FROM THE PLATE SUPPLY THROUGH A VOLTAGE DIVIDER. THE CENTER-TAP OF THE TUBE'S FILAMENT IS CONNECTED TO THE JUNCTION OF R_1 AND R_2 AND THE GRID RETURN IS CONNECTED TO THE NEGATIVE SIDE OF THE POWER SUPPLY. THEREFORE, WHEN THE KEY IS OPEN, THE VOLTAGE DROP ACROSS R_2 IS APPLIED AS BIAS TO THE GRID OF THE TUBE. THIS SERVES AS ADDITIONAL BIAS, CAUSING THE TUBE TO BLOCK WHEN THE KEY IS OPEN.

UPON CLOSING THE KEY, R_2 IS SHORT-CIRCUITED, THEREBY REDUCING THE BIAS VOLTAGE THE PROPER AMOUNT SO THAT THE TUBE CAN OPERATE NORMALLY. RESISTOR R_1 MAY BE THE REGULAR BLEEDER RESISTOR FOR THE POWER SUPPLY AND R_2 CAN IN THE MAJORITY OF CASES HAVE A VALUE OF ABOUT ONE-HALF THAT OF R_1.

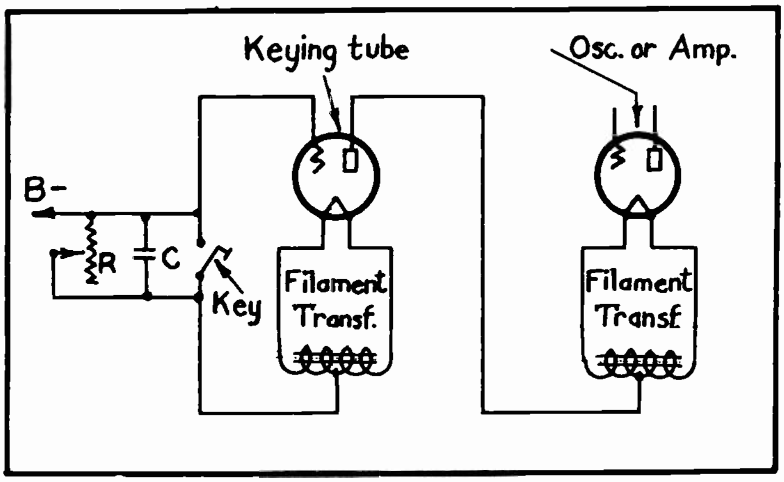


FIG. 9
The Vacuum Tube Keying Method.

IN MULTI-STAGE TRANSMITTERS EMPLOYING AMPLIFIERS OF HIGH POWER OUTPUT, IT IS GENERALLY THE PRACTICE TO INSTALL THE KEY IN ONE OF THE LOW-POWER AMPLIFIER STAGES PRECEDING THE FINAL STAGE. IN SUCH A CASE, EVEN THOUGH THE FINAL POWER AMPLIFIER IS AT ALL TIMES OPERATING, YET IT RECEIVES NO EXITATION NOR DELIVERS ANY POWER OUTPUT EXCEPT WHEN THE KEY IS DEPRESSED IN THE INTERMEDIATE STAGE. HOWEVER, WHEN USING THIS METHOD, IT IS IMPORTANT THAT ALL TUBES FOLLOWING THE KEYED STAGE SHOULD BE FURNISHED WITH A SUFFICIENT BIAS VOLTAGE SO AS TO CUT OFF THE PLATE CURRENT THROUGH THESE TUBES WHEN NO EXITATION IS PRESENT. IF THIS IS NOT DONE, EXCESSIVE PLATE CURRENT FLOWING THROUGH THE FINAL TUBES MAY DAMAGE THEM.

AS A RULE IN MULTI-STAGE TRANSMITTERS, THE KEY IS NOT INSTALLED IN THE OSCILLATOR CIRCUIT SO THAT THE OSCILLATOR MAY REMAIN IN OPERATION CONTINUOUSLY DURING THE KEYING PROCESS.

WHEN KEYING IN AN INTERMEDIATE STAGE, THERE IS ALSO LESS POSSIBILITY FOR BACK-WAVES BEING EMITTED AND ALSO "KEY CLICKS" BECOME LESS BOTHERSOME.

KEYING TROUBLES

IN THE ELEMENTARY TYPE OF KEYING CIRCUITS WITH WHICH YOU ARE NOW FAMILIAR, A CERTAIN FORM OF INTERFERENCE IS SOMETIMES PRODUCED AND WHICH

MAKES ITS PRESENCE KNOWN AS CLICKING OR THUMPING SOUNDS IN NEARBY RECEIVERS EVEN THOUGH THESE RECEIVERS BE TUNED TO FREQUENCIES FAR REMOVED FROM THE OPERATING FREQUENCY OF THE TRANSMITTER IN QUESTION. THIS DISTURBANCE IS KNOWN AS "KEY CLICKS".

THESE KEY CLICKS ARE GENERALLY CAUSED BY STRAY OSCILLATIONS OF SHORT DURATION THAT ARE PRODUCED BY THE RAPID STARTING AND STOPPING OF POWER OUTPUT DURING THE PROCESS OF KEYING. THESE STRAY OSCILLATIONS OR "TRANSIENT OSCILLATIONS", AS THEY ARE FREQUENTLY CALLED, DO NOT HAVE A DEFINITE FREQUENCY AND SPREAD OVER A CONSIDERABLE PORTION OF THE FREQUENCY SPECTRUM. FORTUNATELY, THESE INTERFERRING RADIATIONS DO NOT TRAVEL FAR FROM THE TRANSMITTER BUT NEVERTHELESS THEY ARE EXTREMELY ANNOYING TO THE OPERATORS OF NEARBY RECEIVERS.

THESE TRANSIENT OSCILLATIONS CAN BE PREVENTED BY SLOWING UP THE RATE AT WHICH THE POWER IS APPLIED TO THE TRANSMITTER BUT CARE MUST BE EXERCISED SO THAT THIS SLOWING UP IS NOT CARRIED OUT TO AN EXTREME DEGREE, OTHERWISE THE KEYING WILL NOT BE CLEAR.

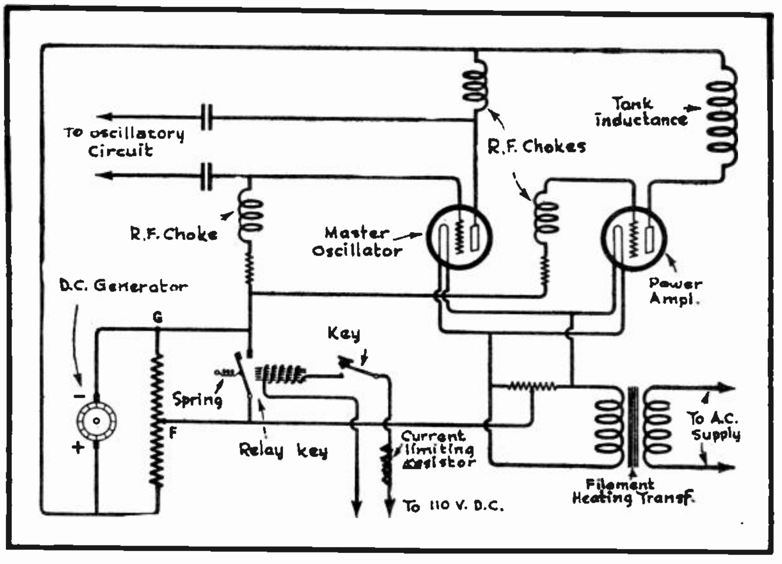


FIG. 10
Application of the Relay Key.

APPLICATION OF KEY FILTER

ONE METHOD OF PREVENTING KEY CLICKS IS TO RETARD THE OTHERWISE SUDDEN APPLICATION OF POWER TO THE TRANSMITTER AND THIS CAN BE ACCOMPLISHED BY THE FILTER SYSTEM WHICH IS ILLUSTRATED IN FIG. 7. THIS FILTER, YOU WILL OBSERVE, CONSISTS OF AN INDUCTANCE CONNECTED IN SERIES WITH THE KEY CIRCUIT. AN INDUCTANCE, YOU WILL RECALL, HAS A NATURAL TENDENCY OF OPPOSING ANY SUDDEN CHANGE IN CURRENT FLOW WHICH PASSES THROUGH IT.

THE INTRODUCTION OF THE INDUCTANCE IN THE KEY CIRCUIT, HOWEVER, IS LIKELY TO CAUSE SPARKING AT THE KEY CONTACTS AND TO PREVENT THIS A CONDENSER C AND RESISTOR R ARE CONNECTED ACROSS THE KEY AS ALSO SHOWN IN FIG. 7. QUITE OFTEN, THE RESISTANCE HERE USED IS OF THE VARIABLE TYPE SO AS TO PERMIT ADJUSTMENT.

THE VALUE OF THE INDUCTANCE ORDINARILY NEEDS BE ONLY OF A RELATIVELY SMALL VALUE, RANGING FROM A LARGE R.F. CHOKE OF AROUND 10 MILLIHENRYS UP TO AN IRON CORE CHOKE OF A FEW HENRYS INDUCTANCE. THIS VALUE CAN BE DETERMINED BY EXPERIMENT — THE INDUCTANCE SHOULD JUST BE SUFFICIENT TO PREVENT CLICKS AND NO MORE. THE CONDENSER AS USED HERE SHOULD ORDINARILY HAVE A CAPACITY OF FROM 0.25 TO 1 MFD. AND IF VARIABLE, A MAXIMUM RESIS-

TANCE OF 50 TO 100 OHMS.

IT ALSO FREQUENTLY HAPPENS THAT OSCILLATIONS ORIGINATE IN THE KEY CIRCUIT AND TRAVEL OVER THE POWER LINES. SUCH OSCILLATIONS CAN BE PREVENTED FROM BECOMING BOTHERSOME BY USING THE ARRANGEMENT SHOWN IN FIG.8. HERE YOU WILL OBSERVE THAT THE INDUCTANCE, CONDENSER, AND RESISTOR COMBINATION IS STILL RETAINED AND THAT AN ADDITIONAL CONDENSER C_2 IS ALSO CONNECTED ACROSS THE LINES LEADING TO THE KEY. THE VALUE FOR C_2 IS APPROXIMATELY 0.1 MFD.

THAT SIDE OF THE LINE WHICH IS CONNECTED TO THE LOW POTENTIAL SIDE OF THE TRANSMITTER (GENERALLY B−) IS INDICATED IN FIG. 8 BY THE GROUND SYMBOL. TO USE THESE FILTER CIRCUITS TO THE BEST ADVANTAGE THE FILTER SHOULD BE INSTALLED AS CLOSE AS POSSIBLE TO THE KEY.

IT IS ALSO DESIRABLE TO INSTALL AN INTERFERENCE ELIMINATING FILTER BETWEEN THE POWER SUPPLY OF THE TRANSMITTER AND THE POWER LINE FROM WHICH IT IS OPERATED. FILTERS OF THIS TYPE WERE ALREADY DESCRIBED TO YOU IN AN EARLIER LESSON TREATING WITH RADIO INTERFERENCE.

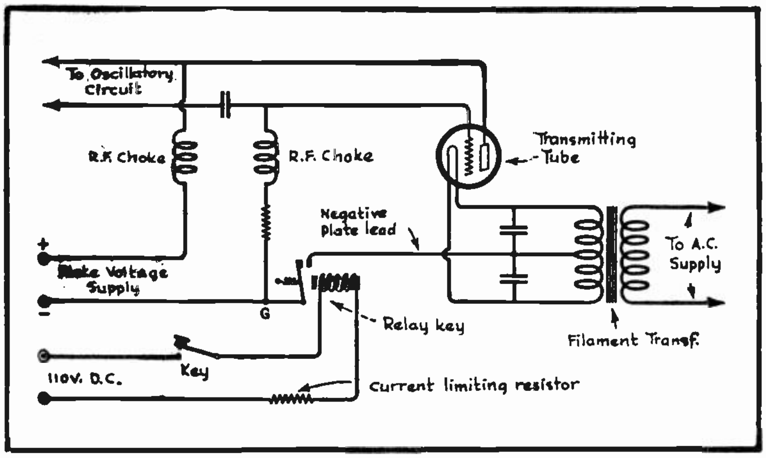


FIG. 11

Another Application of the Relay Key.

THE VACUUM TUBE KEYING METHOD

IN FIG. 9 YOU ARE SHOWN AN ARRANGEMENT IN WHICH A VACUUM TUBE IS USED TO REPLACE THE INDUCTANCE-CAPACITY FILTER IN THE KEYING CIRCUIT. HERE YOU WILL OBSERVE THAT A SPECIAL TUBE KNOWN AS THE "KEYING TUBE" IS SO PLACED IN THE CIRCUIT THAT ALL "B" CURRENT FLOWING THROUGH THE TUBE TO BE KEYED MUST ALSO FLOW THROUGH THE KEYING TUBE IN ORDER TO REACH THE LOW POTENTIAL SIDE OF THE CIRCUIT OR B−.

THE KEY IS INSTALLED IN THE GRID CIRCUIT OF THE KEYING TUBE IN SUCH A MANNER THAT WHEN THE KEY IS IN THE OPEN POSITION, THE FLOW OF PLATE CURRENT THROUGH R WILL CAUSE A VOLTAGE DROP OF SUFFICIENT MAGNITUDE ACROSS IT AND WHICH WHEN APPLIED AS A GRID BIAS TO THE KEYING TUBE WILL CAUSE THIS TUBE TO BLOCK AND THEREBY PREVENT ANY FURTHER PASSAGE OF PLATE CURRENT THROUGH EITHER THE KEYING TUBE OR THE ACTUAL TRANSMITTER TUBE WHICH IS BEING KEYED.

WHEN THE KEY IS CLOSED, RESISTOR R WILL BE SHORT CIRCUITED AND THUS REMOVE THE BIAS VOLTAGE FROM THE KEYING TUBE. THIS TUBE THEN ACTS LIKE A RESISTANCE OF LOW VALUE AND THUS PERMITS THE PLATE CURRENT OF THE TUBE WHICH IS BEING KEYED TO FLOW THROUGH IT. WHEN LARGER CURRENTS ARE BEING

HANDLED, SEVERAL KEYING TUBES ARE FREQUENTLY CONNECTED IN PARALLEL. THIS METHOD OF KEYING ALSO ASSISTS IN THE SUPPRESSION OF ANY TRANSIENT RADIATION WHICH ORIGINATES FROM THE KEYING PROCESS.

THE RELAY KEY

IN TRANSMITTERS OF HIGHER POWER RATING THE KEY ITSELF IS NOT GENERALLY INCLUDED IN THE CIRCUIT IN WHICH THE ACTUAL KEYING IS DONE. INSTEAD, A SPECIAL RELAY KEY IS USED AND THE CIRCUIT IN FIG. 10 SHOWS YOU ONE TYPICAL METHOD IN WHICH THIS IS DONE.

BY STUDYING FIG. 10 CLOSELY, YOU WILL OBSERVE THAT THE KEY RELAY CONSISTS OF AN IRON CORE AROUND WHICH IS PLACED A WINDING. THIS WINDING IS CONNECTED IN SERIES WITH THE REGULAR KEY AND A SEPARATE VOLTAGE SOURCE AND WHICH IN THE CASE OF FIG. 10 IS A 110 VOLT D.C. SUPPLY. A RESISTOR LIMITS THE FLOW OF CURRENT THROUGH THE RELAY COIL.

THIS RELAY KEY IS ALSO PROVIDED WITH AN ARMATURE OR PIVOTED ARM AND ON WHOSE EXTREMETY IS ATTACHED A CONTACT POINT. ANOTHER CONTACT POINT REMAINS STATIONARY.

A SPRING NORMALLY HOLDS THE ARMATURE OF THE RELAY KEY IN THE POSITION SHOWN IN FIG. 10 AND AT WHICH TIME THE CONTACT POINTS ARE SEPARATED.

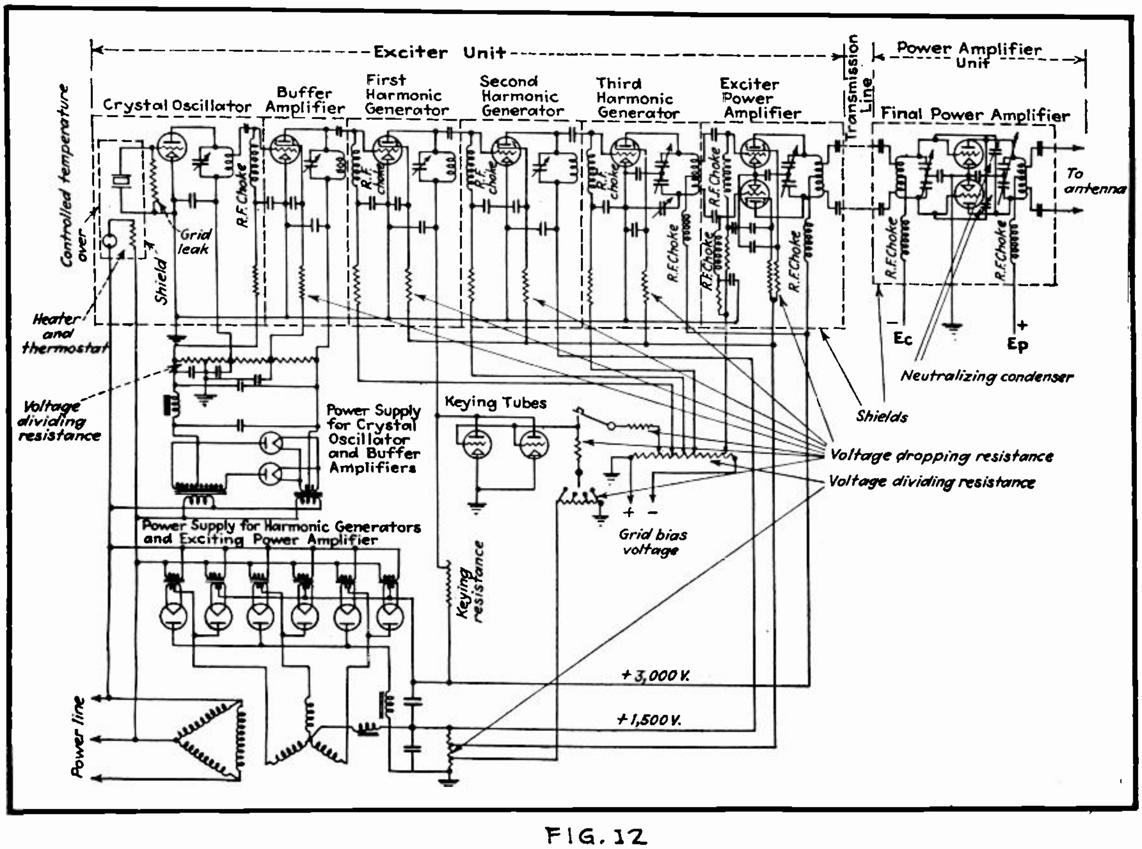


FIG. 12

Circuit Diagram of a 20-40 KW. R.C.A. Short-Wave Code Transmitter.

WHEN THE HAND KEY IS CLOSED, DURING SENDING, THE CIRCUIT THROUGH THE RELAY COIL IS COMPLETED AND THE RESULTING MAGNETIC FIELD THEREBY ESTABLISHED CAUSES THE RELAY ARMATURE TO BE PULLED TOWARDS THE IRON CORE, RESISTING THE SPRING TENSION AND IN THIS WAY CLOSES THE CONTACT POINTS OF THE RELAY. THESE RELAY CONTACT POINTS AT THIS TIME COMPLETE THE KEYING CIRCUIT OF THE TRANSMITTER.

UPON OPENING THE HAND KEY, THE MAGNETIC FIELD OF THE RELAY KEY COLLAPSES AND SPRING TENSION CAUSES THE CONTACTS OF THE RELAY KEY TO SEPARATE. THUS BY OPERATING THE HAND KEY IN THE CONVENTIONAL MANNER, THE RELAY KEY AUTOMATICALLY TAKES CARE OF KEYING THE TRANSMITTER CIRCUIT.

THE ARRANGEMENT IN FIG. 10 IS SUCH THAT WHEN THE KEY IS OPEN, THE VOLTAGE DROP APPEARING ACROSS RESISTOR SECTION G-F IS APPLIED AS A BIAS VOLTAGE TO THE TRANSMITTER TUBES HERE SHOWN. THE BIAS VOLTAGE AT THIS TIME IS GREAT ENOUGH TO BLOCK THE TUBES. UPON CLOSING THE HAND KEY, THE CLOSING OF THE RELAY CONTACTS SHORT CIRCUITS THE BIASING RESISTOR AND PERMITS THE TUBES TO FUNCTION NORMALLY.

ANOTHER APPLICATION OF THE RELAY KEY IS SHOWN YOU IN FIG. 11. HERE THE RELAY CONTACTS CONTROL THE COMPLETION AND INTERRUPTION OF BOTH THE NEGATIVE LEAD OF THE PLATE CIRCUIT AND THE TUBE'S GRID RETURN CIRCUIT. THE HAND KEY CONTROLS THE OPERATION OF THE RELAY KEY IN THE SAME MANNER, AS HAS ALREADY BEEN DESCRIBED.

A HIGH-POWER SHORT-WAVE COMMERCIAL CODE TRANSMITTER

IN FIG. 12 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF A HIGH-POWER SHORT WAVE COMMERCIAL CODE TRANSMITTER WHICH IS DESIGNED TO OPERATE WITHIN A FREQUENCY RANGE OF 6670 KC. TO 21,500 KC. AT ITS LOWER FREQUENCY LIMIT IT IS CAPABLE OF FURNISHING AN OUTPUT OF 50 KW. AND AT ITS HIGHEST FREQUENCY SETTING AN OUTPUT OF 23 KW.

THIS TRANSMITTER IS DIVIDED INTO TWO DISTINCT PARTS, NAMELY, AN EXITER UNIT WHICH CONTAINS THE CRYSTAL OSCILLATOR, BUFFER AMPLIFIER, FREQUENCY MULTIPLIERS (HARMONIC GENERATORS) AND A POWER AMPLIFIER WHICH FURNISHES A POWER OUTPUT OF 1 KW. THE SECOND UNIT CONSISTS OF THE FINAL POWER AMPLIFIER AND IT IS CONNECTED TO THE OUTPUT OF THE EXITER UNIT BY A SHORT TRANSMISSION LINE.

BY USING THIS TWO-UNIT TYPE OF CONSTRUCTION, THE SHIELDING BETWEEN THE FINAL POWER AMPLIFIER AND THE CIRCUITS OF LOWER POWER LEVELS IS GREATLY SIMPLIFIED.

A 7½ WATT TRIODE IS USED IN THE CRYSTAL-CONTROLLED OSCILLATOR CIRCUIT. THIS IS FOLLOWED BY A 75 WATT SCREEN-GRID BUFFER AMPLIFIER AND THEN IN TURN BY A 75 WATT SCREEN-GRID FREQUENCY DOUBLER, A 75 WATT SCREEN GRID FREQUENCY DOUBLER (THE SECOND DOUBLER), A 500 WATT SCREEN-GRID TUBE WHICH IS USED AS A THIRD HARMONIC GENERATOR IF THE OUTPUT FREQUENCY IS IN EXCESS OF 12,000 KC. AND OTHERWISE AS A POWER AMPLIFIER AND FINALLY TWO 500 WATT SCREEN-GRID TUBES IN A PUSH-PULL ARRANGEMENT AT THE OUTPUT OF THE EXITER UNIT.

FOR FREQUENCIES BELOW 12,000 KC. THE CRYSTAL IS GROUND SO THAT THE

OSCILLATOR FREQUENCY WILL BE ONE-FOURTH THAT OF THE FREQUENCY TO BE TRANSMITTED AND TWO DOUBLERS ARE USED. FOR FREQUENCIES ABOVE 12,000 KC. THE CRYSTAL WILL PERMIT THE OSCILLATOR TO OPERATE AT ONE-EIGHTH THE FREQUENCY TO BE TRANSMITTED AND THREE DOUBLERS ARE AT THIS TIME USED.

NOTICE CAREFULLY IN THE CIRCUIT OF FIG. 12 THAT THE VARIOUS SECTIONS OF THE TRANSMITTER PROPER FOLLOW THE SAME GENERAL DESIGNS AS WERE DESCRIBED TO YOU IN DETAIL IN PREVIOUS LESSONS. ALSO OBSERVE HOW EACH OF THE VARIOUS STAGES ARE FULLY SHIELDED FROM EACHOTHER AS INDICATED BY THE DOTTED LINES.

THREE SEPARATE "B" POWER SUPPLIES ARE USED WITH THIS TRANSMITTER AND TWO OF WHICH ARE SHOWN IN THE CIRCUIT OF FIG. 12. THE CRYSTAL OSCILLATOR AND BUFFER AMPLIFIER RECEIVE THEIR "B" SUPPLY FROM A SINGLE PHASE CENTER-TAPPED RECTIFIER USING TYPE 866 MERCURY-VAPOR RECTIFIER TUBES. THE OUTPUT OF THIS RECTIFIER IS EQUIPPED WITH A FILTER AND VOLTAGE DIVIDING SYSTEM.

THE REMAINDER OF THE EXITER RECEIVES ITS "B" SUPPLY FROM A THREE PHASE FULL-WAVE RECTIFIER USING SIX TYPE 872 MERCURY-VAPOR RECTIFIER TUBES. THE OUTPUT OF THIS RECTIFIER IS ALSO EQUIPPED WITH A FILTER AND DIVIDER SYSTEM SO THAT VOLTAGES OF 3000; 1500; AND LESSER VOLTAGES MAY BE OBTAINED. THE GRID BIAS VOLTAGES FOR THE EXITER ARE OBTAINED BY CONNECTING THE OUTPUT OF A 1000 VOLT MOTOR-GENERATOR ACROSS THE + AND — TERMINALS OF THE GRID BIAS VOLTAGE DIVIDING RESISTANCE, ALTHOUGH A RECTIFYING SYSTEM MAY BE USED.

THE POWER-AMPLIFIER UNIT HAS ITS "B" SU-

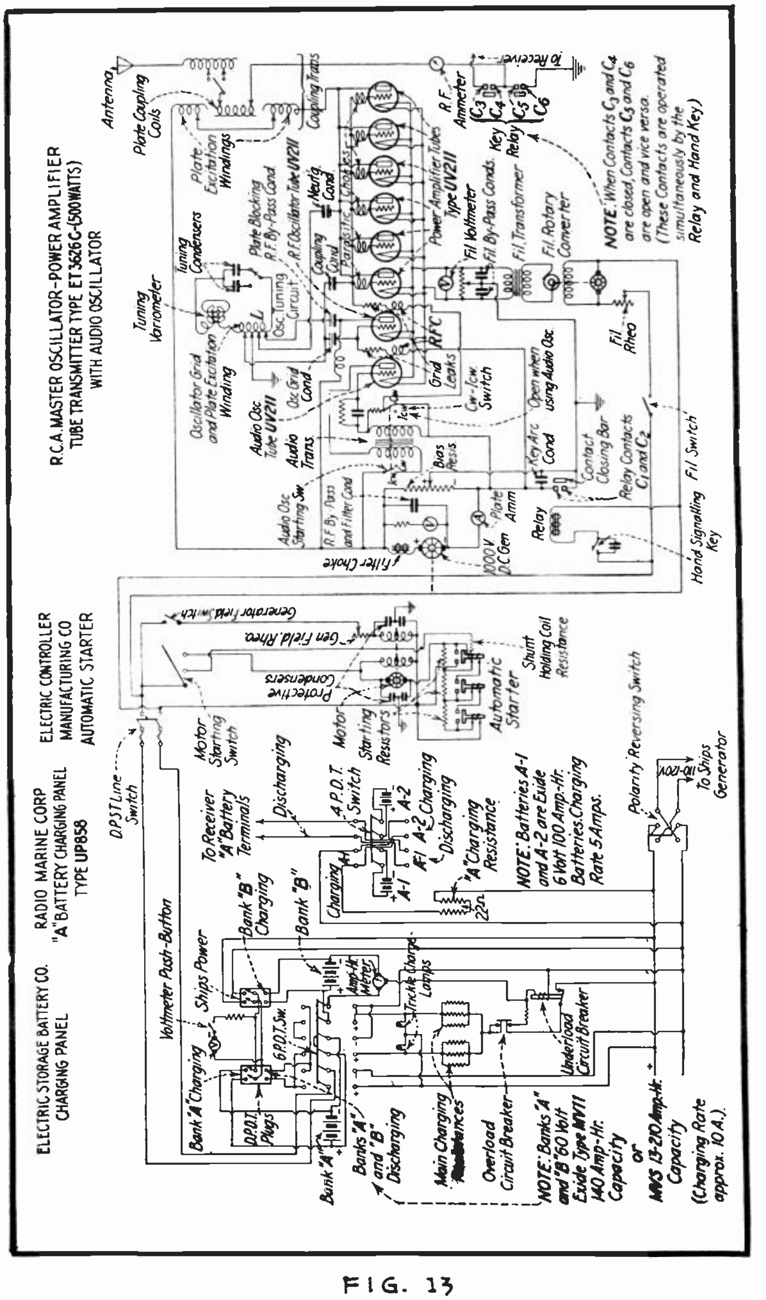


FIG. 13

A Transmitter Designed for Marine Use.

pply furnished by a separate supply not shown in Fig. 12 but which consists of a three-phase full-wave rectifier using type 869 mercury-vapor tubes and delivering a direct current output of 8 amps. at 12,000 volts. Twelve rectifier tubes are employed, being operated in parallel pairs. You will receive transmitter tube data in a later lesson.

The method of keying this transmitter is rather interesting. By referring to Fig. 12 again, you will observe that the keying in this case is done in the first doubler stage by reducing the plate voltage supplied to the doubler tube to the point where the output is insufficient to bring the instantaneous grid potential of the succeeding tube above cut-off.

The keying unit consists of two 50-watt tubes in parallel and the plates of which are fed in parallel with the plate of the first doubler tube through a common resistance from the 3000 volt power supply. When the key is closed, a negative bias exceeding the cut-off value is placed on the grids of the keying tubes so that the keying unit draws no current and allows normal voltage to be applied to the plate of the doubler tube.

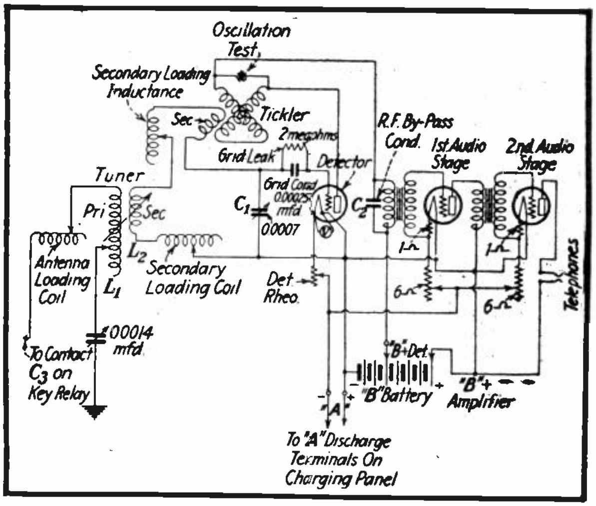


FIG. 14

The Receiver Diagram.

When the key is open, a slightly positive voltage is applied to the grids of the keying tubes, causing these tubes to draw a large plate current through the series resistance and thus reduces to a very low value the potential which is applied to the plate of the doubler tube.

A COMPLETE MARINE TRANSMITTER

In Fig. 13 you are shown the complete circuit diagram of a transmitter which was designed for marine use. The circuit diagram of the receiver which is used with this same transmitter appears in Fig. 14.

The transmitter is of the Master-Oscillator-Power-Amplifier type and is designed for a power output of 500 watts and affords both CW and ICW transmission. It is designed to operate on two-wavelength ranges, one which extends from 1250 to 2500 meters and the other from 600 and 1250 meters.

THE POWER SUPPLY

The auxiliary power supply consists of two 60 volt storage batteries with a switching arrangement whereby they can be connected in parallel or series for either charging or discharging purposes. Overload and

UNDERLOAD CIRCUIT BREAKERS ARE ALSO SUPPLIED SO AS TO PROTECT THE BATTERIES IN CASE A SHORT CIRCUIT OCCURS OR ELSE IF THE CHARGING VOLTAGE DECREASES BEYOND A CERTAIN POINT.

UPON PLACING THE 6 P.D.T. CHARGING SWITCH IN THE "DOWN POSITION" AND THE POLARITY REVERSING SWITCH IN THE PROPER POSITION, CURRENT AS FURNISHED BY THE SHIP'S D.C. GENERATOR WILL FLOW THROUGH THE UNDERLOAD CIRCUIT BREAKER, OVERLOAD CIRCUIT BREAKER, MAIN CHARGING RESISTANCES, THRU THE BATTERY BANKS "A" AND "B", THROUGH THE AMPERE-HOUR METER AND BACK TO THE NEGATIVE SIDE OF THE LINE. THE BATTERIES ARE CONNECTED IN PARALLEL DURING THIS TIME.

AS THE CHARGE PROGRESSES THE AMPERE-HOUR METER READS IN A COUNTER-CLOCKWISE DIRECTION UNTIL ITS HAND REACHES A VERTICAL POSITION AND AT WHICH TIME IT CLOSES A SMALL CONTACT AND SHORT-CIRCUITS THE HOLDING COIL OF THE UNDERLOAD CIRCUIT BREAKER, OPENING THE CHARGING CIRCUIT.

WHEN THE BATTERIES ARE FULLY CHARGED, THE OVERLOAD CIRCUIT BREAKER CAN BE OPENED SO AS TO DISCONNECT THE MAIN CHARGING RESISTANCES. BY LEAVING THE 6 P.D.T. SWITCH IN THE CHARGING POSITION AT THIS TIME, THE BATTERIES CAN STILL BE SUPPLIED WITH A SMALL TRICKLE CHARGE THROUGH TWO SMALL LAMPS. THIS KEEPS THE BATTERIES IN A GOOD CONDITION WHEN NOT IN USE.

THE 4 P.D.T. SWITCH WHICH IS LOCATED AT THE RIGHT OF THE 6 P.D.T. CHARGING SWITCH PERMITS EITHER ONE OF THE TWO "A" BATTERIES FOR THE RECEIVER TO BE CHARGED WHILE THE OTHER IS IN USE.

WITH THE 6 P.D.T. SWITCH PLACED IN THE UPWARD POSITION, THE ENTIRE CHARGING SYSTEM IS DISCONNECTED AND THE TWO 60 VOLT BANKS ARE CONNECTED IN SERIES SO AS TO SUPPLY AN E.M.F. OF 120 VOLTS. THIS VOLTAGE MAY BE APPLIED TO THE MOTOR STARTER AND GENERATOR BY CLOSING THE D.P.S.T. LINE SWITCH AT THE TOP.

BY PLACING THE 6 P.D.T. SWITCH IN THE DOWNWARD POSITION THE SHIP'S GENERATOR CAN BE USED TO OPERATE THE MOTOR STARTER AND GENERATOR, AT THE SAME TIME CHARGING THE BATTERIES.

THE MOTOR STARTER AND MOTOR GENERATOR

BY CLOSING THE MOTOR STARTING SWITCH, THE VOLTAGE FROM THE SHIP'S D.C. LINE OR ELSE FROM THE BATTERIES IS APPLIED TO THE MOTOR AND GENERATOR UNITS. CURRENT WILL THEN FLOW THROUGH THE MOTOR ARMATURE, STARTING RESISTANCES AND MOTOR FIELD. NO CURRENT WILL FLOW THROUGH THE GENERATOR FIELD UNTIL THE GENERATOR FIELD SWITCH IS CLOSED.

THE CURRENT WHICH IS NOW FLOWING THROUGH THE MOTOR ARMATURE AND STARTING RESISTANCES ALSO FLOWS THROUGH THE FIRST PLUNGER COIL OF THE AUTOMATIC STARTER. AFTER A FEW SECONDS THIS PLUNGER RISES AND SHORT CIRCUITS THE FIRST RESISTANCE WHICH ALLOWS MORE CURRENT TO FLOW INTO THE ARMATURE. THE SECOND PLUNGER COIL THEN BECOMES ENERGIZED AND AFTER A FEW SECONDS IT ALSO RISES AND SHORT-CIRCUITS THE SECOND RESISTANCE, ALLOWING MORE CURRENT TO FLOW INTO THE ARMATURE. THE THIRD PLUNGER COIL THEN BECOMES ENERGIZED AND AFTER A FEW SECONDS SHORT-CIRCUITS THE THIRD AND FINAL RESISTANCE WHICH ALLOWS THE FULL CURRENT TO FLOW THRU THE MOTOR ARMATURE. THE THIRD PLUNGER IS ALSO PROVIDED WITH A SHUNT HOLDING COIL WHICH KEEPS

THE PLUNGER IN AN UPWARD POSITION DURING THE TIME THAT THE MOTOR IS OPERATING.

WITH THE MOTOR FIELD AND ARMATURE NOW FULLY EXITED AND RUNNING AT FULL SPEED, THE GENERATOR FIELD SWITCH MAY BE CLOSED TO EXITE THE GENERATOR FIELD. THE DIRECT-DURRENT GENERATOR WILL GENERATE AN E.M.F. OF 1,000 VOLTS AND WHICH MAY BE REGULATED BY VARYING THE GENERATOR FIELD RHEOSTAT UNTIL THE DESIRED VOLTAGE IS OBTAINED. THIS GENERATOR FIELD SWITCH SHOULD NOT BE CLOSED UNTIL THE TUBE FILAMENTS ARE LIGHTED. A FILTER IS INSTALLED AT THE OUTPUT OF THIS GENERATOR SO AS TO FURNISH A D.C. SUPPLY FREE FROM RIPPLE.

THE TRANSMITTER

UPON CLOSING THE FILAMENT SWITCH, A D.C. SUPPLY IS FURNISHED THE ROTARY CONVERTER AND THIS UNIT IN TURN CAUSES AN ALTERNATING CURRENT TO FLOW THROUGH THE PRIMARY WINDING OF THE FILAMENT TRANSFORMER. A STEP-DOWN RATIO IS OFFERED BY THIS TRANSFORMER SO THAT A FILAMENT VOLTAGE OF 10 VOLTS WILL BE APPLIED TO THE FILAMENTS OF THE TRANSMITTER TUBES. THIS VOLTAGE IS CONTROLLED BY THE FILAMENT RHEOSTAT.

UPON OPERATING THE HAND KEY, THE RELAY KEY CONTROLS THE TRANSMITTER. WITH THE KEY IN THE OPEN POSITION, A HIGH NEGATIVE BIAS VOLTAGE, FURNISHED BY THE RESISTOR WHICH IS CONNECTED ACROSS THE D.C. GENERATOR, CAUSES THE TRANSMITTER TUBES TO BLOCK AND RADIATION CEASES.

BY CLOSING THE KEY, THE "B" CIRCUIT OF THE TRANSMITTER AND THE ANTENNA CIRCUIT TO THE TRANSMITTER ARE COMPLETED AND AT THE SAME TIME, THE EXCESS BIAS VOLTAGE IS REMOVED FROM THE TUBES AND THE RECEIVER IS DISCONNECTED FROM THE RECEIVER.

WITH THE CW-ICW SWITCH IN THE CW POSITION AND THE AUDIO-OSCILLATOR NOT OPERATING, CONTINUOUS WAVE (CW) SIGNALS WILL BE RADIATED. FOR ICW SIGNALLING, THE CW-ICW SWITCH IS CLOSED TO THE ICW POSITION. THIS CLOSES THE AUDIO-OSCILLATOR STARTING SWITCH CAUSING THE AUDIO OSCILLATOR TO OPERATE. THE OUTPUT OF THIS AUDIO OSCILLATOR MODULATES THE CONTINUOUS WAVES GENERATED BY THE R.F. OSCILLATOR AND THIS RESULTS IN THE EMISSION OF AN INTERRUPTED CONTINUOUS WAVE (ICW). A STANDARD MARCONI ANTENNA IS USED WITH THIS TRANSMITTER.

OPERATING PROCEDURE

TO PREPARE THIS TRANSMITTER FOR OPERATION, THE PROCEDURE IS AS FOLLOWS: TURN THE FIELD AND FILAMENT RHEOSTATS TO THEIR LOWEST VOLTAGE POSITION. CLOSE THE MAIN LINE SWITCH AND PRESS THE "START" BUTTON AND PERMIT THE MOTOR GENERATOR TO COME UP TO SPEED. ADJUST FILAMENT VOLTAGE FOR A FILAMENT E.M.F. OF 10 VOLTS. WHEN TUBE FILAMENTS ARE HOT, ADJUST GENERATOR-FIELD RHEOSTAT FOR A PLATE VOLTAGE OF 1,000 VOLTS.

NEXT THROW THE WAVE-RANGE TRANSFER SWITCH TO THE POSITION FOR THE WAVE-RANGE DESIRED. THEN SET THE "EXITER TUNING" AND "RANGE SWITCH" TO THE WAVELENGTH DESIRED. SET THE CW-ICW SWITCH TO THE CW POSITION.

NOW ADJUST THE ANTENNA INDUCTANCE SWITCHES TO RANGE DESIRED AND ADJUST THE PROPER "ANTENNA TUNING KNOB" FOR A MAXIMUM READING ON THE

RADIATION METER WHILE PRESSING THE "TEST" PUSH BUTTON. THE SET IS NOW TUNED AND THE TELEGRAPH KEY MAY BE OPERATED FOR THE TRANSMISSION OF SIGNALS.

TO SHUT DOWN THE TRANSMITTER, PRESS THE "STOP" BUTTON.

THE RECEIVER AS USED WITH THIS TRANSMITTER EMPLOYS DESIGN PRINCIPLES WITH WHICH YOU ARE ALREADY FAMILIAR AND FOR THIS REASON IT IS NOT NECESSARY TO OFFER A DESCRIPTIVE EXPLANATION REGARDING IT.

Feb 14, 1942

EXAMINATION QUESTIONS

LESSON NO. T-II

1. - DRAW A COMPLETE CIRCUIT DIAGRAM OF AN OSCILLATOR - AMPLIFIER C.W. TRANSMITTER TOGETHER WITH ITS POWER SUPPLY.

2. - EXPLAIN IN DETAIL HOW YOU WOULD ADJUST FOR OPERATION THE TRANSMITTER WHOSE DIAGRAM YOU HAVE DRAWN IN ANSWER TO QUESTION #1.

3. - DRAW A CIRCUIT DIAGRAM OF A KEYING CIRCUIT WHOSE OPERATION IS BASED UPON BLOCKING WITH BIAS VOLTAGE THE GRID OF THE TUBE WHICH IS BEING KEYED AND EXPLAIN HOW THIS SYSTEM FUNCTIONS.

4. - DRAW A CIRCUIT DIAGRAM OF A KEY FILTER; EXPLAIN THE REASON FOR USING IT.

5. - DRAW A CIRCUIT DIAGRAM WHICH SHOWS HOW A KEYING TUBE MAY BE USED IN THE TRANSMITTER AND EXPLAIN HOW THIS SYSTEM OPERATES.

6. - WHAT ARE THE ADVANTAGES OF USING A RELAY KEY IN TRANSMITTERS OF HIGHER POWER RATING?

7. - DRAW A CIRCUIT DIAGRAM WHICH ILLUSTRATES HOW A RELAY KEY MAY BE USED IN A TRANSMITTER CIRCUIT AND EXPLAIN HOW THIS PARTICULAR SYSTEM OPERATES.

8. - DESCRIBE SOME OF THE MORE IMPORTANT FEATURES WHICH MAY BE FOUND IN A COMMERCIAL TRANSMITTER DESIGNED FOR MARINE USE.

9. - WHAT IS THE GENERAL PROCEDURE FOR OPERATING A TRANSMITTER SUCH AS YOU HAVE DESCRIBED IN ANSWER TO QUESTION 8?

10. - WHAT IS THE ADVANTAGE OF USING A SEPARATE POWER SUPPLY FOR THE OSCILLATOR OF AN OSCILLATOR-AMPLIFIER TRANSMITTER?

RADIO - TELEVISION

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Transmitters

LESSON NO. 12

MESSAGE HANDLING AND OPERATING REGULATIONS

HAVING BY THIS TIME FAMILIARIZED YOURSELF WITH THE CONSTRUCTION AND OPERATION OF CODE TRANSMITTERS, AS WELL AS WITH THE CODE ITSELF, YOU ARE NOW PREPARED TO LEARN ABOUT THE PROCEDURE WHICH IS USED IN THE HANDLING OF MESSAGES WITH THIS METHOD.

TO BEGIN WITH, CLEAR AND DISTINCT SENDING AT A MODERATE SPEED IS MUCH PREFERRED OVER ERRATIC SENDING AT AN EXCESSIVE SPEED.

CALLING A STATION

THE PROCEDURE FOR CALLING A STATION IS AS FOLLOWS: FIRST, DETERMINE WHETHER OR NOT THE STATION TO BE CALLED IS ALREADY COMMUNICATING WITH SOME OTHER STATION. THIS IS DETERMINED BY "LISTENING IN" FOR A SHORT PERIOD ON THE FREQUENCY AT WHICH THE STATION TO BE CALLED OPERATES. BY DOING THIS, UNNECESSARY INTERFERENCE IS AVOIDED. IF THE TRANSMITTING FREQUENCY OF THE STATION TO BE CALLED IS NOT ALREADY KNOWN, THEN IT CAN

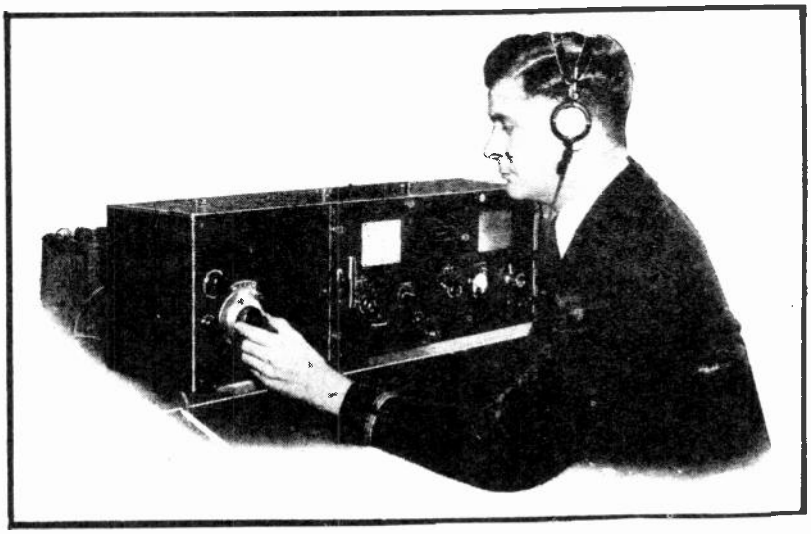


FIG. 1

Opportunities and Adventure Await the Commercial Operator.

BE DETERMINED FROM A "CALL BOOK" IN WHICH ALL STATIONS ARE LISTED.

HAVING THUS DETERMINED THAT THE STATION TO BE CALLED IS NOT ALREADY COMMUNICATING, THE NEXT STEP IS TO SEND THREE TIMES IN SUCCESSION THE CALL LETTERS OF THE STATION YOU ARE CALLING. THIS SHOULD BE FOLLOWED BY THE SIGNAL "DE" (FROM OR — . . .) TRANSMITTED ONCE AND THEN SEND THREE TIMES IN SUCCESSION THE CALL LETTERS OF YOUR STATION (THE CALLING STATION).

FOR EXAMPLE, LET US SUPPOSE THAT YOU ARE THE OPERATOR OF STATION WXOH AND DESIRE TO COMMUNICATE WITH STATION WCNR. THIS BEING THE CASE YOU WOULD TRANSMIT AS FOLLOWS:

WCNR WCNR WCNR DE WXOH WXOH WXOH

IT IS OF COURSE IMPORTANT THAT THE STATION MAKING THE CALL TRANSMIT ON THE FREQUENCY AT WHICH THE STATION BEING CALLED KEEPS WATCH.

IT THE STATION BEING CALLED (STATION WCNR IN OUR CASE) DOES NOT ANSWER THE FIRST CALL, THEN TWO MINUTES MUST ELAPSE BEFORE CALLING AGAIN. IF THE SECOND CALL IS NOT ANSWERED, THEN TWO MINUTES MUST ELAPSE BEFORE THE THIRD CALL IS MADE. IF NO RESPONSE IS RECEIVED FROM THE THIRD CALL, THEN FIFTEEN MINUTES SHOULD ELAPSE BEFORE CALLING IS RESUMED. IT IS OF UTMOST IMPORTANCE THAT THE CALLING OPERATOR DOES NOT INTERFERE WITH COMMUNICATIONS BEING EXCHANGED BETWEEN OTHER STATIONS.

ANSWERING A CALL

IN ANSWERING A CALL, THE STATION BEING CALLED SHOULD REPLY BY TRANSMITTING NOT MORE THAN THREE TIMES THE CALL SIGNAL OF THE CALLING STATION, FOLLOWED BY THE WORD "DE" (FROM) AND THEN ITS OWN CALL SIGNAL AND THE LETTER K WHICH IS THE SIGNAL TO GO AHEAD. FOR EXAMPLE, STATION WCNR WOULD ANSWER STATION WXOH IN THE FOLLOWING MANNER: WXOH WXOH WXOH DE WCNR K.

TO ACKNOWLEDGE THE ANSWER, THE CALLING STATION (WXOH) NOW CALLS STATION WCNR AGAIN AS FOLLOWS: WCNR DE WXOH AND PROCEEDS WITH THE MESSAGE.

IF FOR SOME REASON OR OTHER, THE STATION BEING CALLED IS UNABLE TO RECEIVE THE MESSAGE, THEN AT THE TIME OF ACKNOWLEDGING THE CALL, THE WAIT SIGNAL SHOULD BE GIVEN IN PLACE OF THE LETTER K AND THIS SHOULD BE FOLLOWED BY A NUMBER INDICATING IN MINUTES THE PROBABLE DURATION OF THE WAIT OR ANY FURTHER EXPLANATION IF NECESSARY.

TRANSMITTING A RADIOGRAM

IN FIG. 2 YOU ARE SHOWN A TYPICAL EXAMPLE OF A RADIOGRAM AS IT IS PREPARED ON SHIPBOARD PREPARATORY TO TRANSMISSION. A MESSAGE AS THIS CAN BE DIVIDED INTO FOUR DISTINCT PARTS OR SECTIONS, NAMELY, AS THE PREAMBLE, ADDRESS, TEXT, AND SIGNATURE. IN FIG. 3 YOU ARE SHOWN HOW THIS DIVISION IS MADE.

WHEN SENDING A MESSAGE OF THIS TYPE THE BREAK SIGNAL (— ... —) IS

TRANSMITTED TO SEPARATE THE ADDRESS FROM THE TEXT AND THE TEXT FROM THE SIGNATURE. THE MESSAGE IS TERMINATED WITH THE SIGNAL . – . – . AFTER WHICH THE CALLING STATION GIVES HIS LETTERS AND ASKS THE STATION BEING CALLED TO ACKNOWLEDGE RECEIPT OF THE MESSAGE.

THE COMPLETE TRANSMISSION OF THIS PARTICULAR MESSAGE WOULD PROGRESS AS FOLLOWS — ASSUMING THAT STATION WXOH IS CALLING WCNR:

WCNR WCNR WCNR DE WXOH WXOH WXOH
(STATION WCNR ANSWERING.) WXOH WXOH WXOH DE WCNR K
WCNR DE WXOH
P 2 R 16 RADIO 88 SANTA BARBARA 10.35 A.M.
TO: C.H. TAYLOR 33 SOUTH AVE DENVER (COLO) – . . . –
EXPECT TO ARRIVE PIER 13 NEWYORK SATURDAY
LOVE – . . . –
CLARA . – . – . WXOH – . –

IF THE RECEIVING STATION DOES NOT ACKNOWLEDGE RECEIPT OF THE MESSAGE, THE MESSAGE IS NOT CONSIDERED AS BEING SENT AT ALL. THEREFORE, UPON RECEIVING THE MESSAGE JUST DESCRIBED, STATION WCNR WOULD ACKNOWLEDGE THE FACT IN THE FOLLOWING MANNER:

WCNR DE WXOH No 2 . – . – . –

NOTICE THAT IN THIS ACKNOWLEDGEMENT THE RADIOGRAM IS ACKNOWLEDGED BY ITS NUMBER (No.2); THE SIGNAL . – . MEANS THAT THE MESSAGE WAS RECEIVED O.K.; AND THE FINAL K OR – . – MEANS FOR THE CALLING STATION TO GO AHEAD. THE CALLING STATION WXOH THEN REPLIES AS FOLLOWS: WCNR DE WXOH . . . – . – (TRANSMISSION FINISHED OR CONCLUSION OF CORRESPONDENCE).

THE EXPRESSION P 2 R 16 WHICH APPEARS IN THE PREAMBLE OF THIS MESSAGE INDICATES THAT THIS IS THE SECOND RADIOGRAM OF THE ORDINARY PAID TYPE SENT AND THAT IT CONSISTS OF 16 WORDS ACCORDING TO THE CABLE – COUNT SYSTEM. SOMETIMES THE LETTER W IS USED TO INDICATE "NUMBER OF WORDS" —

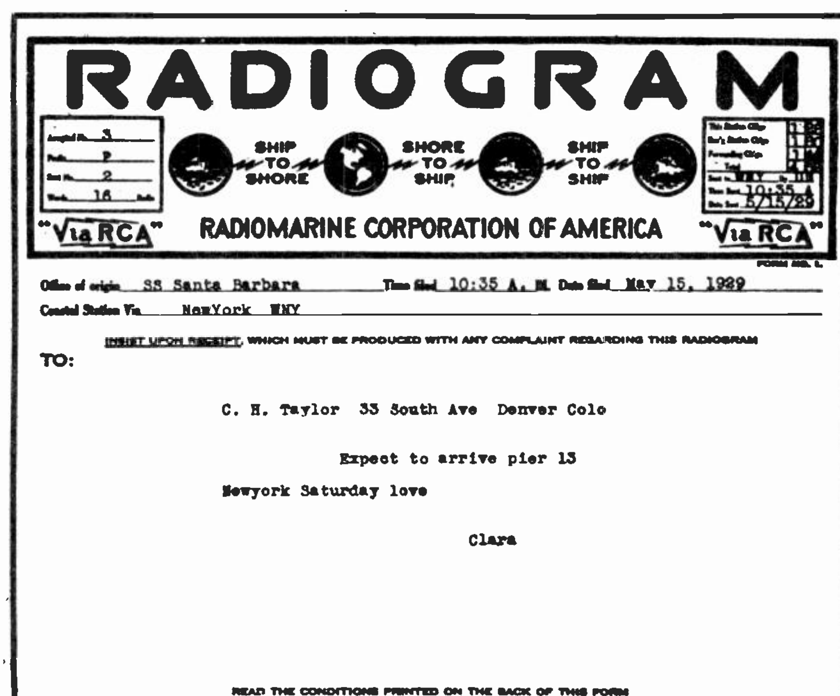

RADIOGRAM
SHIP TO SHORE — SHORE TO SHIP — SHIP TO SHIP
"Via RCA" RADIOMARINE CORPORATION OF AMERICA "Via RCA"
Office of origin SS Santa Barbara Time filed 10:35 A. M. Date filed May 15, 1929
Coastal Station Via NewYork WNY
INSIST UPON RECEIPT, WHICH MUST BE PRODUCED WITH ANY COMPLAINT REGARDING THIS RADIOGRAM
TO:
C. H. Taylor 33 South Ave Denver Colo
Expect to arrive pier 13
Newyork Saturday love
Clara
READ THE CONDITIONS PRINTED ON THE BACK OF THIS FORM

FIG. 2
A Radiogram Originating on Shipboard.

THUS W 16.

CERTAIN CLASSES OF RADIOGRAMS ARE INDICATED BY THE FOLLOWING CONVENTIONAL SIGNS WHICH ARE TRANSMITTED IN THE PREAMBLE AND AGAIN AS THE FIRST ITEM OF THE ADDRESS. SUCH SIGNS ARE COUNTED AND CHARGED FOR IN THE ADDRESS AS ONE WORD. THESE SIGNS ARE AS FOLLOWS:

RP, AND THE AMOUNT PREPAID —— RADIOGRAMS WITH PREPAID REPLY.
POST —— RADIOGRAMS TO BE DELIVERED BY MAIL.
TC —— COLLATED RADIOGRAMS (FOR VERIFICATION PURPOSES ONLY).
PR —— RADIOGRAMS TO BE POSTED AS REGISTERED LETTERS.
EXPRESS —— RADIOGRAMS FOR SPECIAL DELIVERY WHEN THE COST OF DELIVERY IS TO BE COLLECTED FROM THE ADDRESSEE.
XP —— RADIOGRAMS FOR SPECIAL DELIVERY IN THE COUNTRY OF THE COAST STATION THROUGH WHICH THE MESSAGE IS SENT, WHEN THE COST OF THE SPECIAL DELIVERY IS PREPAID.
JOUR —— RADIOGRAMS NOT TO BE DELIVERED DURING THE NIGHT TIME.
NUIT —— RADIOGRAMS TO BE DELIVERED AT NIGHT TIME IF RECEIVED THEN.
TR —— RADIOGRAMS TO BE CALLED FOR AT A TELEGRAPH OFFICE.
GP —— RADIOGRAMS TO BE CALLED FOR AT A POST OFFICE.
TM, AND THE FIGURE REPRESENTING THE NUMBER OF ADDRESSES —— RADIOGRAMS WITH MULTIPLE ADDRESSES.

PC —— RADIOGRAMS WITH ACKNOWLEDGEMENT OF RECEIPT BY TELEGRAPH.
PCP —— RADIOGRAMS WITH ACKNOWLEDGEMENT OF RECEIPT BY POST.
CR —— RADIOGRAMS OF ACKNOWLEDGEMENT OF "PC" OR "PCP" RADIOGRAMS.
D —— RADIOGRAMS TO BE GIVEN PRIORITY OVER THE LAND TELEGRAPH SYSTEM, THAT IS, URGENT MESSAGES.
ST —— PAID SERVICE ADVICES.
OL —— OCEAN LETTERS.
GOVT —— RADIOGRAMS ON UNITED STATES GOVERNMENT BUSINESS.
PRESSE —— RADIOGRAMS CONTAINING PRESS NEWS.

PREAMBLE:	–	P 2 R 16 RADIO SS SANTA BARBARA 10.35 A.M.
ADDRESS:	–	TO: C.H. TAYLOR 33 SOUTH AVE DENVER (COLO)
TEXT:	–	EXPECT TO ARRIVE PIER 13 NEWYORK SATURDAY LOVE
SIGNATURE:	–	CLARA

FIG. 3
Components of the Message.

IN FIG. 4 YOU ARE SHOWN AN EXAMPLE OF A TYPICAL "REPLY PREPAID" RADIOGRAM.

THE CABLE-COUNT SYSTEM

IN COUNTING THE WORDS CONTAINED IN A RADIOGRAM AND FOR WHICH A CHARGE IS MADE, THE CABLE-COUNT SYSTEM IS USED. THIS SYSTEM PROVIDES THAT ALL WORDS IN THE ADDRESS, TEXT, AND SIGNATURE MUST BE COUNTED AND CHARGED FOR.

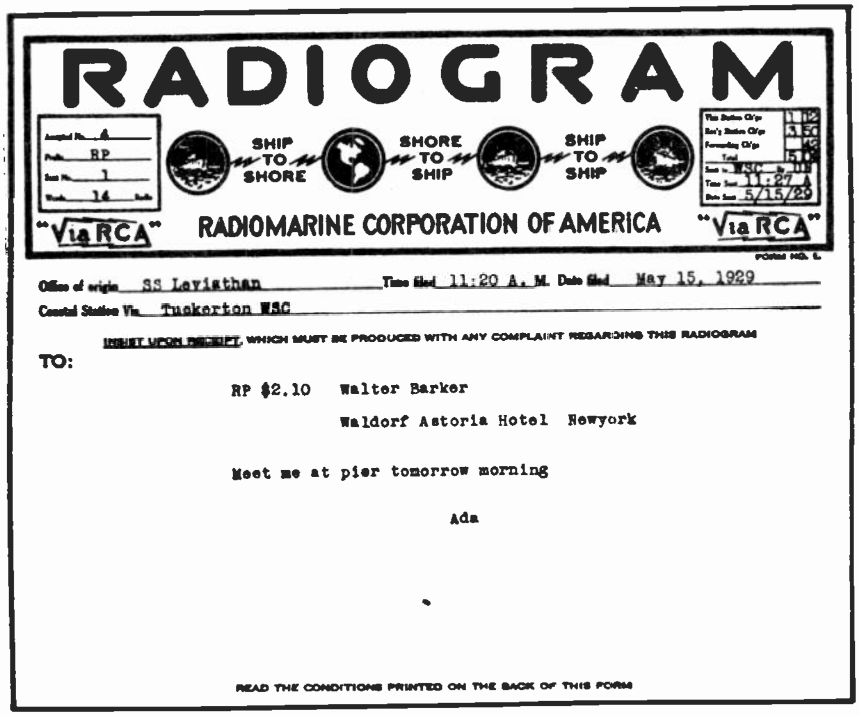
IN THIS SYSTEM, MESSAGES ARE DIVIDED INTO THREE DISTINCT CLASSES AS FOLLOWS: (1) PLAIN LANGUAGE; (2) CODE LANGUAGE; AND (3) CIPHER LANGUAGE.

IN THE CASE OF PLAIN-LANGUAGE, THE MESSAGES MUST BE WRITTEN ENTIRELY IN PLAIN LANGUAGE AND THE WORDS ARE COUNTED ON THE BASIS OF 15 CHARACTERS TO THE WORD. ANY FRACTIONAL PART OF 15 CHARACTERS IS ALSO COUNTED AS 1 WORD. NUMBERS UP TO 5 IN A GROUP ARE COUNTED AS ONE WORD AND NUMBERS OVER 5 IN A GROUP ARE COUNTED AS TWO WORDS.

EXAMPLES:

BUILDING ——— 1 WORD
PARENTHESIS ——— 1 WORD
UNCONSTITUTIONAL — 2 WORDS
6,742 ——— 1 WORD
358 ——— 1 WORD
247,956 ——— 2 WORDS

CODE LANGUAGE CONSISTS OF PRONOUNCEABLE WORDS BUT WHICH HAVE NO DIRECT MEANING AND WHICH DO NOT EXCEED 10 CHARACTERS IN LENGTH. EXAMPLES OF CODE LANGUAGE ARE AS FOLLOWS; NRTOSU = 1 WORD; X-RAY = 2 WORDS.


RADIOGRAM

Accepted No. 4
Prefix RP
Sent No. 1
Words 14

SHIP TO SHORE — SHORE TO SHIP — SHIP TO SHIP

1.12
3.50
.50
WSC
11:27 A
5/15/29

"Via RCA" RADIOMARINE CORPORATION OF AMERICA "Via RCA"

Office of origin SS Leviathan Time filed 11:20 A. M. Date filed May 15, 1929

Coastal Station Via Tuckerton WSC

INSIST UPON RECEIPT, WHICH MUST BE PRODUCED WITH ANY COMPLAINT REGARDING THIS RADIOGRAM

TO:

RP $2.10 Walter Barker

Waldorf Astoria Hotel Newyork

Meet me at pier tomorrow morning

Ada

READ THE CONDITIONS PRINTED ON THE BACK OF THIS FORM

FIG. 4

A "Reply Prepaid" Radiogram.

IF THE CODE WORDS ARE NON-PRONOUNCEABLE OR ELSE PRONOUNCEABLE BUT EXCEED 10 CHARACTERS IN LENGTH THEN THEY ARE COUNTED ACCORDING TO THE CIPHER RATE. CIPHER LANGUAGE IS COUNTED AT THE RATE OF 5 LETTERS TO THE WORD AND MAY BE MADE UP OF ANY COMBINATION OF LETTERS OR FIGURES SUCH AS: ARSQO = 1 WORD; PNOSJR = 2 WORDS; H 4T3 = 4 WORDS.

WHEN SENDING RADIOGRAMS, THE WORD STREET, ROAD, PARK, OR SQUARE IS ALWAYS COUNTED AS ONE WORD ASIDE FROM ITS DESIGNATOR IN THE ADDRESS. HYPHENATED OR COMPOUND WORDS ARE COUNTED AS SO MANY SEPARATE WORDS, DEPENDING ON THE NUMBER OF PARTS.

NAMES OF PLACES SUCH AS NEW YORK, NEW LONDON ETC. ARE COUNTED AS ONE

WORD' IN THE ADDRESS AND TWO WORDS IN THE TEXT.

IF NEW YORK IS WRITTEN AS NEWYORK OR NEW LONDON IS WRITTEN AS NEWLONDON ETC. THEN THEY ARE COUNTED AS ONE WORD IN THE TEXT. SUCH NAMES, HOWEVER, SHOULD BE WRITTEN AS TWO SEPARATE WORDS IN THE ADDRESS.

RADIO COMPASS BEARINGS

OPERATORS OF MOBILE STATIONS ARE OFTEN REQUIRED TO OBTAIN A RADIO COMPASS BEARING. THE UNITED STATES GOVERNMENT HAS DRAWN UP THE FOLLOWING REGULATIONS REGARDING RADIO COMPASS BEARINGS: ALL RADIO COMPASS COMMUNICATIONS ARE TO BE HANDLED ON THE 800 METER WAVELENGTH. SHIPS ARE NOW EQUIPPED WITH THIS ADDITIONAL OPERATING WAVELENGTH FOR RADIO COMPASS EXCLUSIVELY. WHEN A COMPASS BEARING IS DESIRED, THE RADIO OPERATOR OF THE SHIP CALLS THE NEAREST COMPASS BEARING CONTROL STATION ON 800 METERS AND SENDS THE "Q" CODE SIGNAL QTE FOLLOWED BY THE QUESTION MARK (. . — — . .) AND WHICH SIGNIFIES THAT HIS SHIP DESIRES A COMPASS BEARING.

FOR EXAMPLE, IF YOU WERE THE OPERATOR ON THE SS SANTA BARBARA WHOSE CALL SIGNAL IS WXOH AND THE CAPTAIN OF THE VESSEL REQUESTED YOU TO OBTAIN A COMPASS BEARING FROM THE CAPE JUNE COMPASS BEARING STATION WHOSE CALL SIGNAL IS RNO, THEN YOUR PROCEDURE WOULD BE AS FOLLOWS:

RNO RNO RNO DE WXOH WXOH WXOH — . . . — QTE . . — — . . . — . — . — . — (THIS WOULD BE INTERPRETED AS WXOH CALLING RNO; BREAK; WHAT IS MY TRUE BEARING?; END OF MESSAGE; GO AHEAD.)

STATION RNO WOULD THEN RESPOND AS FOLLOWS:

WXOH DE RNO — . — STATION WXOH WOULD THEN CONTINUE AS FOLLOWS: RNO DE WXOH — . . . — QTE . . — — . . WXOH MO WXOH MO WXOH MO (THIS ALTERNATION OF WXOH AND MO SHOULD BE SENT FOR A PERIOD OF NOT MORE THAN 50 SECONDS, SENDING SLOWLY AND PROLONGING THE DASHES.) THEN PROCEED WITH . — . — . — . — RNO WILL THEN PROCEED TO TRANSMIT THE BEARING IN THE FOLLOWING MANNER: WXOH DE RNO — . . . — QTE CAPE JUNE 130 CAPE NEW HALL 115 SEAL BEACH 095 AT 0127 . — . — . — . — (THESE BEARINGS OF COURSE WILL DEPEND UPON THE PARTICULAR POSITION OF THE MOBILE STATION AT THE TIME IN QUESTION).

AFTER THE BEARING HAS BEEN TRANSMITTED BY THE COMPASS BEARING STATION, THE MOBILE STATION REPEATS THE FIGURES TO THE BEARING STATION FOR VERIFICATION AND THIS IS DONE AS FOLLOWS:

RNO DE WXOH — . . . — 130 115 095 0127 . . — — . . . — . — . — . — RNO THEN RESPONDS: WXOH DE RNO . — . . . . . — . —

STANDARD TIME

ANOTHER IMPORTANT SUBJECT WITH WHICH THE RADIO OPERATOR SHOULD BE FAMILIAR IS THAT TREATING WITH THE DIFFERENT TIME SYSTEMS WHICH ARE USED. THE THREE SYSTEMS WHICH ARE USED FOR THIS PURPOSE ARE EASTERN STANDARD TIME (EST), PACIFIC TIME (PT) AND GREENWICH MEAN TIME (GMT).

THERE IS A DIFFERENCE OF FIVE HOURS BETWEEN GREENWICH MEAN TIME AND EASTERN STANDARD TIME, AND A DIFFERENCE OF EIGHT HOURS BETWEEN GREENWICH MEAN TIME AND PACIFIC STANDARD TIME. THAT IS TO SAY, WHEN IT IS 2 A.M. GREENWICH MEAN TIME, IT IS 9 P.M. EASTERN STANDARD TIME AND 6 P.M. PACIFIC STANDARD TIME.

IN FIG. 5 YOU ARE SHOWN A STANDARD TIME CHART WHICH YOU SHOULD FIND TO BE BOTH INTERESTING AND HELPFUL. IT IS OF INTEREST TO NOTE THAT TIME CHANGES 1 HOUR WITH EACH 15 DEGREES DIFFERENCE IN LONGITUDE. FOR EXAMPLE, WHEN IT IS 2 A.M. IN LONDON (GMT), IT IS 9 P.M. IN NEW YORK (EST) AND 6 P.M. IN SAN FRANCISCO (PST).

TWENTY-FOUR-HOUR TIME SYSTEM

RADIOTELEGRAMS ARE FILED ON THE BASIS OF THE 24-HOUR SYSTEM. IN THIS SYSTEM THE HOURS FOR THE ENTIRE CALENDER DAY ARE COUNTED FROM 0 TO 23 STARTING AT MIDNIGHT. THIS PERMITS THE ABREVIATIONS A.M. AND P.M. TO BE ELIMINATED AND INCREASES THE ACCURACY. THE MINUTES 01 TO 59 ARE INDICATED AFTER THE HOURS, THUS 2:15 P.M. WOULD BE 1415; 5:37 A.M. WOULD BE 0537; 11:59 P.M. WOULD BE 2359 ETC.

THE DISTRESS SIGNAL

THE "DISTRESS SIGNAL", AS YOU WILL RECALL FROM PREVIOUS INSTRUCTIONS, IS SOS OR • • • — — — • • • AND WHICH MEANS THAT THE MOBILE STATION IN QUESTION IS THREATENED BY GRAVE AND IMMENENT DANGER AND REQUESTS IMMEDIATE ASSISTANCE.

THE INTERNATIONAL CALLING AND DISTRESS FREQUENCY IS 500 KC., WHILE IN THE GREAT LAKES REGION OF THE UNITED STATES A FREQUENCY OF 410 KC. IS USED FOR THIS PURPOSE.

THE OPERATOR IS NOT PERMITTED TO GIVE THE DISTRESS SIGNAL EXCEPT BY AUTHORITY OF THE

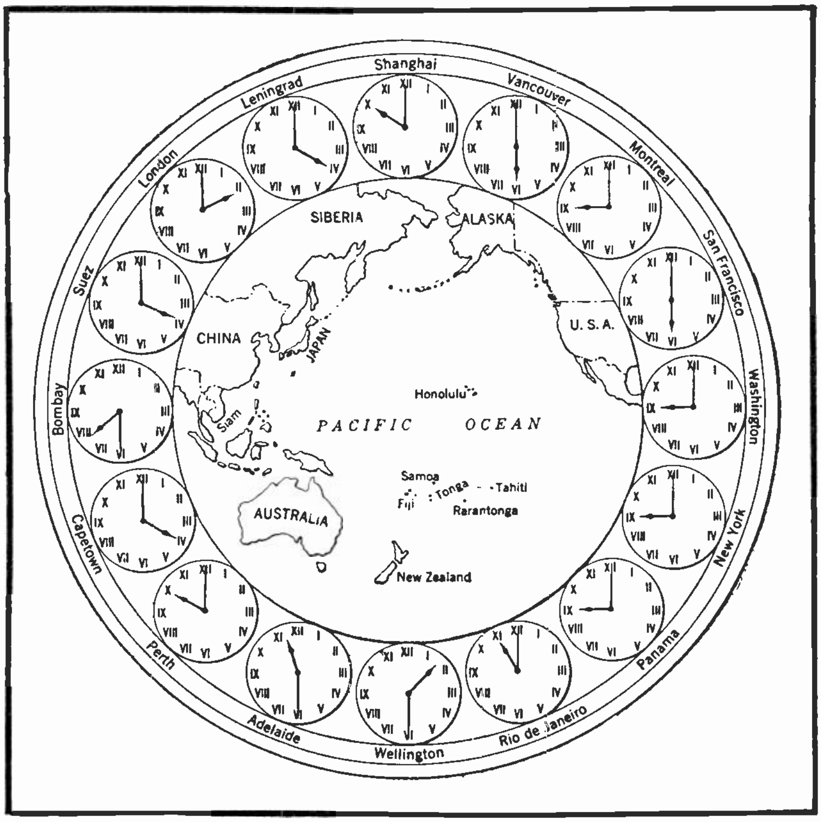


FIG. 5
Standard Time Chart.

MASTER OR PERSON IN CHARGE OF THE SHIP, AIRCRAFT, OR MOBILE STATION.

IN GIVING THE DISTRESS SIGNAL, THE PROCEDURE IS AS FOLLOWS: TRANSMIT THE DISTRESS SIGNAL THREE TIMES IN SUCCESSION, FOLLOWED BY THE WORD DE AND THEN THE CALL SIGNAL OF THE MOBILE STATION IN DISTRESS ALSO SENT THREE TIMES.

THIS CALL SHOULD NOT BE ADDRESSED TO ANY PARTICULAR STATION AND IT IS REQURED THAT ALL LAND OR MOBILE STATIONS CEASE ALL TRANSMISSION CAPABLE OF INTERFERING WITH THE DISTRESS CALLS OR MESSAGES AND THEY MUST LISTEN ON THE WAVE USED FOR THE DISTRESS CALL. THE DISTRESS CALL HAS ABSOLUTE PRIORITY OVER ALL OTHER TRANSMISSIONS.

THE DISTRESS MESSAGE FOLLOWING THE DISTRESS CALL SHOULD INCLUDE THE NAME OF THE SHIP OR OTHER MOBILE UNIT IN DISTRESS, INFORMATION CONCERNING ITS POSITION AND THE NATURE OF THE DISTRESS AND THE KIND OF ASSISTANCE DESIRED.

THE DISTRESS CALL AND MESSAGE SHOULD BE REPEATED AT INTERVALS UNTIL AN ANSWER IS RECEIVED. THESE INTERVALS, HOWEVER, SHOULD BE OF SUFFICIENT LENGTH SO AS TO PERMIT STATIONS ANSWERING THE CALL TO PLACE THEIR TRANSMITTER IN OPERATION.

IF THE STATION IN DISTRESS RECEIVES NO ANSWER TO THE DISTRESS CALL WHEN TRANSMITTING IT AT 500 KC., THEN THE CALL AND MESSAGE MAY BE REPEATED ON ANY OTHER AVAILABLE WAVE ON WHICH ATTENTION MIGHT BE ATTRACTED.

STATIONS WHICH RECEIVE A DISTRESS MESSAGE FROM A MOBILE STATION IN THEIR IMMEDIATE VICINITY MUST AT ONCE ACKNOWLEDGE RECEIPT THEREOF AND EXERCISE SPECIAL PRECAUTIONS SO AS NOT TO INTERFERE WITH THE TRANSMISSION OF THE ACKNOWLEDGEMENTS OF RECEIPT OF THE SAME MESSAGE SENT BY OTHER STATIONS. IF THERE IS GOOD REASON THAT SOME OTHER STATION IS LOCATED STILL NEARER TO THE STATION IN DISTRESS, THEN PREFERENCE SHOULD BE GIVEN TO THE NEARER STATION FOR ANSWERING THE CALL BUT YET TO BE READY TO SEND AN ACKNOWLEDGEMENT IF OTHERS FAIL TO DO SO.

TO ACKNOWLEDGE RECEIPT OF A DISTRESS MESSAGE THE PROCEDURE IS AS FOLLOWS: TRANSMIT THREE TIMES THE CALL SIGNAL OF THE STATION IN DISTRESS, FOLLOWED BY THE WORD DE, THE CALL SIGNAL OF THE STATION ACKNOWLEDGING RECEIPT (THREE TIMES), GROUP R R R, DISTRESS SIGNAL. IF THE ACKNOWLEDGING STATION IS ALSO MOBILE, THEN IT SHOULD ALSO INCLUDE ITS NAME AND POSITION AS A PART OF ITS ACKNOWLEDGEMENT.

A SHIP WHICH RECEIVES A DISTRESS MESSAGE MAY TRANSMIT THE MESSAGE IF THE SHIP IN DISTRESS IS NOT ITSELF IN A POSITION TO DO SO OR IF THE MASTER OF THE VESSEL JUDGES THAT FURTHER HELP IS NECESSARY. ALL COMMUNICATIONS RELATING TO DISTRESS MESSAGES MUST BE DELIVERED IMMEDIATELY TO THE MASTER OF THE SHIP.

THE RADIOTELPHONE DISTRESS SIGNAL IS THE SPOKEN EXPRESSION MAYDAY. THIS IS SPOKEN THREE TIMES FOLLOWED BY THE NAME OF THE STATION SPOKEN THREE TIMES.

THE AUTOMATIC ALARM SIGNAL

THE AUTOMATIC ALARM SIGNAL IS USED TO ANNOUNCE THAT A DISTRESS CALL WILL FOLLOW IMMEDIATELY. THE ALARM SIGNAL IS COMPOSED OF A SERIES OF 12 DASHES SENT IN ONE MINUTE, THE DURATION OF EACH DASH BEING 4 SECONDS AND THE DURATION OF THE INTERVAL BETWEEN TWO DASHES, 1 SECOND.

THE URGENT SIGNAL

THE URGENT SIGNAL IS X X X SENT SEVERAL TIMES BEFORE THE CALL LETTERS. IT IS USED TO INDICATE THAT THE CALLING STATION HAS A VERY URGENT MESSAGE CONCERNING THE SAFETY OF THE SHIP OR ANOTHER SHIP, OR THE SAFETY OF ANY PERSON ON BOARD THE SHIP OR IN SIGHT OF THE SHIP. THIS SIGNAL SHALL BE TRANSMITTED ONLY WITH THE AUTHORIZATION OF THE MASTER OR PERSON RESPONSIBLE FOR THE SHIP.

THE SAFETY SIGNAL

THE SAFETY SIGNAL CONSISTS OF THE GROUP T T T WHICH IS TRANSMITTED WITH THE LETTERS WELL SEPARATED, FOLLOWED BY THE WORD "DE" AND BY THE CALL SIGNAL OF THE STATION SENDING IT. THIS SIGNAL INDICATES THAT THE STATION SENDING IT IS ABOUT TO TRANSMIT A MESSAGE CONCERNING THE SAFETY OF NAVIGATION OR GIVING OTHER IMPORTANT INFORMATION RELATIVE TO METEOROLOGICAL WARNING MESSAGES.

THE SAFETY SIGNAL AND THE SAFETY MESSAGE SHALL BE SENT AT 500 KC. AND IF NECESSARY, ON THE NORMAL LISTENING WAVE OF SHIP AND AIRCRAFT STATIONS. IT SHALL BE SENT ONCE DURING THE FIRST SILENT PERIOD AND NEAR THE END OF THAT PERIOD. ALL STATIONS HEARING IT MUST CONTINUE TO LISTEN ON THE NORMAL SHIP CALLING WAVE OR ON THE AUTHORIZED AIRCRAFT STATION WAVE UNTIL THE MESSAGE PRECEDED BY THE SAFETY SIGNAL SHALL HAVE ENDED. THE TRANSMISSION OF THIS MESSAGE SHALL BEGIN IMMEDIATELY AFTER THE END OF THE SILENT PERIOD.

THE CQ SIGNAL

THE SIGNAL CQ IS THE SIGNAL OF INQUIRY. STATIONS DESIRING TO ENTER INTO COMMUNICATION WITH MOBILE STATIONS WITHOUT, HOWEVER, KNOWING THE NAMES OF MOBILE STATIONS WHICH ARE WITHIN THEIR RANGE OF ACTION, MAY USE THE SIGNAL OF THE STATION CALLED IN THE CALLING FORMULA, THIS FORMULA BEING FOLLOWED BY THE LETTER K.

IN REGIONS WHERE TRAFFIC IS HEAVY, THE USE OF THE CALL CQ FOLLOWED BY THE LETTER K IS FORBIDDEN EXCEPT IN COMBINATION WITH URGENT SIGNALS. THE CALL CQ NOT FOLLOWED BY THE LETTER K SHALL BE EMPLOYED FOR RADIOTELEGRAMS OF GENERAL INFORMATION, TIME SIGNALS, REGULAR METEOROLOGICAL INFORMATION, GENERAL SAFETY NOTICES, AND INFORMATION OF ALL KINDS INTENDED TO BE READ BY ANYONE WHO CAN RECEIVE THEM.

VARIOUS REGULATIONS

THE FOLLOWING ARE REGULATIONS OF VARIOUS TYPES AND WITH WHICH THE COMMERCIAL OPERATOR SHOULD BE FAMILIAR:

1. – Table I specifies the time periods during which a radio watch must be maintained on all ships within the zones indicated. These are known as "zones of watch" and in Table I the figures indicate time on the 24-hour time system. The International Law also requires that all stations in mobile maritime service must listen-in on the distress wave for three minutes twice each hour, beginning at the 15th minute and at the 45th minute after each hour, and also during the time of distress communications.

2. – Two International silent periods are to be observed per hour. Each of these silent periods should be three minutes long, beginning at the 15th minute and at the 45th minute after each hour Greenwich Mean Time. During these periods the transmitter shall not be used.

3. – During transmissions "to all stations" of time signals and of meteorological messages intended for stations of the mobile service, all stations in that service and the transmissions of which might interfere with the reception of the signal and messages in question, must keep silent in order to permit all stations so desiring to receive these signals and messages.

4. – No person receiving or assisting in receiving any radio communication shall divulge or publish its contents or any part of it to any person other than the addressee, his agent, or attorney, or master of the ship on which the message is sent or received, or in response to a subpoena issued by a court of competent jurisdiction, or in demand of other lawful authority. For violating this law the violator may be punished by a fine of not more than $500 for each and every offense.

TABLE NO. I

ZONES OF WATCH SCHEDULE

	Zones	Duration of hours of service Greenwich Mean Time — One operator ships	Duration of hours of service Greenwich Mean Time — Two operator ships
A........	Eastern Atlantic Ocean, Mediterranean, North Sea, Baltic	From 8 to 10h 12 to 14h 16 to 18h 20 to 22h	From 0 to 6h 8 to 14h 16 to 18h 20 to 22h
B........	Indian Ocean, eastern Arctic Ocean	From 4 to 6h 8 to 10h 12 to 14h 16 to 18h	From 0 to 2h 4 to 10h 12 to 14h 16 to 18h 20 to 24h
C........	China Sea, western Pacific Ocean	From 0 to 2h 4 to 6h 8 to 10h 12 to 14h	From 0 to 6h 8 to 10h 12 to 14h 16 to 22h
D.......	Central Pacific Ocean	From 0 to 2h 4 to 6h 8 to 10h 20 to 22h	From 0 to 2h 4 to 6h 8 to 10h 12 to 18h 20 to 24h
E........	Eastern Pacific Ocean	From 0 to 2h 4 to 6h 16 to 18h 20 to 22h	From 0 to 2h 4 to 6h 8 to 14h 16 to 22h
F........	Western Atlantic Ocean and Gulf of Mexico	From 0 to 2h 12 to 14h 16 to 18h 20 to 22h	From 0 to 2h 4 to 10h 12 to 18h 20 to 22h

5. – The ship's master has the right to censure any messages received and transmitted by the radio station on shipboard.

6. – Vessels plying 200 miles or more between ports and licensed to carry,

OR CARRYING, FIFTY OR MORE PASSENGERS OR CREW SHALL BE EQUIPPED WITH RADIO APPARATUS AND BE IN CHARGE OF TWO OR MORE OPERATORS AND MAINTAIN A CONTINUOUS WATCH. EMERGENCY EQUIPMENT, INDEPENDENT OF THE SHIP'S MAIN SOURCE OF POWER SUPPLY, CAPABLE OF TRANSMITTING AND RECEIVING MESSAGES OVER A DISTANCE OF 100 MILES DAY OR NIGHT FOR A PERIOD OF AT LEAST FOUR HOURS, MUST BE PROVIDED.

7. - MAXIMUM POWER SHALL BE USED IN TRANSMITTING DISTRESS MESSAGES OR MESSAGES RELATED HERETO. IN ALL OTHER CLASSES OF RADIO CORRESPONDENCE ONLY THAT AMOUNT OF POWER NECESSARY TO INSURE RELIABLE COMMUNICATION SHALL BE USED. WHEN WITHIN 5 NAUTICAL MILES OF NAVAL OR MILITARY STATIONS THE TRANSFORMER INPUT SHALL NOT EXCEED $\frac{1}{2}$ KW AND WHEN WITHIN 15 MILES OF SUCH STATIONS THE TRANSFORMER INPUT SHALL NOT EXCEED 1 KW.

8. - SUPERFLUOUS SIGNALS ARE THOSE WHICH ARE UNNECESSARY IN CARRYING OUT EFFICIENT RADIO CORRESPONDENCE. THEY ARE FORBIDDEN.

9. - NO PERSON, FIRM, COMPANY OR CORPORATION WITHIN THE JURISDICTION OF THE UNITED STATES SHALL KNOWINGLY UTTER OR TRANSMITK OR CAUSE TO BE UTTERED OR TRANSMITTED, ANY FALSE OR FRAUDULENT SIGNAL OF DISTRESS OR COMMUNICATION RELATING THERETO.

10.- THE PRIORITY OF VARIOUS CLASSES OF RADIO COMMUNICATIONS FOLLOW THE ORDER AS HERE GIVEN.

(A) DISTRESS CALLS, DISTRESS MESSAGES, AND DISTRESS TRAFFIC.

(B) COMMUNICATIONS PRECEDED BY AN URGENT SIGNAL.

(C) COMMUNICATIONS PRECEDED BY THE SAFETY SIGNAL.

(D) COMMUNICATIONS RELATIVE TO RADIO COMPASS BEARINGS.

(E) ALL OTHER COMMUNICATIONS.

11. - ALL STATIONS ARE BOUND TO EXCHANGE RADIO COMMUNICATIONS OR SIGNALS WITH OTHER STATIONS REGARDLESS OF THE RADIO SYSTEM USED.

12. - IF IT IS NECESSARY TO COMMUNICATE WITH A FOREIGN VESSEL WHOSE CREW CANNOT UNDERSTAND ENGLISH, THEN THE COMMUNICATION SHOULD BE CONDUCTED BY MEANS OF THE INTERNATIONAL SIGNAL CODE AND THE INTERNATIONAL RADIOTELEGRAPH ABREVIATIONS.

13. - IN TABLE II YOU ARE GIVEN A HANDY REFERENCE TABLE OF ALL WAVE LENGTH ALLOCATIONS FOR VARIOUS PURPOSES.

14. - THE VIOLATIONS AND THEIR PENALTIES TO WHICH AN OPERATOR IS SUBJECT UNDER THE RADIO ACT OF 1927 ARE AS FOLLOWS:

AN OPERATOR'S LICENSE MAY BE SUSPENDED FOR A PERIOD NOT EXCEEDING TWO YEARS FOR: (A) FAILURE TO CARRY OUT THE LAWFUL ORDERS OF THE MASTER OF THE VESSEL ON WHICH HE IS EMPLOYED, (B) WILLFULLY DAMAGING OR PERMITTING RADIO APPARATUS TO BE DAMAGED, (C) TRANSMITTING SUPERFLUOUS RADIO COM

TABLE NO. II

WAVE-LENGTH ALLOCATIONS

Frequencies, kilocycles per second	Approximate wave lengths, meters	Services
10 to 100	30,000 to 3,000	Fixed services
100 to 110	3,000 to 2,725	Fixed services and mobile services
110 to 125	2,725 to 2,400	Mobile services
125 to 150[1]	2,400 to 2,000[1]	Maritime mobile services *open to public correspondence exclusively*
150 to 160	2,000 to 1,875	Mobile services
160 to 194	1,875 to 1,550	a. Broadcasting b. Fixed services c. Mobile services The conditions for use of this band are subject to the following regional arrangements: All regions where broadcasting stations now exist working on frequencies below 300 kilocycles per second (above 1,000 meters): broadcasting Other regions: Fixed services, Mobile services
194 to 285	1,550 to 1,050	Regional arrangements will respect the rights of other regions in this band a. Mobile service b. Fixed service c. Broadcasting The conditions for use of this band are subject to the following regional arrangements: Europe: a. *Air mobile service exclusively* b. *Air fixed services exclusively* c. Within the band 250 to 285 kilocycles per second (1,200 to 1,050 meters). Fixed service *not open to public correspondence.* d. Broadcasting within the band 194 to 224 kilocycles per second (1,550 to 1,340 meters) Other regions: a. Mobile services except commercial ship stations b. Fixed air services *exclusively* c. Fixed services *not open to public correspondence*
285 to 315	1,050 to 950	Radio beacons
315 to 350[2]	950 to 850[2]	*Air mobile services exclusively*
350 to 360	850 to 830	Mobile services *not open to public correspondence*
360 to 390	830 to 770	a. Radio compass service b. Mobile services, on condition that they do not interfere with radio compass service
390 to 460	770 to 650	Mobile services
460 to 485	650 to 620	Mobile services (*except damped waves and radiotelephony*)
485 to 515[3]	620 to 580[3]	Mobile services (distress, call, etc.)
515 to 550	580 to 545	Mobile services *not open to public correspondence (except damped waves and radiotelephony)*
550 to 1,300[4]	545 to 230[4]	Broadcasting: a. Broadcasting
1,300 to 1,500	230 to 200	b. Maritime mobile services, waves of 1,365 kilocycles per second (220 meters) exclusively

CONTINUED

Frequencies, kilocycles per second	Approximate wave lengths, meters	Services
1,500 to 1,715	200 to 175	Mobile services
1,715 to 2,000	175 to 150	Mobile services Fixed services Amateurs
2,000 to 2,250	150 to 133	Mobile services and fixed services
2,250 to 2,750	133 to 109	Mobile services
2,750 to 2,850	109 to 105	Fixed services
2,850 to 3,500	105 to 85	Mobile services and fixed services
3,500 to 4,000	85 to 75	Mobile services Fixed services Amateurs
4,000 to 5,500	75 to 54	Mobile services and fixed services
5,500 to 5,700	54 to 52.7	Mobile services
5,700 to 6,000	52.7 to 50	Fixed services
6,000 to 6,150	50 to 48.8	Broadcasting
6,150 to 6,675	48.8 to 45	Mobile services
6,675 to 7,000	45 to 42.8	Fixed services
7,000 to 7,300	42.8 to 41	Amateurs
7,300 to 8,200	41 to 36.6	Fixed services
8,200 to 8,550	36.6 to 35.1	Mobile services
8,550 to 8,990	35.1 to 33.7	Mobile services and fixed services
8,900 to 9,500	33.7 to 31.6	Fixed services
9,500 to 9,600	31.6 to 31.2	Broadcasting
9,600 to 11,000	31.2 to 27.3	Fixed services
11,000 to 11,400	27.3 to 26.3	Mobile services
11,400 to 11,700	26.3 to 25.6	Fixed services
11,700 to 11,900	25.6 to 25.2	Broadcasting
11,900 to 12,300	25.2 to 24.4	Fixed services
12,300 to 12,825	24.4 to 23.4	Mobile services
12,825 to 13,350	23.4 to 22.4	Mobile services and fixed services
13,350 to 14,000	22.4 to 21.4	Fixed services
14,000 to 14,400	21.4 to 20.8	Amateurs
14,400 to 15,000	20.8 to 19.85	Fixed services
15,100 to 15,350	19.85 to 19.55	Broadcasting
15,350 to 16,400	19.55 to 18.3	Fixed services
16,400 to 17,100	18.3 to 17.5	Mobile services
17,100 to 17,750	17.5 to 16.9	Mobile services and fixed services
17,750 to 17,800	16.9 to 16.85	Broadcasting
17,800 to 21,450	16.85 to 14	Fixed services
21,450 to 21,550	14 to 13.9	Broadcasting
21,550 to 22,300	13.9 to 13.45	Mobile services
22,300 to 23,000	13.45 to 13.1	Mobile services and fixed services
23,000 to 28,000	13.1 to 10.7	Not reserved
28,000 to 30,000	10.7 to 10	Amateurs and experimental
30,000 to 56,000	10 to 5.35	Not reserved
56,000 to 60,000	5.35 to 5	Amateurs and experimental
Above 60,000	Below 5	Not reserved

[1] The wave of 143 kilocycles per second (2,100 meters) is the calling wave for mobile stations using long continuous waves.

[2] The wave of 333 kilocycles per second (900 meters) is the international calling wave for air services.

[3] The wave of 500 kilocycles per second (600 meters) is the international calling and distress wave. It may be used for other purposes on condition that it will not interfere with call signals and distress signals.

[4] Mobile services may use the band 550 to 1,300 kilocycles per second (545 to 230 meters) on condition that this will not cause interference with the services of a country which uses this band exclusively for broadcasting.

NOTE.—It is recognised that short waves (frequencies from 6,000 to 23,000 kilocycles per second approximately—wave lengths from 50 to 13 meters approximately) are very efficient for long-distance communications. It is recommended that, as a general rule, this band of waves be reserved for this purpose, in services between fixed points.

MUNICATIONS OR SIGNALS OR RADIO COMMUNICATIONS CONTAINING PROFANE OR OBSCENE WORDS OR LANGUAGE, (D) WILLFULLY OR MALICIOUSLY INTERFERING WITH ANY RADIO COMMUNICATIONS OR SIGNALS, (E) ANY IMPROPER ALTERATION OF THE SERVICE RECORD ON THE LICENSE, OR THE FORGERY OF MASTERS' OR EMPLOYERS' SIGNATURES THEREON OR (F) VIOLATION OF ANY PROVISION OF ANY ACT OR TREATY BINDING ON THE UNITED STATES WHICH THE SECRETARY OF COMMERCE OR THE COMMISSION IS AUTHORIZED BY THE RADIO ACT OF 1927 TO ADMINISTER, OR OF ANY REGULATION MADE BY THE COMMISSION OR THE SECRETARY OF COMMERCE UNDER ANY SUCH ACT OR TREATY.

ANY OPERATOR FAILING OR REFUSING TO OBSERVE OR VIOLATING ANY RULE, REGULATION, RESTRICTION, OR CONDITION MADE OR IMPOSED BY THE LICENSING AUTHORITY UNDER THE AUTHORITY OF THE RADIO ACT OF 1927 OR OF ANY INTERNATIONAL RADIO CONVENTION OR TREATY RATIFIED OR ADHERED TO BY THE UNITED STATES, IN ADDITION TO ANY OTHER PENALTIES PROVIDED BY LAW, UPON CONVICTION THEREOF BY A COURT OF COMPETENT JURISDICTION, SHALL BE PUNISHED BY A FINE OF NOT MORE THAN $500 FOR EACH AND EVERY OFFENSE.

ANY OPERATOR WHO SHALL VIOLATE ANY PROVISION OF THE RADIO ACT OF 1927, OR SHALL KNOWINGLY MAKE ANY FALSE OATH OR AFFIRMATION IN ANY AFFIDAVIT REQUIRED OR AUTHORIZED BY THE RADIO ACT OF 1927, OR SHALL KNOWINGLY SWEAR FALSELY TO A MATERIAL MATTER IN ANY HEARING AUTHORIZED BY THE ACT, UPON THE CONVICTION THEREOF IN ANY COURT OF COMPETENT JURISDICTION SHALL BE PUNISHED BY A FINE OF NOT MORE THAN $5000 OR BY IMPRISONMENT FOR A TERM OF NOT MORE THAN FIVE YEARS, OR BOTH, FOR EACH AND EVERY SUCH OFFENSE.

15. — EVERY SHIP STATION WHOSE RADIO SERVICE IS ON THE VERGE OF BEING CLOSED BY REASON OF ITS ARRIVAL IN PORT MUST NOTIFY THE NEAREST LAND STATION. A CONSTANT RADIO WATCH SHALL BE MAINTAINED WHEN ENTERING ANY PORT OF CALL, BEGINNING EIGHT HOURS BEFORE ARRIVAL.

16. — BROADCASTING TRANSMITTERS ARE PERMITTED BY LAW TO HAVE A FREQUENCY DEVIATION NOT IN EXCESS OF 50 CYCLES, PLUS OR MINUS.

17. — WHEN IT IS NECESSARY TO MAKE TEST SIGNALS IN ORDER TO ADJUST THE APPARATUS BEFORE PROCEEDING WITH A CALL OR TRANSMISSION, THEN THE SIGNALS MUST NOT BE MADE FOR MORE THAN ABOUT 10 SECONDS AND THEY MUST BE COMPOSED OF A SERIES OF V'S FOLLOWED BY THE CALL SIGNAL OF THE SENDING STATION.

IF A STATION SENDS TEST SIGNALS AT THE REQUEST OF ANOTHER STATION TO PERMIT THE LATTER TO ADJUST ITS RECEIVING APPARATUS, THESE SIGNALS MUST LIKEWISE BE COMPOSED OF A SERIES OF V'S IN WHICH THE CALL SIGNAL OF THE TRANSMITTING STATION SHALL APPEAR SEVERAL TIMES.

TESTS AND ADJUSTMENTS IN ANY STATION MUST BE CONDUCTED SO AS NOT TO INTERFERE WITH THE SERVICE OF OTHER STATIONS ENGAGED IN AUTHORIZED CORRESPONDENCE. THE TEST AND ADJUSTMENT SIGNALS MUST BE CHOSEN SO THAT NO CONFUSION CAN BE PRODUCED WITH A SIGNAL, ABBREVIATION ETC. OF SPECIAL MEANING DEFINED BY THE REGULATIONS.

ANY STATION TRANSMITTING FOR TESTS, ADJUSTMENTS, OR EXPERIMENTS, MUST DURING THE COURSE OF THESE TRANSMISSIONS SEND ITS CALL SIGNALS AT FREQUENT INTERVALS.

AMATEUR RULES AND REGULATIONS

For those who are interested in operating an amateur station, the following rules and regulations are pointed out. It is to be noted that those rules here given apply particularly to amateur operation and were therefore not given earlier in this lesson where commercial operating was of primary consideration. It is, however, advisable that even the amateur operator be familiar with ALL of the rules and regulations which have been presented in this lesson.

1. — The term "amateur" when used without further descriptive words means a person interested in radio technique solely with a personal aim and without accepting payment for handling messages of any kind.

2. — The various bands which are set aside for amateur use are designated as such in Table II of this lesson.

3. — In the United States none other than citizens of this country may obtain an amateur station license and no station may be operated on premises which are controlled by an alien.

4. — All amateur operators are required to keep an accurate "log" (record) of all communications in which they engage and are obliged to make it available to authorized government representatives upon demand. This log must specify the date and time of all transmissions; the name of the person operating the transmitter at that time; the station called; nature of transmission; the frequency band used; the location of the transmitter at each transmission if it is of the portable type; and the input power to the final amplifier stage.

5. — The maximum input power allowed for an amateur station is 1 Kw. This means a maximum of 1 Kw. to the plate circuit of the final amplifier.

6. — An amateur station may not broadcast any form of entertainment.

7. — If an amateur station causes interference with broadcast reception on receivers of modern design, the station is required to observe a silent period (called "quiet hours") from 8:00 P.M. to 10:30 P.M. local time and on Sundays during an additional period extending from 10:30 A.M. until 1 P.M.

8. — Amateurs in different countries must confine their exchange to communications having to do with their experiments and/or to remarks of such a nature that they would not be sufficiently important to send by public telegraph or cable service. Unless special arrangements have been made between governments of the two countries concerned, third-party messages (that is, messages addressed to or from some person other than either of the amateurs concerned in the contact) may not be handled.

9. — In the event that the operator of an amateur station should here a distress signal being transmitted from a ship or aircraft, then

HE SHOULD CEASE ALL TRANSMISSION CAPABLE OF INTERFERING WITH THE SIGNALS OF THE DISTRESSED SHIP, OR STATIONS COMMUNICATING WITH IT. THE OPERATOR SHOULD CONTINUE TO LISTEN UNTIL IT IS APPARENT THAT THE SHIP IS RECEIVING ASSISTANCE.

IF NO ONE SEEMS TO ANSWER THE SHIP, FULL PARTICULARS SHOULD IMMEDIATELY BE CONVEYED BY LAND LINE TO THE NEAREST GOVERNMENT OR COMMERCIAL STATION. EVERYTHING POSSIBLE SHOULD BE DONE TO BRING ASSISTANCE TO THE DISTRESSED SHIP WITHOUT RISKING RADIO INTERFERENCE TO THOSE IN A POSITION TO AID.

IF YOU INTEND TO ENGAGE IN COMMERCIAL OPERATING OR TO BECOME ACTIVE IN THE FIELD OF BROADCASTING, THEN YOU SHOULD STUDY THIS LESSON WITH SPECIAL CARE BECAUSE QUESTIONS CONCERNING THE SUBJECT MATTER CONTAINED HEREIN ARE ASKED IN THE GOVERNMENT EXAMINATIONS WHICH QUALIFY YOU FOR AN OPERATOR'S LICENSE. EVEN THOUGH YOU DO NOT SELECT ANY OF THESE PARTICULAR FIELDS FOR SPECIALIZATION, IT IS MOST ADVISABLE THAT YOU HAVE A CLEAR KNOWLEDGE OF THIS MATTER, FOR YOU NEVER CAN TELL BUT THAT YOU MIGHT HAVE NEED FOR IT SOME TIME IN THE FUTURE, EVEN THOUGH YOU MAY NOT REALIZE IT NOW.

WITHOUT A DOUBT, YOU ARE GOING TO FIND THE FOLLOWING LESSON TO BE OF SPECIAL INTEREST IN THAT YOU WILL AT THAT TIME COMMENCE YOUR STUDY OF RADIO TELEPHONE TRANSMITTERS, WHICH PERMIT THE TRANSMISSION OF VOICE BY MEANS OF RADIO. HOWEVER, BEFORE CONTINUING WITH THE NEXT LESSON, FIRST MAKE SURE THAT YOU HAVE A PERFECT UNDERSTANDING OF EVERYTHING WHICH HAS BEEN COVERED UP UNTIL NOW REGARDING CODE TRANSMITTERS BECAUSE THE MAJORITY OF THESE SAME PRINCIPLES ARE AGAIN GOING TO BE EMPLOYED IN YOUR PHONE TRANSMITTER STUDIES WHICH ARE NOW TO COME. SINCE IT WILL BE ASSUMED THAT YOU ARE ALREADY WELL INFORMED CONCERNING THE SUBJECTS OF PREVIOUS LESSONS, NONE OF THESE SHALL BE REPEATED IN THE FOLLOWING LESSONS. THEREFORE, IF THERE IS ANY DOUBT WHATEVER IN YOUR MIND REGARDING ANY ONE OF THESE SUBJECTS, IT IS ADVISABLE BEFORE CONTINUING WITH YOUR ADVANCED WORK THAT YOU REVIEW YOUR PREVIOUS TRANSMITTER LESSONS VERY CAREFULLY — ESPECIALLY THOSE WHICH TREAT WITH OSCILLATORS, AMPLIFIERS, ANTENNA SYSTEMS, AND POWER SUPPLIES.

Ans Feb 21, 1942

Examination Questions

LESSON NO. T-12

A business may be ever so successful, but it is never so sure -- never secure, until it holds its old friends by Service and increases its circle of New Friends on the basis of Satisfaction.

1. – What is the general routine which is to be followed when calling a station?

2. – If you were an operator aboard ship, how would you obtain a radio compass bearing?

3. – How would you answer a call from another station previous to the transmission of the actual message?

4. – Explain the relation between Eastern Standard Time, Pacific Standard Time, and Greenwich Mean Time.

5. – Explain in detail how a Radiogram should be transmitted.

6. – If you were an operator aboard ship, how would you send the distress signal?

7. – Explain in detail the twenty-four-hour time system.

8. – What is meant by the expression "zones of watch"?

9. – What is the law regarding the secrecy of messages which are handled by radio communication?

10.– State the order of priority of various classes of radio communication.

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Transmitters

LESSON NO. 13

RADIO · TELEGRAPH · TRANSMITTERS

YOUR TRANSMITTER STUDIES UP TO THE PRESENT TIME HAVE TREATED EXCLUSIVELY WITH CODE TRANSMITTERS, BUT COMMENCING WITH THIS LESSON YOU ARE GOING TO BE TOLD A GREAT DEAL ABOUT TRANSMITTERS WHICH ARE SUITABLE FOR THE TRANSMISSION OF BOTH VOICE AND MUSIC. TRANSMITTERS OF THIS TYPE ARE GENERALLY CLASSIFIED AS RADIO TELEPHONE TRANSMITTERS AND FREQUENTLY FOR THE SAKE OF CONVENIENCE REFERRED TO SIMPLY AS "PHONE TRANSMITTERS".

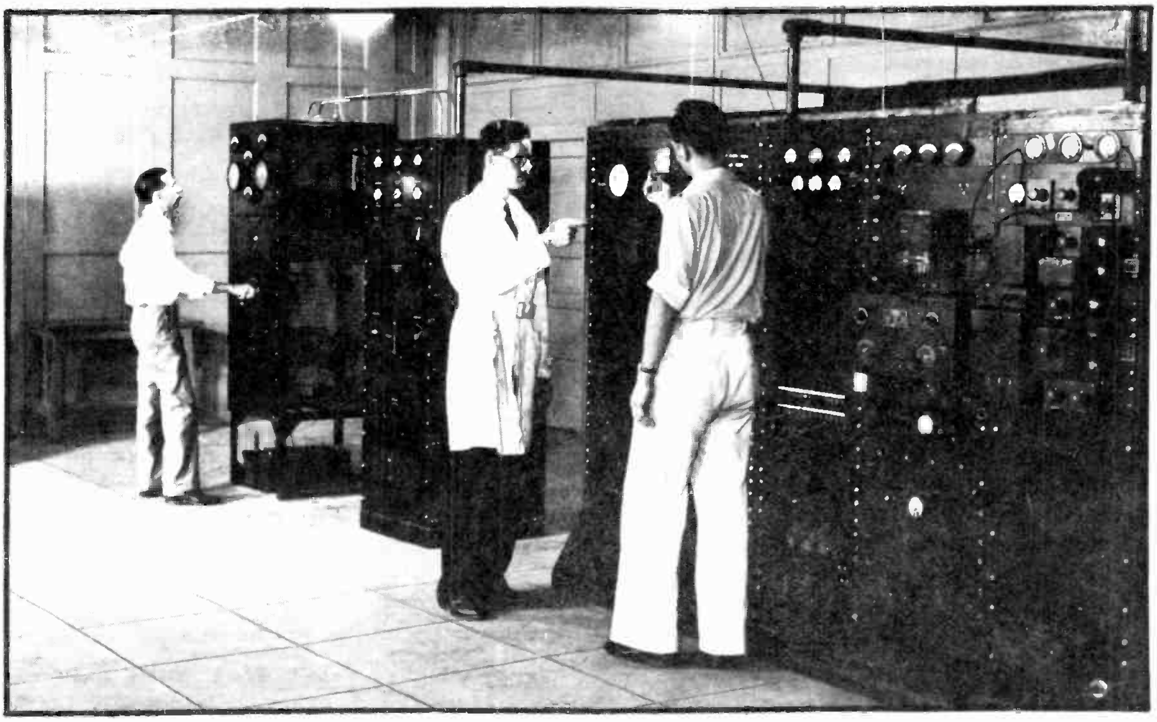

FIG.1
A Section of National's Transmitter Room.

IT IS IMPORTANT THAT YOU BEAR IN MIND THAT THE RADIO FREQUENCY SECTION OF PHONE TRANSMITTERS IS FUNDAMENTALLY THE SAME AS THAT OF A CODE TRANSMITTER. IN BOTH CASES, THIS SECTION OF THE TRANSMITTER GENERATES AND AMPLIFIES RADIO FREQUENCY ENERGY SO THAT THE NECESSARY ELECTROMAGNETIC WAVES MAY BE RADIATED IN ORDER TO CARRY THE MESSAGE OR PROGRAM THROUGH SPACE. THIS MEANS THAT EVERYTHING WHICH YOU HAVE LEARNED SO FAR CONCERNING TRANSMITTERS IS GOING TO BE OF GREAT VALUE TO YOU IN THE STUDIES WHICH ARE NOW TO COME.

THERE ARE OF COURSE SOME RADICAL DIFFERENCES BETWEEN CODE AND PHONE TRANSMITTERS BUT THESE SHALL ALL BE POINTED OUT TO YOU AS WE ADVANCE THRU THIS MOST INTERESTING PART OF YOUR TRANSMITTER STUDIES.

MODULATION

IN FIG. 2 YOU ARE SHOWN A BLOCK DIAGRAM OF A TYPICAL RADIO TELEPHONE TRANSMITTER. AS YOU WILL OBSERVE, THE OSCILLATOR, R.F. AMPLIFIER, POWER AMPLIFIER AND THE ANTENNA ARE PLACED IN THIS SYSTEM IN THE SAME MANNER AS YOU FOUND THEM IN CODE TRANSMITTERS. THIS SECTION OF THE PHONE TRANSMITTER IS SO CONSTRUCTED THAT WHEN NO SOUNDS ARE BEING PICKED UP BY THE MICROPHONE, A CONTINUOUS TYPE WAVE WILL BE RADIATED BY THE ANTENNA SYSTEM. THIS IS KNOWN AS THE CARRIER WAVE.

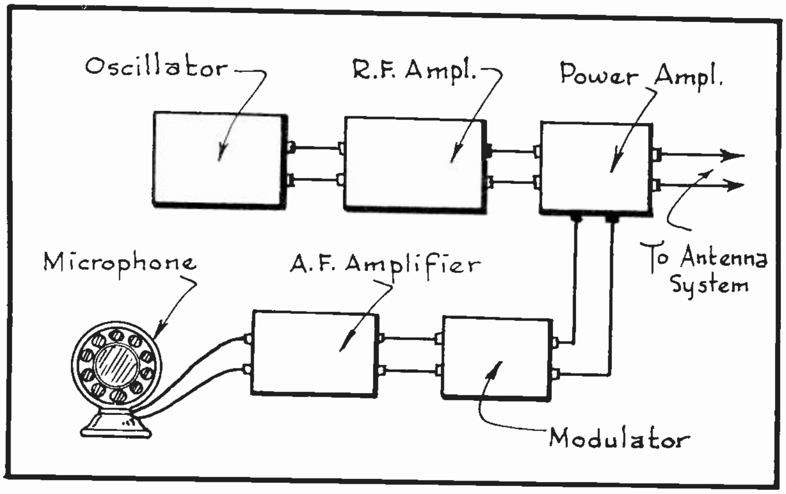

FIG. 2

Block Diagram of a Typical Radio Telephone Transmitter.

WHENEVER SOUND WAVES ACT UPON THE MICROPHONE, THEN THESE ARE CONVERTED TO ELECTRICAL IMPULSES IN THE USUAL WAY AND ARE AMPLIFIED BY THE A.F. AMPLIFIER. THE TASK OF THE MODULATOR IS TO UTILIZE THE AMPLIFIED A.F. SIGNALS IN SUCH A MANNER THAT THE R.F. WAVE-FORM AT THE OUTPUT OF THE TRANSMITTER WILL HAVE EITHER ITS FREQUENCY OR AMPLITUDE VARIED IN ACCORDANCE WITH THE AUDIO WAVE-FORM AS FURNISHED BY THE A.F. AMPLIFIER. THIS PROCESS OF VARYING THE R.F. WAVE-FORM OF THE TRANSMITTER EITHER IN FREQUENCY OR AMPLITUDE AT AN AUDIO FREQUENCY RATE IS KNOWN AS MODULATION.

ALTHOUGH MODULATION CAN BE ACCOMPLISHED BY VARYING EITHER THE FREQUENCY OR AMPLITUDE OF THE R.F. WAVE AT AN AUDIO FREQUENCY RATE, YET COMMERCIALLY ONLY "AMPLITUDE MODULATION" IS USED IN MODERN RADIO TELEPHONE EQUIPMENT.

THE MODULATED WAVE

IN FIG.3 YOU ARE SHOWN WHAT HAPPENS TO THE CARRIER WAVE WHEN AMP-

LITUDE MODULATION TAKES PLACE. NOTICE AT THE RIGHT OF FIG. 3 HOW THE CARRIER FREQUENCY IS OF THE PURE C.W. (CONTINUOUS) TYPE AND OF CONSTANT AMPLITUDE AT THAT TIME WHEN NO MODULATION OCCURS.

WHEN MODULATION OCCURS, THE CARRIER FREQUENCY STILL REMAINS CONSTANT BUT THE AMPLITUDE OF THIS WAVE-FORM INCREASES AND DECREASES IN ACCORDANCE WITH THE AUDIO FREQUENCY VARIATIONS. WE THEN HAVE A CONDITION AS PICTURED IN THAT PORTION OF FIG. 3 WHERE MODULATION IS SHOWN AS TAKING PLACE.

THE EXTENT OR AMOUNT THAT THE CARRIER WAVE IS CHANGED DURING THE PROCESS OF MODULATION IS EXPRESSED AS A PERCENTAGE AND IS COMMONLY REFERRED TO AS THE PERCENTAGE OF MODULATION.

THE CARRIER WAVE NORMALLY HAS A CERTAIN VALUE OR AMPLITUDE AND WHEN "FULL MODULATION" OR 100% MODULATION OCCURS, WE HAVE A CONDITION AS PICTURED AT "A" OF FIG. 4. IN THIS CASE, WE FIND THAT WHEN THE POSITIVE PEAK OF THE AUDIO WAVE REACHES ITS MAXIMUM VALUE, THE PEAKS OF THE CARR-

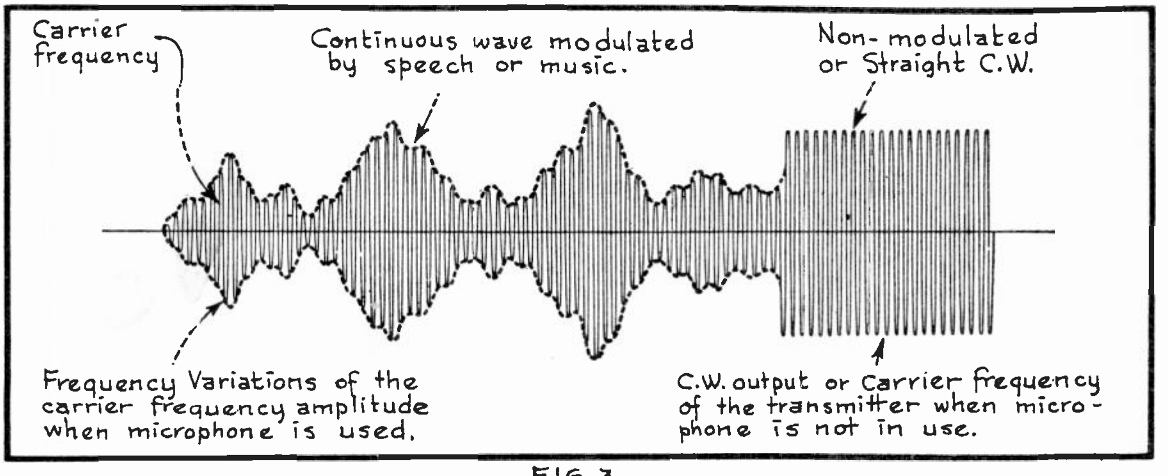

FIG. 3
Modulating the Carrier Frequency.

IER WAVE BECOME DOUBLE THE VALUE REACHED WHEN NO MODULATION IS OCCURING. ALSO, WHEN THE OTHER HALF OF THE AUDIO WAVE REACHES A MAXIMUM VALUE IN A NEGATIVE DIRECTION, THE CARRIER-WAVE PEAKS ARE REDUCED TO ZERO.

THE CONDITION OF 100% MODULATION IS IDEAL AND IS STRIVED FOR IN ALL HIGH QUALITY TRANSMITTERS.

WHENEVER THE CARRIER-WAVE IS LESS THAN 100% MODULATED, THEN WE HAVE A CONDITION SOMEWHAT AS THAT ILLUSTRATED AT "B" OF FIG. 4. HERE YOU WILL OBSERVE THAT THE PEAKS OF THE CARRIER-WAVE NO LONGER BECOME EQUAL TO TWICE THEIR UN-MODULATED AMPLITUDE WHEN THE A.F. WAVE IS AT ITS POSITIVE MAXIMUM VALUE, NOR IS THE CARRIER WAVE REDUCED TO ZERO WHEN THE A.F. WAVE IS AT ITS NEGATIVE MAXIMUM VALUE.

THE REPRODUCTION OF THE SOUNDS AT THE RECEIVER IS GREATLY AFFECTED BY THE EXTENT TO WHICH THE CARRIER-WAVE IS MODULATED. FOR INSTANCE, AS FAR AS THE RECEIVER IS CONCERNED, A 10-WATT CARRIER MODULATED 100% IS PRACTICALLY AS EFFECTIVE AS A 40-WATT CARRIER WHICH IS MODULATED ONLY 50%.

AT "C" OF FIG. 4 YOU ARE SHOWN WHAT OCCURS WHEN "OVER-MODULATION" TAKES PLACE. WHEN THIS HAPPENS, WE FIND THAT WHEN THE POSITIVE PEAK OF THE AUDIO WAVE REACHES ITS MAXIMUM VALUE, THE PEAKS OF THE CARRIER WAVE BECOME MORE THAN DOUBLE THE VALUE REACHED WHEN NO MODULATION OCCURS. FURTHERMORE, WHEN THE OTHER HALF OF THE AUDIO WAVE REACHES A MAXIMUM VALUE IN A NEGATIVE DIRECTION, THE NEGATIVE PEAK OF THE ENVELOPE IS CUT OFF ENTIRELY. THIS THEN IS A CASE OF UNSYMMETRICAL MODULATION IN THAT THE AVERAGE AMPLITUDE IS NO LONGER THE SAME AS THE UNMODULATED AMPLITUDE AND DISTORTION RESULTS EVEN THOUGH THE MODULATING SIGNAL BE A PURE TONE. OVER-MODULATION, THEREFORE, IS UNDESIRABLE.

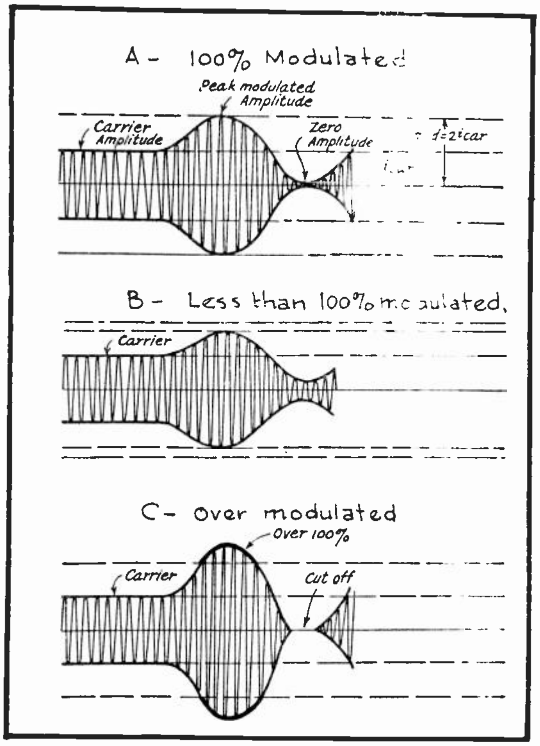

FIG. 4
Various Degrees of Modulation.

THE PERCENTAGE OF MODULATION(M) CAN BE CALCULATED WITH THE AID OF THE FOLLOWING FORMULA:

$$M = \frac{I\ \text{MODULATED} - I\ \text{CARRIER}}{I\ \text{CARRIER}} \times 100$$

WHERE "I MODULATED" IS THE PEAK-CURRENT VALUE AT THE MAXIMUM AMPLITUDE OF THE MODULATED WAVE AND "I CARRIER" IS THE PEAK-CURRENT VALUE OF THE CARRIER AMPLITUDE.

THE EXPRESSION MODULATION FACTOR IS ALSO FREQUENTLY USED. THIS VALUE IS EQUAL TO THE PERCENTAGE OF MODULATION DIVIDED BY 100 — THAT IS, SIMPLY WITH THE PERCENT SIGN REMOVED AND THE DECIMAL POINT MOVED TWO PLACES TOWARDS THE LEFT. IN OTHER WORDS, A MODULATION PERCENTAGE OF 100% IS EQUIVALENT TO A MODULATION FACTOR OF 1; A MODULATION PERCENTAGE OF 50% IS EQUIVALENT TO A MODULATION FACTOR OF 0.5 ETC.

SIDE BANDS

WHEN DEALING WITH MODULATED WAVE-FORMS, WE MUST IN ADDITION TO THE CARRIER FREQUENCY ALSO CONSIDER THE "SIDE-BAND FREQUENCIES". FOR EXAMPLE, STANDARD BROADCAST TRANSMITTERS ARE CAPABLE OF HANDLING AUDIO FREQUENCIES UP TO 5000 CYCLES PER SECOND. ALTHOUGH IT IS TRUE THAT FOR HIGH FIDELITY RECEPTION, A.F. SIGNALS OF STILL HIGHER FREQUENCY WOULD BE REQUIRED, YET THESE HIGHER FREQUENCIES ARE NOT ABSOLUTELY ESSENTIAL FOR SATISFACTORY RESULTS.

AT ANY RATE, ASSUMING THAT AN AUDIO FREQUENCY OF 5000 CYCLES IS BEING HANDLED BY A CERTAIN TRANSMITTER, THIS WOULD MEAN THAT IN ADDITION TO THE CARRIER FREQUENCY, OUR MODULATED WAVE-FORM WOULD ALSO CONSISTS OF TWO SIDE-BAND COMPONENTS EXTENDING 5000 CYCLES ON EACH SIDE OF THE CARRIER FREQUENCY.

IN FIG. 5, FOR INSTANCE, WE HAVE ONE CURVE ILLUSTRATING AN AUDIO FREQUENCY OF 5000 CYCLES BESIDE ANOTHER CURVE WHICH REPRESENTS A STATION'S CARRIER FREQUENCY OF 800 KC. OR 800,000 CYCLES. THE LOWER SIDE-BAND FRE-

QUENCY WOULD THEN BE EQUAL TO 800,000 MINUS 5,000 OR 795,000 CYCLES. THE HIGHER SIDE-BAND FREQUENCY IN THIS SAME INSTANCE WOULD BE EQUAL TO 800,000 PLUS 5,000 OR 805,000 CYCLES.

THE INTERACTION BETWEEN THESE THREE DISTINCT FREQUENCIES PRODUCES THE RESULTANT AMPLITUDE CHANGE IN THE OUTPUT WAVE-FORM, CHANGING IT TO THE SHAPE DESIGNATED AS THE "RESULTANT MODULATED WAVE-FORM" IN FIG. 5. THIS RESULTANT WAVE SHAPE AT EACH POINT REPRESENTS THE INSTANTANEOUS SUM OF THE CARRIER, LOWER SIDE-BAND, AND HIGHER SIDE BAND FREQUENCIES.

ALTHOUGH IT IS TRUE THAT THE BAND WIDTH OCCUPIED BY THE SIDE BANDS IN THIS PARTICULAR CASE AMOUNTS TO 5,000 PLUS 5,000 OR 10,000 CYCLES, YET THE ACTUAL RESULTANT FREQUENCY DUE TO THE INTERACTIONS JUST EXPLAINED IS 5,000 CYCLES AND THE RECEIVER'S SPEAKER UNIT WILL THEREFORE RESPOND TO THIS 5000 CYCLE FREQUENCY AND REPRODUCE THE CORRESPONDING TONE.

THE MODULATION FACTOR CAN ALSO BE DETERMINED IN TERMS OF THE SIDE-BAND AND CARRIER FREQUENCIES BY APPLYING THE FOLLOWING FORMULA:

$$\text{MODULATION FACTOR} = \frac{I_1 + I_2}{I_C}$$

WHERE I_1 = PEAK-CURRENT VALUE OF THE LOWER SIDE-BAND FREQUENCY; I_2 = PEAK-CURRENT VALUE OF THE UPPER SIDE-BAND FREQUENCY; AND I_C = PEAK-CURRENT VAL- OF THE CARRIER FREQUENCY.

METHODS OF MODULATION

NOW THAT YOU ARE FAMILIAR WITH THE GENERAL THEORY PERTAINING TO THE MODULATED WAVE-FORM, YOU WILL NEXT BE INTERESTED IN LEARNING JUST EXACTLY HOW MODULATION IS ACCOMPLISHED.

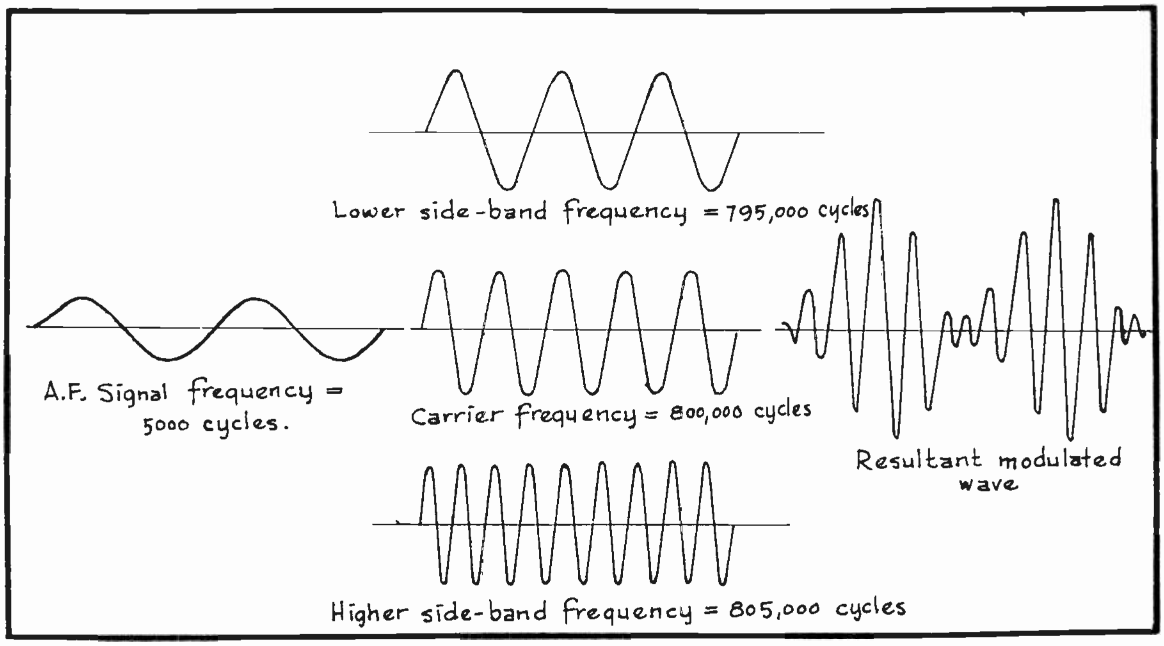

FIG. 5
The Carrier and Side-Band Frequency Relation.

THERE ARE TWO GENERAL TYPES OF MODULATION SYSTEMS WHICH ARE USED, NAMELY, PLATE MODULATION AND GRID MODULATION. PLATE MODULATION WAS INVENTED BY R.A. HEISING AND THEREFORE THIS METHOD IS ALSO KNOWN AS THE "HEISING MODULATION SYSTEM". THE HEISING SYSTEM SHALL BE EXPLAINED TO YOU FIRST.

THE HEISING MODULATING SYSTEM

IN FIG. 6 YOU ARE SHOWN THE BASIC HEISING MODULATING SYSTEM. BY STUDYING THIS CIRCUIT CAREFULLY YOU WILL NOTE THAT AN IRON CORE CHOKE COIL, CALLED THE "PLATE REACTOR", IS CONNECTED BETWEEN B+ AND THE PLATE OF BOTH THE R.F. AMPLIFIER AND THE MODULATOR TUBE. THEREFORE, THE PLATE CURRENT WHICH IS DRAWN BY BOTH OF THESE TUBES MUST FLOW THROUGH THIS SAME REACTOR.

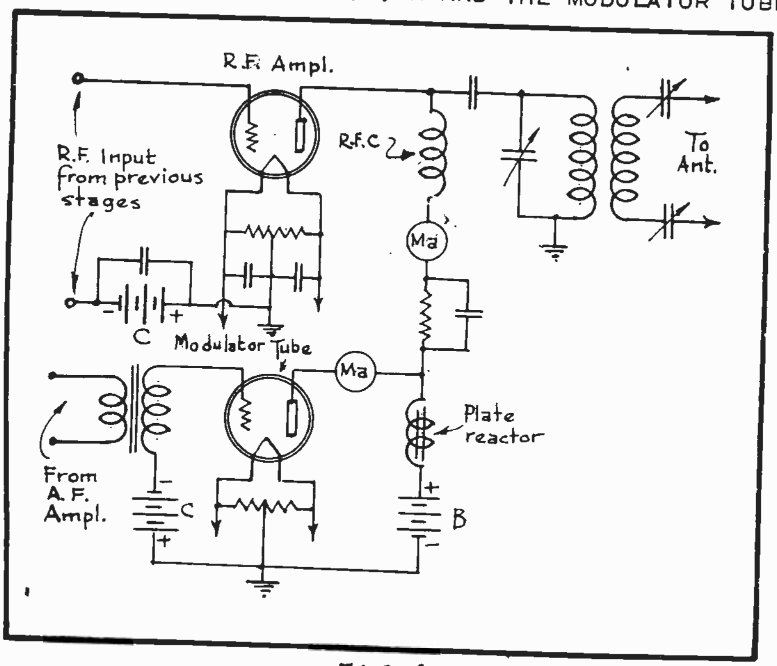

FIG. 6
The Basic Heising Modulating System.

AT THE TIME THAT THE MODULATOR TUBE IS NOT IN USE, THE PLATE CURRENT FLOWING THRU THE R.F. AMPLIFIER WILL VARY ABOVE AND BELOW ITS NORMAL VALUE AT A RADIO FREQUENCY RATE IN ACCORDANCE WITH THE FREQUENCY WHICH IS GENERATED BY THE TRANSMITTER'S OSCILLATOR. THE GRID CIRCUIT OF THE MODULATOR TUBE, ON THE OTHER HAND, IS EXITED AT AN AUDIO FREQUENCY RATE IN ACCORDANCE WITH THE AMPLIFIED SIGNAL ENERGY AS FURNISHED BY THE MICROPHONE AND A.F. AMPLIFIER. THEREFORE, THE PLATE CURRENT WHICH FLOWS THROUGH THIS TUBE WILL VARY ABOVE AND BELOW ITS NORMAL VALUE AT THE AUDIO FREQUENCY RATE ALREADY MENTIONED.

DUE TO THE HIGH SELF-INDUCTANCE OF THE PLATE REACTOR, IT TENDS TO MAINTAIN THE TOTAL CURRENT WHICH FLOWS THROUGH IT AT A PRACTICALLY CONSTANT VALUE. IN OTHER WORDS, WHENEVER, THE CURRENT FLOWING THRU THIS REACTOR TENDS TO INCREASE, ADDITIONAL LINES OF FORCE WILL SPREAD OUT AROUND IT AND WILL CUT THROUGH THE TURNS OF THE WINDING, PRODUCING A COUNTER-ELECTROMOTIVE FORCE WHICH AUTOMATICALLY RETARDS THE FLOW OF CURRENT. SHOULD THE CURRENT FLOW THROUGH THE REACTOR TEND TO DECREASE WITH RESPECT TO ITS NORMAL VALUE, THEN THE COLLAPSING EFFECT OF THE LINES OF FORCE WOULD INDUCE A REACTANCE VOLTAGE ACROSS THIS COIL, TENDING TO INCREASE THE FLOW OF CURRENT. IN THIS MANNER, THE CURRENT WHICH IS PASSED BY THE REACTOR REMAINS VERY NEARLY CONSTANT IN VALUE.

TO FURTHER ILLUSTRATE THIS POINT, LET US LOOK AT FIG.7. HERE YOU

ARE SHOWN IN A MORE SIMPLIFIED FORM THE RELATION BETWEEN THE R.F. AMPLIFIER AND MODULATOR TUBE, AS WELL AS THEIR CONNECTION TO THE "B" CIRCUIT.

AS A PRACTICAL EXAMPLE, LET US ASSUME THAT THE NORMAL PLATE CURRENT PASSING THROUGH THE REACTOR AMOUNTS TO 100 MA. AND THAT THIS CURRENT DIVIDES EQUALLY BETWEEN THE PLATE CIRCUITS OF THE AMPLIFIER AND MODULATOR TUBES, 50 MA. FLOWING THROUGH EACH TUBE.

NOW LET US SUPPOSE THAT AN AUDIO SIGNAL CAUSES A POSITIVE CHARGE TO BE APPLIED TO THE GRID OF THE MODULATOR TUBE AT ONE PARTICULAR INSTANT AND THAT THIS CHARGE IS SUFFICIENT TO CAUSE THE PLATE CURRENT THROUGH THIS TUBE TO INCREASE FROM 50 TO 60 MA. SINCE THE REACTOR TENDS TO MAINTAIN THE TOTAL "B" CURRENT AT 100 MA., THE INCREASE IN CURRENT THROUGH THE MODULATOR TUBE WILL BRING ABOUT A CORRESPONDING DECREASE IN THE CURRENT FLOWING THROUGH THE AMPLIFIER TUBE. IN OTHER WORDS, ONLY 100 MINUS 60 OR 40 MA. WILL AT THIS TIME BE AVAILABLE FOR THE AMPLIFIER TUBE.

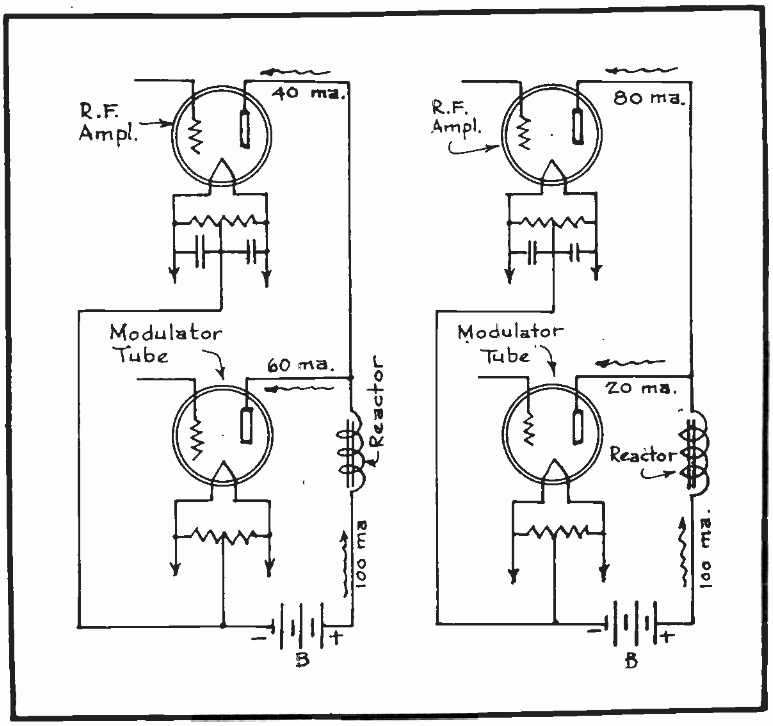

FIG. 7

Diagrammatic Explanation of the "Constant Current" Principle.

AT THE NEXT INSTANT, LET US ASSUME THAT THE AUDIO SIGNAL CAUSES A NEGATIVE CHARGE TO BE APPLIED TO THE GRID OF THE MODULATOR TUBE, AND THAT THIS CHARGE IS SUFFICIENT TO CAUSE THE PLATE CURRENT THROUGH THIS TUBE TO DROP DOWN TO 20 MA. THE REACTOR IN THIS CASE WILL STILL TEND TO MAINTAIN A TOTAL CURRENT FLOW OF 100 MA. AND SO 100 MINUS 20 OR 80 MA. WILL AT THIS TIME FLOW THROUGH THE R.F. AMPLIFIER TUBE.

BY FOLLOWING THIS SAME TREND OF THOUGHT, IT CAN BE SEEN THAT BY APPLYING A FLUCTUATING VOLTAGE OF AUDIO FREQUENCY TO THE GRID OF THE MODULATOR TUBE, THE PLATE CURRENT THROUGH THE R.F. AMPLIFIER TUBE WILL VARY CORRESPONDINGLY. AT THE SAME TIME, HOWEVER, THE R.F. AMPLIFIER IS HAVING ITS PLATE CURRENT VARIED AT A RADIO FREQUENCY RATE DUE TO THE EXITING VOLTAGE WHICH IS BEING APPLIED ACROSS ITS GRID CIRCUIT. THE NET RESULT IS THAT THE AMPLITUDE OF THE CARRIER WAVE IS INCREASED AND DECREASED WITH RESPECT TO ITS NORMAL VALUE IN ACCORDANCE WITH THE A.F. SIGNAL WHICH IS HANDLED BY THE MODULATOR TUBE. THE MODULATOR TUBE, YOU

WILL NOTICE, OPERATES UPON THE SAME PRINCIPLE AS A POWER TUBE OF AN A.F. AMPLIFIER.

THE HEISING SYSTEM OF MODULATION, AS JUST EXPLAINED, IS ALSO FREQUENTLY REFERRED TO AS THE "CONSTANT-CURRENT SYSTEM" OF MODULATION AND FROM WHAT YOU HAVE ALREADY LEARNED ABOUT THIS METHOD, YOU CAN READILY SEE HOW THIS CLASSIFICATION ALSO APPLIES TO THIS METHOD OF MODULATION.

A TRANSFORMER-COUPLED MODULATOR

IN FIG. 8 YOU ARE SHOWN A SOMEWHAT DIFFERENT CIRCUIT IN ORDER TO OBTAIN PLATE MODULATION. THIS CIRCUIT IS ESSENTIALLY THE SAME AS THAT OF FIG.6 WITH THE EXCEPTION THAT THE PLATE REACTOR IS REPLACED WITH A MODULATION TRANSFORMER. THE PRIMARY WINDING OF THIS TRANSFORMER IS CONNECTED IN SERIES WITH THE PLATE CIRCUIT OF THE MODULATOR TUBE, WHILE THE SECONDARY WINDING OF THIS SAME TRANSFORMER IS CONNECTED IN SERIES WITH THE PLATE CIRCUIT OF THE R.F. AMPLIFIER TUBE.

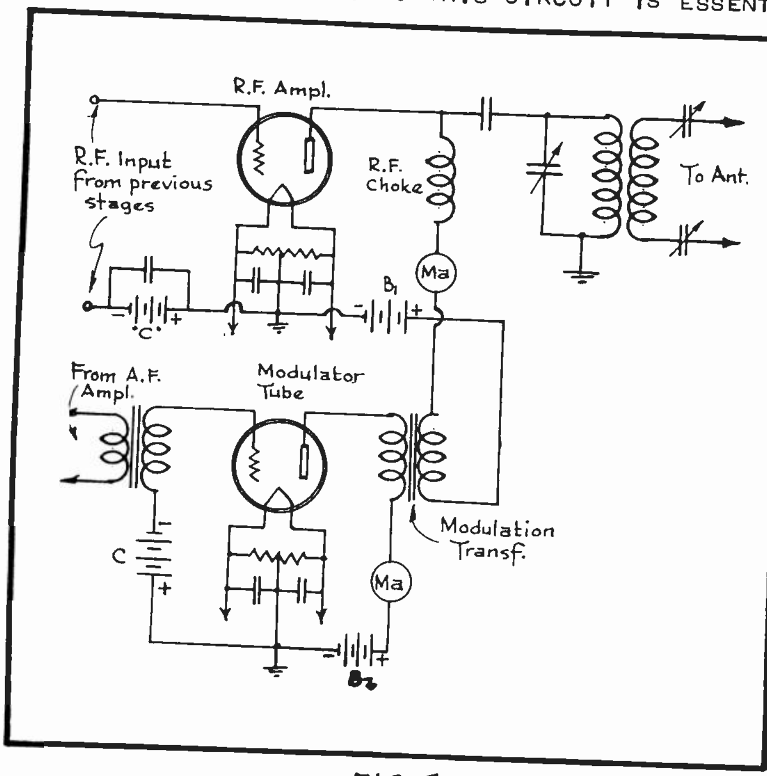

FIG. 8

Application of the Modulation Transformer.

IN THIS MANNER, A.F. SIGNAL VOLTAGES CAN BE INDUCED INTO THE SECONDARY WINDING THROUGH WHICH THE R.F. AMPLIFIER TUBE IS DRAWING ITS PLATE CURRENT. AT TIMES, THE A.F. SIGNAL VOLTAGE APPEARING IN THIS WINDING WILL BE EFFECTIVELY ADDED TO THE PLATE VOLTAGE AS APPLIED TO THE R.F. TUBE AND THEREBY CAUSE ITS PLATE CURRENT TO INCREASE CORRESPONDINGLY. AT OTHER TIMES, THE A.F. SIGNAL VOLTAGE APPEARING ACROSS THE SECONDARY WINDING OF THE MODULATION TRANSFORMER WILL BE OF OPPOSITE SIGN TO THAT OF THE APPLIED PLATE VOLTAGE AND IN THIS WAY REDUCE THE FLOW OF PLATE CURRENT THROUGH THE R.F. AMPLIFIER TUBE.

SO HERE AGAIN, WE HAVE A SUBTRACTION FROM AND AN ADDING TO THE RADIO FREQUENCY CURRENT VARIATIONS THROUGH THE PLATE CIRCUIT OF THE R.F. AMPLIFIER, SO THAT THIS OCCURS AT AN AUDIO FREQUENCY RATE AND FURNISHES US WITH A MODULATED WAVE-FORM.

A PUSH-PULL MODULATOR

QUITE OFTEN, INSTEAD OF USING ONLY A SINGLE MODULATOR TUBE AS SO FAR SHOWN, A PAIR OF MODULATOR TUBES ARE CONNECTED IN A PARALLEL, PUSH-PULL, OR A CLASS "B" ARRANGEMENT. WHEN THIS IS DONE, THE MODULATION CIRCUIT, HOWEVER, REMAINS TRUE TO FORM AS A STUDY OF THE PUSH-PULL MODULATOR IN FIG. 9 WILL SOON DISCLOSE.

GRID MODULATION

IN FIG. 10 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF A SYSTEM WHICH IS KNOWN AS GRID BIAS MODULATION OR SIMPLY AS GRID MODULATION.

BY STUDYING THIS DIAGRAM CAREFULLY, YOU WILL OBSERVE THAT THE CIRCUIT FOR THE MODULATOR TUBE IS THE SAME AS THAT EMPLOYED IN THE OTHER CIRCUITS SO FAR SHOWN YOU. HOWEVER, THE SECONDARY WINDING OF THE MODULATION TRANSFORMER IS CONNECTED IN SERIES WITH THE GRID BIAS CIRCUIT OF THE R.F. AMPLIFIER.

WHEN NO A.F. SIGNAL VOLTAGES ARE BEING HANDLED BY THE MODULATOR TUBE, A STEADY BIAS VOLTAGE IS APPLIED TO THE GRID CIRCUIT OF THE R.F. AMPLIFIER AND THEREFORE THIS TUBE WILL AMPLIFY THE CARRIER FREQUENCY IN THE CUSTOMARY MANNER.

AT THE TIME THAT THE MODULATOR TUBE IS HANDLING A.F. SIGNALS, VOLTAGES OF CORRESPONDING FREQUENCY WILL BE INDUCED INTO THE SECONDARY WINDING OF THE MODULATION TRANSFORMER. THESE SECONDARY VOLTAGE VARIATIONS WILL ALTERNATELY BE ADDED TO AND SUBTRACTED FROM THE BIAS VOLTAGE WHICH IS NORMALLY APPLIED TO THE R.F. AMPLIFIER TUBE — DEPENDING UPON THE POLARITY OF THE INDUCED VOLTAGE AT ANY PARTICULAR INSTANT.

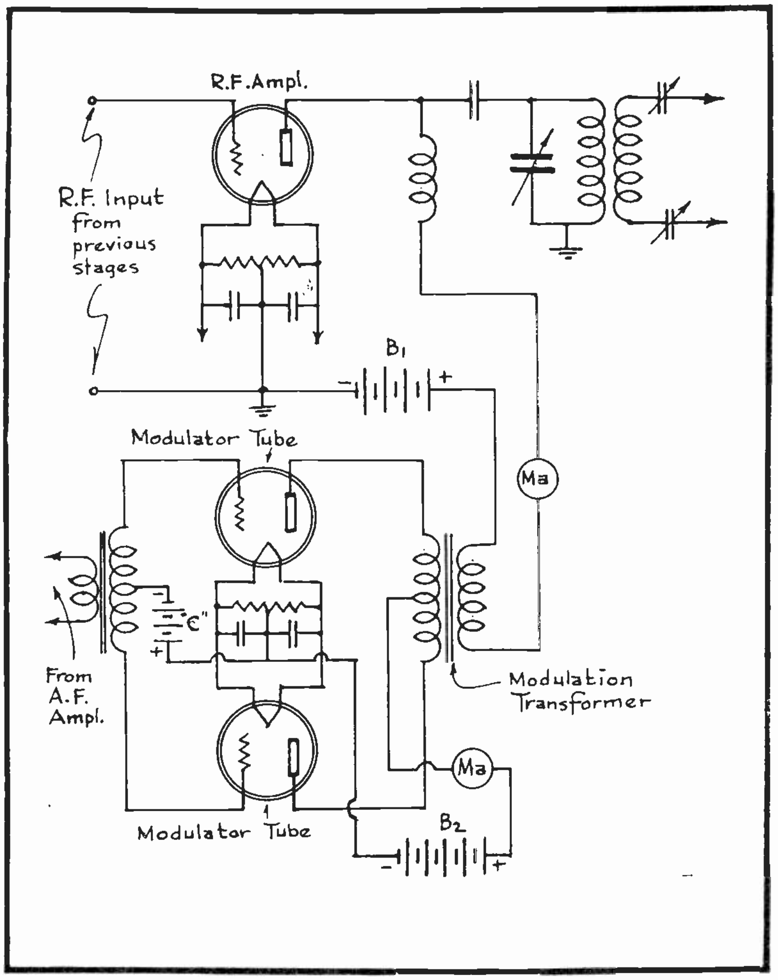

FIG. 9
Application of Push-Pull Modulator Tubes.

THUS IT IS CLEAR

THAT THE BIAS VOLTAGE OF THE R.F. AMPLIFIER WILL VARY AT AN AUDIO FREQUENCY RATE AND IN ACCORDANCE WITH THE OUTPUT OF THE MODULATOR TUBE. THEREFORE, A CORRESPONDING VARIATION IN THE PLATE CURRENT THROUGH THE R.F. AMPLIFIER WILL ALSO OCCUR AND THE NET RESULT IS THAT THE R.F. CURRENT VARIATIONS WHICH ARE ALSO HANDLED BY THE R.F. AMPLIFIER WILL HAVE THEIR AMPLITUDE (INTENSITY) VARIED AT AN AUDIO FREQUENCY RATE. THUS MODULATION HAS TAKEN PLACE AND A MODULATED WAVE OF CORRESPONDING PATTERN WILL BE RADIATED BY THE ANTENNA SYSTEM.

LOW LEVEL AND HIGH LEVEL MODULATION

IN ALL OF THE MODULATION SYSTEMS WHICH WERE SHOWN YOU SO FAR IN THIS LESSON, THE FINAL R.F. STAGE OF THE TRANSMITTER WAS MODULATED. WHEN SUCH IS THE CASE, THE SYSTEM IS GENERALLY REFERRED TO AS EMPLOYING HIGH LEVEL MODULATION. WHEN THIS IS DONE, ALL R.F. STAGES PRECEDING THE STAGE IN WHICH MODULATION OCCURS MAY BE STRAIGHT R.F. AMPLIFIERS OF RATHER HIGH GAIN AND NEED NOT NECESSARILY BE LINEAR IN THEIR OPERATING CHARACTERISTICS. FOR HIGH LEVEL MODULATION, PLATE MODULATION IS MOST EXTENSIVELY USED.

IN SUCH CIRCUIT ARRANGEMENTS WHERE AN R.F. STAGE PREVIOUS TO THE FINAL STAGE OF THE TRANSMITTER IS MODULATED, THEN THE SYSTEM IS SAID TO BE OF THE LOW LEVEL MODULATION TYPE. WHEN SUCH IS THE CASE, EITHER PLATE OR GRID MODULATION CAN BE USED. THIS ARRANGEMENT ALSO PERMITS THE USE OF AN AUDIO AMPLIFIER OF LESS POWER OUTPUT THAN DOES HIGH LEVEL MODULATION BUT IT IS EQUALLY TRUE THAT WHEN LOW LEVEL MODULATION IS EMPLOYED, ALL STAGES OF THE TRANSMITTER FOLLOWING THAT IN WHICH MODULATION OCCURS MUST BE LINEAR AMPLIFIERS SO THAT THE MODULATED CARRIER FREQUENCY CAN BE AMPLIFIED SATISFACTORILY.

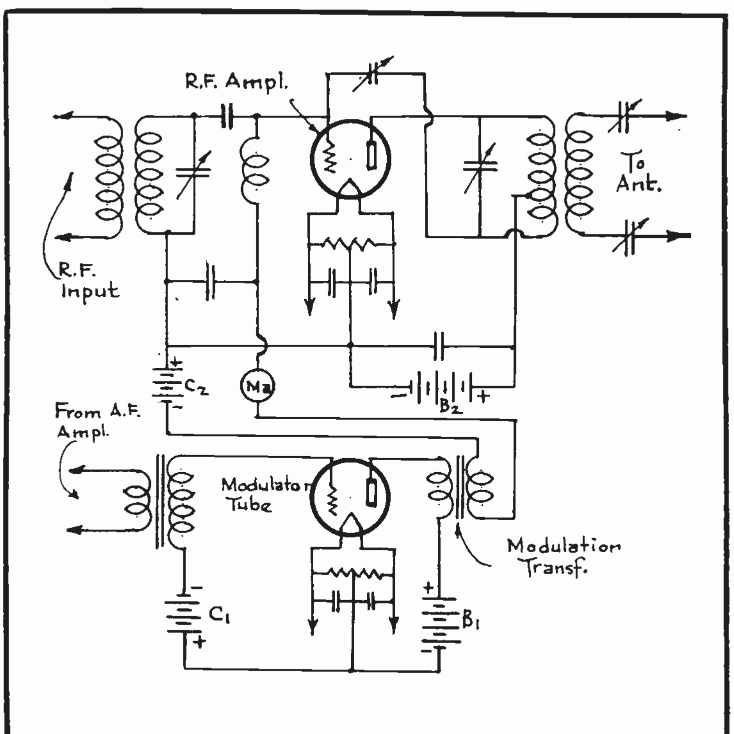

FIG. 10
Grid Modulation.

CLASSES OF MODULATORS AND AMPLIFIERS

AS YOU HAVE ALREADY BEEN SHOWN, THE MODULATOR IS ESSENTIALLY AN AUDIO-FREQUENCY AMPLIFIER AND THEREFORE ITS BASIC DESIGN FOLLOWS CONSIDERABLY THAT OF THE CONVENTIONAL A.F. AMPLIFIERS WITH WHICH YOU ARE ALREADY FAMILIAR. SIMILARLY, MODULATORS MAY ALSO BE OF EITHER ONE OF TWO BASIC TYPES THAT

IS, A CLASS A OR CLASS B TYPE, THE SAME AS REGULAR A.F. AMPLIFIERS. WITH THIS RESPECT THERE ARE ALSO CERTAIN MODIFICATIONS, THE SAME AS WE FIND THEM IN GENERAL A.F. AMPLIFIER PRACTICE.

IN TRANSMITTER PRACTICE, WE ALSO DEAL WITH A THIRD DISTINCTIVE CLASS, NAMELY CLASS C, AND WHICH IS CONFINED TO THE R.F. SECTION OF THE EQUIPMENT. SO THAT YOU WILL HAVE A CLEAR MENTAL CONCEPTION CONCERNING THE DIFFERENCES BETWEEN THESE THREE DISTINCT CLASSES OF AMPLIFIERS, IT WILL BE WELL THAT WE COMPARE THEIR CHARACTERISTICS BRIEFLY AT THIS TIME.

CLASS "A" AMPLIFIERS

A CLASS "A" AMPLIFIER, YOU WILL RECALL, IS DESIGNED IN SUCH A MANNER THAT THE PLATE OUTPUT WAVE SHAPES ARE ESSENTIALLY THE SAME AS THOSE OF THE EXITING GRID VOLTAGE. ITS NEGATIVE GRID BIAS VOLTAGE IS SO CHOSEN THAT THE PLATE CURRENT IS THE SAME WITH AND WITHOUT GRID EXITATION. ALSO THE ALTERNATING GRID EXITATION VOLTAGE AND THE LOAD RESISTANCE ARE SUCH AS TO MAKE ITS DYNAMIC CHARACTERISTICS ESSENTIALLY LINEAR.

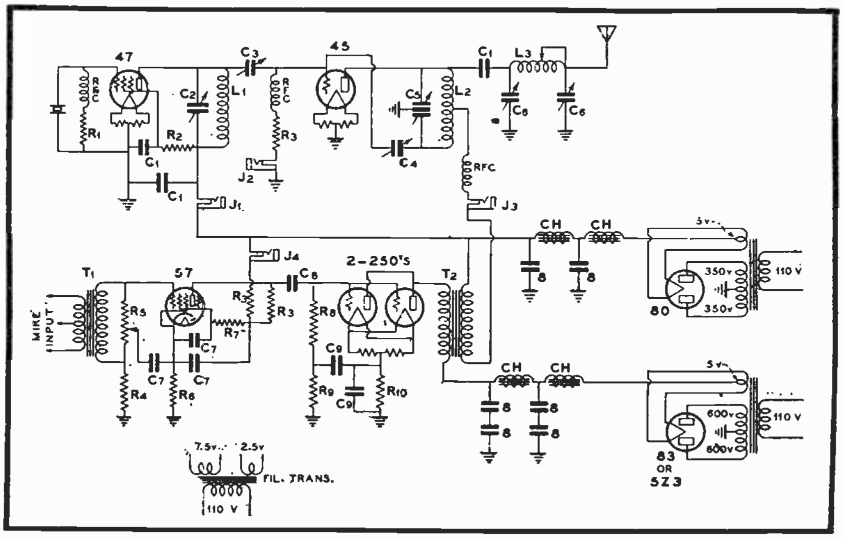

FIG. 11.
A 15-Watt Phone Transmitter.

BY DEFINITION THE TERM "LINEAR" REFERS TO A RELATION BETWEEN ELECTRICAL QUANTITIES WHICH IS SUCH THAT A CHANGE IN ONE IS ACCOMPANIED BY AN EXACTLY PROPORTIONAL CHANGE IN ANOTHER. "LINEAR AMPLIFICATION", ON THE OTHER HAND, IS AMPLIFICATION OF SUCH A NATURE THAT THE SIGNAL OUTPUT VOLTAGE AT ANY FREQUENCY AND ANY VALUE IS DIRECTLY PROPORTIONAL TO THE INPUT VOLTAGE. A CLASS "A" AMPLIFIER OPERATES ON THE STRAIGHT PORTION OF THE PLATE CURRENT—GRID VOLTAGE CHARACTERISTIC CURVE.

NOT ONLY ARE CLASS "A" AMPLIFIERS RESTRICTED TO A.F. AMPLIFIERS AND MODULATORS BUT THEY MAY BE USED AS R.F. AMPLIFIERS AS WELL.

CLASS "B" AMPLIFIERS

IN CLASS "B" AMPLIFIERS A PUSH—PUSH ARRANGEMENT OF TUBES IS GENERALLY EMPLOYED AND THIS SYSTEM OPERATES AT THE LOWER PORTION OF THE PLATE CURRENT—GRID VOLTAGE CHARACTERISTIC CURVE AND WITH SUFFICIENT BIAS VOLTAGE APPLIED SO THAT A VERY SMALL PLATE CURRENT FLOWS AT THE TIME NO SIGNAL VOLTAGE EXITES THE GRID CIRCUIT. ALTHOUGH THIS SYSTEM WILL NOT FUNCTION SATISFACTORILY AS AN A.F. AMPLIFIER WHEN ONLY A SINGLE

TUBE IS USED, YET IN A RADIO FREQUENCY AMPLIFIER, EITHER A SINGLE OR A TWO-TUBE ARRANGEMENT MAY BE OPERATED UNDER CLASS "B" CHARACTERISTICS, ALTHOUGH A TWO-TUBE CIRCUIT IS PREFERABLE IN EITHER CASE.

WHEN A TUBE IS OPERATING AS A CLASS B AMPLIFIER, THE OUTPUT POWER IS PROPORTIONAL TO THE SQUARE OF THE GRID-EXITATION VOLTAGE AND CONSEQUENTLY CAUSES THE OUTPUT TO RESEMBLE A LINEAR CHARACTERISTIC. CLASS "B" AMPLIFIERS ARE THEREFORE ALSO FREQUENTLY CLASSIFIED AS LINEAR AMPLIFIERS. THE PLATE EFFICIENCY OF THE CLASS B AMPLIFIER IS HIGHER THAN THE PLATE EFFICIENCY OF A CLASS A AMPLIFIER BECAUSE NO D.C. PLATE CURRENT FLOWS WHEN THE GRID EXITING VOLTAGE IS REMOVED. IT IS FOR THIS REASON THAT A CLASS B AMPLIFIER IS ALWAYS USED IN THE AMPLIFICATION OF MODULATED WAVES WHEN PLATE EFFICIENCY IS OF IMPORTANCE.

CLASS "C" AMPLIFIERS

A CLASS C AMPLIFIER IS PRACTICALLY THE SAME AS A CLASS B AMPLIFIER WITH THE EXCEPTION THAT IN THE CASE OF THE CLASS C AMPLIFIER, THE BIAS VOLTAGE IS ADJUSTED TO A POINT FAR BEYOND THE CUT-OFF ON THE PLATE CURRENT-GRID VOLTAGE CHARACTERISTIC CURVE. GENERALLY, THE NEGATIVE BIAS USED IS BETWEEN ONE AND ONE-HALF TO TWICE THE CUT-OFF BIAS VOLTAGE.

THE CLASS C AMPLIFIERS MUST RECEIVE A CONSIDERABLE GREATER GRID EXITATION IN ORDER TO OVERCOME THE HEAVY NEGATIVE BIAS IF SUITABLE PLATE-CURRENT PEAKS ARE TO BE PRODUCED IN THE OUTPUT CIRCUIT. FOR THIS REASON, CLASS C AMPLIFIERS ARE USED ONLY IN TRANSMITTING CIRCUITS BECAUSE OF THE RELATIVELY HIGHER GRID VOLTAGES THAT MAY BE PRODUCED IN THESE CIRCUITS. ALSO THE USE OF A CLASS C AMPLIFIER PROVIDES A HIGH EFFICIENCY IN THE CONVERSION OF DIRECT-CURRENT PLATE-SUPPLY POWER TO ALTERNATING-CURRENT ENERGY BUT RESULTS IN A NON-LINEAR RELATION BETWEEN THE APPLIED VOLTAGE AND THE POWER OUTPUT. THE OUTPUT OF THE CLASS C AMPLIFIER VARIES ESSENTIALLY AS THE SQUARE OF THE PLATE VOLTAGE WITHIN LIMITS.

NOW THAT YOU ARE FAMILIAR WITH THE VARIOUS SECTIONS OF RADIO TELEPHONE TRANSMITTERS AND THE MANNER IN WHICH THEY OPERATE, YOU WILL NEXT BE INTERESTED IN STUDYING CIRCUITS OF THIS TYPE AS A WHOLE RATHER THAN IN PART. FOR THIS REASON, THE COMPLETE CIRCUITS OF TYPICAL TRANSMITTERS OF THIS TYPE ARE ILLUSTRATED AND EXPLAINED TO YOU IN THE FOLLOWING PAGES.

A 15-WATT PHONE TRANSMITTER

IN FIG. 11 YOU ARE SHOWN THE COMPLETE CIRCUIT DIAGRAM OF A PHONE TRANSMITTER WHICH FURNISHES A 15-WATT CARRIER. THIS TRANSMITTER YOU WILL OBSERVE, CONSISTS OF A 47 CRYSTAL CONTROLLED OSCILLATOR, FOLLOWED BY A FINAL AMPLIFIER IN WHICH A TYPE 45 TUBE IS USED.

THE A.F. CHANNEL CONSISTS OF THE MICROPHONE CIRCUIT FEEDING INTO A 57 TUBE OPERATING AS AN A.F. AMPLIFIER AND WHICH IS FOLLOWED BY A PAIR OF 250'S CONNECTED IN PARALLEL. PLATE MODULATION IS EMPLOYED.

THE ELECTRICAL VALUES FOR THE VARIOUS PARTS USED IN THIS TRANSMITTER ARE AS FOLLOWS: C_1 = .006 MFD; C_2 = 100 MMFD.; C_3 = 25 MMFD.;

C_4 = 25 MMFD; C_5 = 40 MMFD. SPLIT-STATOR VARIABLE; C_6 = 350 MMFD; C_7 = 1 MMFD; C_8 = .01 MFD; C_9 = 1 MFD; R_1 = 30,000 OHMS, 5 WATT; R_2 = 30,000 OHMS, 2 WATT; R_3 = 50,000 OHMS, 5 WATT; R_4 AND R_5 = 1/4 MEG; R_8 = 500,000 OHMS; R_9 = 25,000 OHMS; R_{10} = 400 OHMS; 10 WATT; T_1 = MICROPHONE MATCHING INPUT TRANSFORMER; T_2 = 2:1 STEP-UP TRANSFORMER OF FAIRLY HEAVY CONSTRUCTION; CH = 30 HENRY FILTER CHOKES RATED AT 100 MA.

THIS TRANSMITTER IS TUNED AND NEUTRALIZED IN THE SAME MANNER AS HAS ALREADY BEEN EXPLAINED IN PREVIOUS LESSONS AND BEFORE TURNING ON THE POWER FOR THE MODULATOR.

A 50-WATT GRID-MODULATED PHONE TRANSMITTER

THE CIRCUIT DIAGRAM WHICH APPEARS IN FIG. 12 IS THAT OF A 50-WATT, GRID-MODULATED PHONE TRANSMITTER. HERE WE HAVE A 47 CRYSTAL OSCILLATOR, FOLLOWED BY A 46 BUFFER AND A PAIR OF PARALLEL CONNECTED 211 E'S IN THE FINAL STAGE. IN THE A.F. SECTION, A 56 TUBE IS USED AT THE INPUT, FOLLOWED BY ANOTHER 56 IN THE INTERMEDIATE STAGE, AND A PAIR OF 45'S CONNECTED IN PUSH-PULL OPERATING AS MODULATORS.

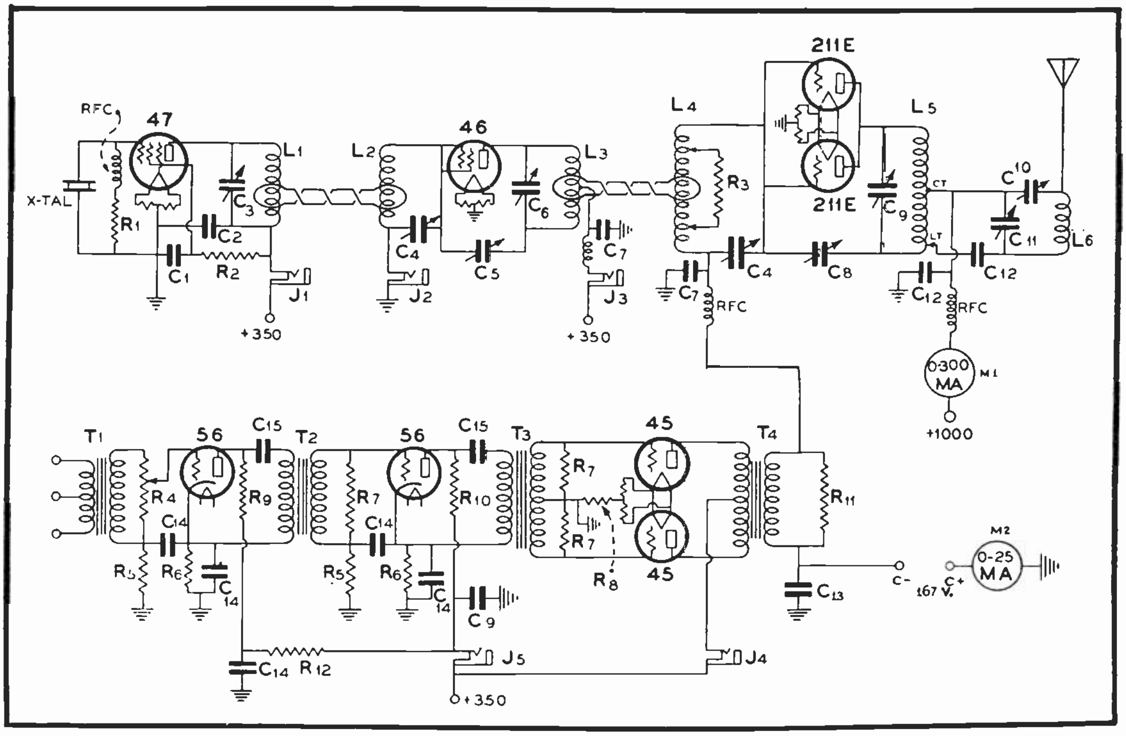

FIG. 12.
The 50 Watt Phone Transmitter.

THE ELECTRICAL VALUES FOR THE PARTS USED IN THIS CIRCUIT ARE LISTED IN TABLE I.

THE CHIEF PURPOSE OF R_3 IN THIS CIRCUIT IS TO STABILIZE THE LOAD ON THE BUFFER STAGE WHILE R_{11} SERVES THE SAME PURPOSE FOR THE MODULATORS.

A 1000-Watt Transmitter

The circuit diagram for a 1000 watt Radio Telephone transmitter appears in Fig. 13. In this case a 59 tube is used in a Tri-Tet oscillator circuit and followed in turn by a 59 buffer, a 210 buffer, an HK 354 buffer-driver stage and a final power stage with a pair of HK 354's.

TABLE I

LIST OF PARTS

R-1—15,000 to 50,000 ohms.
R2—50,000 ohms.
R3—20,000 ohms, 25 watts non-inductive.
R4—200,000 ohm potentiometer.
R5—.1 meg.
R6—2500 ohms.
R7—200,000 ohms.
R8—1000 ohms.
R9—30,000 ohms
R9—30,000 ohms.
R10—20,000 ohms.
R11—3,000 ohms.
R12—20,000 ohms.
C1—.01ufd.
C2—.006 ufd.
C3—100 uufd. variable.
C4—100 uufd. variable.
C5—50 uufd. variable.
C6—100 uufd. variable.
C7—.001 ufd.
C8—100 uufd. variable.
C9—150 uufd. variable.
C10—350 uufd. variable.
C11—350 uufd. variable.
C12—.006 ufd.
C-13—2 ufd.
C14—1 ufd.
C15—.25 ufd.
T1—Mike to grid transformer.
T2—Triode plate to grid transformer.
T3—Triode plate to PP grids.
T4—Class B input transformer, 2 to 1 or 3 to 1 step-down.

The A.F. system is rather conventional in design and plate modulation is used.

This same transmitter is also so arranged that CW code transmission can be employed. For this purpose, the keying relay shorts out the coupling link between the driver stage and the final amplifier. Since the final amplifier uses grid-leak bias for reasons of economy and flexibility, it is necessary to provide a means of preventing excessive plate current with the key up. This is accomplished with the aid of a second relay which is actuated by the rectified grid current through the grid leak and which cuts in the 1500 ohms of cathode bias whenever the excitation fails.

The electrical values for the various parts used in this transmitter are given in Table II.

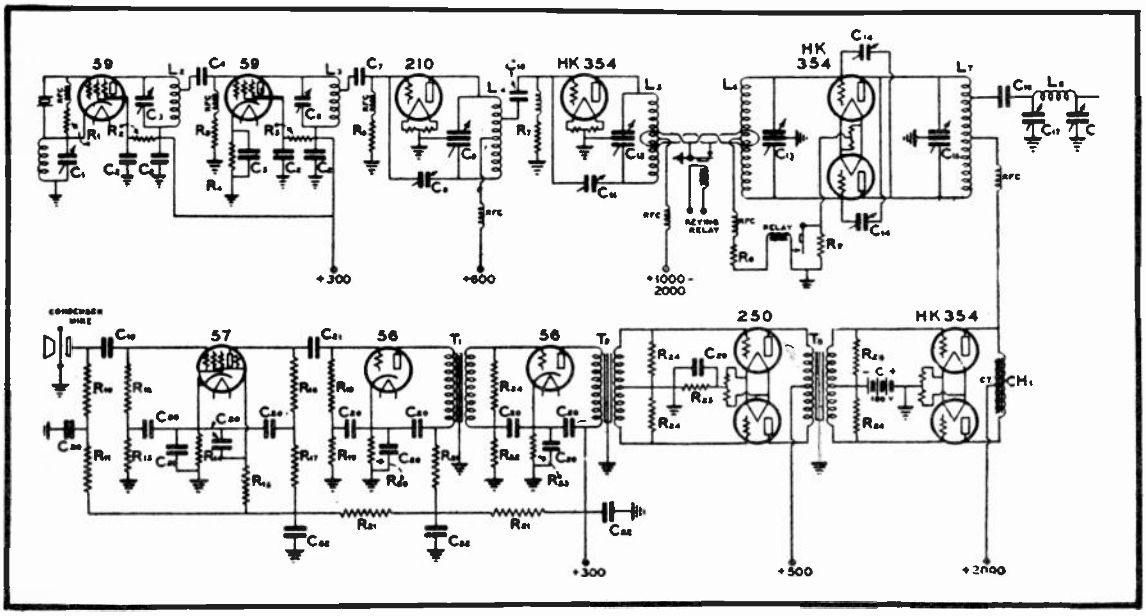

FIG. 13

The 1000-Watt Transmitter.

ALSO NOTICE IN THE CIRCUIT OF FIG. 13 THAT A CONDENSER MICROPHONE IS USED AND THAT ALL AMPLIFICATION WHICH IS NECESSARY FOR ITS SATISFACTORY OPERATION IS INCLUDED IN THE A.F. CHANNEL. ALSO OBSERVE HOW THE MODULATION CHOKE IS CENTER TAPPED AND CONNECTED TO THE PLATES OF THE MODULATOR TUBES IN THE SAME MANNER AS THE PRIMARY WINDING OF AN OUTPUT PUSH-PULL TRANSFORMER.

HAVING COMPLETED THIS LESSON, YOU SHOULD NOW HAVE A GOOD UNDERSTANDING OF THE CONSTRUCTIONAL FEATURES AND OPERATING PRINCIPLES OF RADIO TELEPHONE TRANSMITTERS. THIS HAS SUPPLIED YOU WITH THE BASIC KNOWLEDGE CONCERNING THESE CIRCUITS SO THAT YOU WILL BE BETTER ABLE TO UNDERSTAND THE VARIOUS TRANSMITTER DESIGN PROBLEMS WHICH WILL BE PRESENTED TO YOU IN A LESSON SOON TO COME.

IN THE LESSON IMMEDIATELY TO FOLLOW, YOU WILL BE GIVEN THE OPERATING CHARACTERISTICS AND OTHER ENGINEERING DATA PERTAINING TO THE MORE COMMON TRANSMITTER TUBES AND WHICH YOU WILL FIND TO BE OF GREAT VALUE.

TABLE II

LIST OF PARTS

C1—140 mmf. Hammarlund Condenser.
C2—.01 mfd. C3—50 mmf. Hammarlund.
C4—.00025. C5—.0001. C6—50 mmf. Hammarlund.
C7—.00025. C8—22 mmf. Neutralizing.
C9—100 mmf. split stator. C10—.00025.
C11—15 mmf. neutralizing. C12—100 mmf. split stator.
C13—100 mmf. split stator. C14—15 mmf. neutralizing.
15—100 mmf. split stator. C16—.001.
C17—250 mmf. C18—250 mmf. C19—.001.
C20—1 mfd. C21—.01 mfd. C22—8mfd.
R1, R2, R3, R5, R17, R19—50,000 ohms.
R4—1000 ohms. R6, R7—15,000 ohms.

R8—25,000 ohms. R9—1500 ohms.
R10—10 megohms. R11—5 megohms.
R12—½ megohm. R13—¼ megohm.
R14—750 ohms. R15—½ megohm.
R16—¼ megohm. R18—¼ megohm.
R20—2500 ohms. R21—20,000 ohms.
R22—¼ megohm. R23—2500 ohms.
R24—1 megohm. R25—750 ohms.
R26—10,000 ohms.
T1—Triode Plate to Grid.
T2—Push-Pull Input. T3—Class B Input, 1:1 for 354's; 2:1 for 357's.
Ch—Class B Output Choke, 92 henries.

Answered Mar 22, 1942

EXAMINATION QUESTIONS

LESSON NO. 13

In all your self-development, have a definite purpose in view. What is the good of a wonderful character if it does not accomplish something besides its own development?

1. - EXPLAIN IN DETAIL WHAT IS MEANT BY THE EXPRESSION "AMPLITUDE MODULATION".

2. - MAKE A DIAGRAMMATIC ILLUSTRATION OF A WAVE-FORM WHICH IS MODULATED 100% AND EXPLAIN IN DETAIL THE FULL MEANING OF THE DRAWING.

3. - WHAT IS MEANT BY THE EXPRESSION "MODULATION FACTOR"?

4. - DESCRIBE IN DETAIL THE SIDE-BAND FREQUENCIES WHICH EXIST IN THE WAVE-FORM WHICH IS RADIATED BY A BROADCAST TRANSMITTER.

5. - HOW CAN THE PERCENTAGE OF MODULATION BE DETERMINED?

6. - DRAW A CIRCUIT DIAGRAM OF A HEISING MODULATION SYSTEM USING A PLATE REACTOR AND EXPLAIN IN DETAIL HOW THIS SYSTEM OPERATES.

7. - DRAW A CIRCUIT DIAGRAM OF A GRID MODULATION SYSTEM AND EXPLAIN IN DETAIL HOW THIS SYSTEM OPERATES.

8. - DESCRIBE FULLY THE OPERATING CHARACTERISTICS OF A CLASS "C" AMPLIFIER.

9. - WHAT IS THE EFFECT OF OVER-MODULATION UPON RECEPTION?

10. - DRAW A COMPLETE CIRCUIT DIAGRAM OF A RADIO-TELEPHONE TRANSMITTER AND EXPLAIN THE OPERATION OF THE VARIOUS UNITS OR SECTIONS WHICH ARE INCLUDED IN IT.

RADIO - TELEVISION

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NATIONAL SCHOOLS

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Los Angeles, California

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Transmitters

LESSON NO. 14

• TRANSMITTER TUBES •

IN FUNDAMENTAL DESIGN, TRANSMITTING TUBES ARE THE SAME AS RECEIVER TUBES, THAT IS, TRANSMITTING TUBES OF THE TRIODE TYPE ALSO CONSIST OF A FILAMENT, PLATE AND GRID; TRANSMITTING TUBES OF THE TETRODE TYPE ALSO CONSIST OF A FILAMENT, CONTROL GRID, PLATE, AND SCREEN GRID THE SAME AS THE CORRESPONDING RECEIVER TUBE ETC. IN FACT, AS YOU HAVE ALREADY LEARNED, IF THE POWER HANDLING REQUIREMENTS ARE NOT TOO HIGH, RECEIVING TYPE TUBES CAN BE MADE TO SERVE AS TRANSMITTER TUBES AND THIS PRACTICE IS BEING USED SATISFACTORILY IN THOUSANDS OF AMATEUR TRANSMITTERS.

IN SPITE OF THIS SIMILARITY, THERE IS ALSO A RADICAL DIFFERENCE BETWEEN THE RECEIVER AND TRANSMITTER TUBES BUT THIS DIFFERENCE EXISTS LARGELY IN CONSTRUCTIONAL DETAILS SO AS TO ENABLE THE TRANSMITTER TUBES TO HANDLE LARGER POWERS.

OUR FIRST STEP IN THIS LESSON WILL BE TO POINT OUT THE MORE IMPORTANT CONSTRUCTIONAL FEATURES OF THE VARIOUS DISTINCTIVE TYPES OF TRANSMITTER TUBES AND THIS WILL BE FOLLOWED BY DATA CONCERNING THE OPERATING CHARACTERISTICS OF SOME OF THE TRANSMITTER TUBES WHICH ARE MOST COMMONLY USED IN PRACTICE.

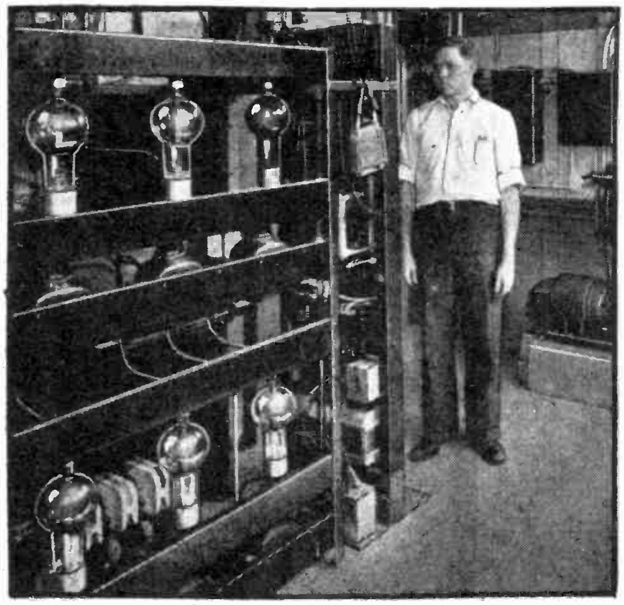

FIG. I

Bank of Rectifier Tubes In a Short-Wave Broadcast Station.

CONSTRUCTIONAL FEATURES

IN FIG.2 YOU ARE SHOWN THE TYPE 800 TUBE. THIS TUBE IS A

TRIODE OF RATHER LOW POWER RATING BUT DESIGNED PRIMARILY FOR OPERATION IN HIGH FREQUENCY CIRCUITS. THE MOST INTERESTING FEATURE OF THIS TUBE IS THAT THE GRID AND PLATE CONNECTIONS ARE MADE AT TWO METAL CAPS WHICH ARE PLACED ON THE CREST OF THE GLASS BULB. THIS FORM OF CONSTRUCTION REDUCES THE GRID-PLATE CAPACITY OF THE TUBE AND ITS CONNECTING CIRCUITS AND WHICH IS OF VITAL IMPORTANCE IN CIRCUITS OPERATING AT HIGH FREQUENCIES. AT THE SAME TIME, GOOD INSULATIVE PROPERTIES ARE ALSO INTRODUCED BY THIS ARRANGEMENT.

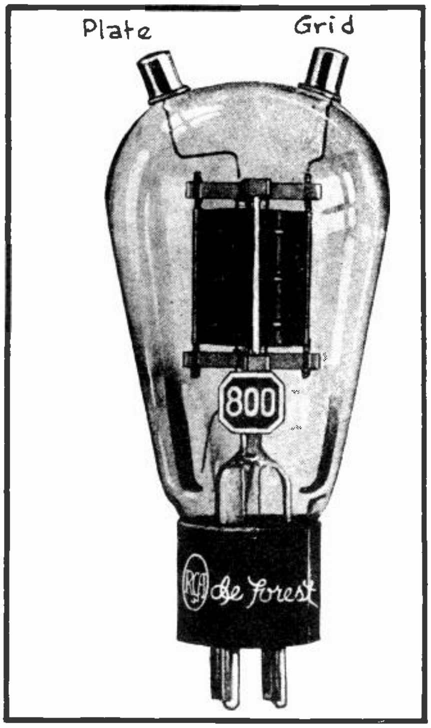

FIG. 2
The Type 800 Tube.

A FOUR-PRONG BASE IS USED IN THIS CASE, THE TWO LARGER ONES TAKING CARE OF THE FILAMENT CONNECTIONS WHILE THE TWO SMALLER ONES ARE BLANK. THE OVER-ALL HEIGHT OF THIS TUBE IS 6 3/8" WHILE THE MAXIMUM DIAMETER OF ITS GLASS BULB IS 2 11/16".

50 WATT TUBES

THE CONSTRUCTIONAL FEATURES OF A TYPICAL 50 WATT TUBE ARE SHOWN IN FIG. 3, WHERE THE 203-A IS USED AS THE EXAMPLE. THIS TUBE IS ALSO A TRIODE AND FITTED WITH FOUR BASE PRONGS OF THE SHORT TYPE. IN THIS CASE, ALL OF THE ELEMENTS ARE CONNECTED TO THE BASE PRONGS IN THE USUAL WAY. THE OVERALL HEIGHT OF THIS TUBE IS 7 7/8" AND ITS MAXIMUM DIAMETER IS 2 5/16".

A STILL DIFFERENT FORM OF TUBE CONSTRUCTION IS SHOWN IN FIG. 4, WHERE A 50 WATT TUBE APPEARS AT THE LEFT AND A 150 WATT TUBE AT THE RIGHT. HERE THE GLASS BULB IS OF MAXIMUM DIAMETER AT THE APPROXIMATE CENTER AND REDUCED AT EACH END. BOTH OF THESE TUBES ARE OF THE TRIODE TYPE AND HAVE THEIR FILAMENT CONNECTIONS MADE AT THE BASE PRONGS, WHILE THE GRID CONNECTION IS MADE AT A CAP AT THE UPPERMOST END OF THE TUBE AND THE PLATE CONNECTION AT THE METAL CAP WHICH IS PROVIDED AT THE SIDE OF THE LOWER PORTION OF THE GLASS BULB. THIS FORM OF CONSTRUCTION ALSO PERMITS WIDE SEPARATION BETWEEN THE GRID AND PLATE CIRCUIT WIRING AS WELL AS GOOD INSULATIVE PROPERTIES. THE APPROXIMATE OVERALL HEIGHT OF A TUBE OF THIS TYPE IS 8 3/4" AND ITS MAXIMUM BULB DIAMETER IS 4 1/4".

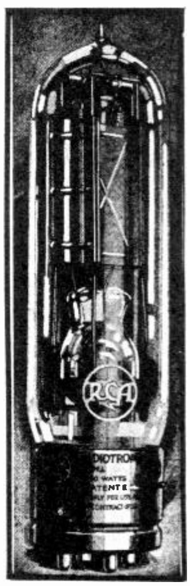

FIG. 3
The 203-A

THE 204-A

IN FIG. 5 YOU ARE SHOWN THE CONSTRUCTIONAL FEATURES OF THE 204-A, WHICH IS RATED AT 250 WATTS. THIS TUBE IS FITTED WITH A THREE-PRONG BASE AND A METAL CAP CONNECTION AT THE OPPOSITE END. THE TWO OUTER AND LARGER BASE PRONGS ARE FOR THE FILAMENT CONNECTIONS WHILE THE CENTER PRONG OF THIS GROUP IS FOR THE GRID CONNECTION. THE PLATE CONNECTION IS MADE AT THE METALLIC CAP.

THIS TUBE IS TO BE FITTED IN SPECIAL END MOUNTINGS AND WHICH ARE ALSO SHOWN IN FIG. 5. IT MAY BE MOUNTED EITHER IN A VERTICAL POSITION WITH THE FILAMENT END UP OR IN A HORIZONTAL POSITION WITH THE PLATE IN A VERTICAL PLANE (ON EDGE). YOU WILL ACQUIRE SOME IDEA AS TO THE SIZE OF THIS TUBE FROM ITS DIMENSIONS AND WHICH ARE AS FOLLOWS: OVERALL HEIGHT = $14\frac{1}{4}$" ; MAXIMUM DIAMETER = $4\frac{1}{16}$".

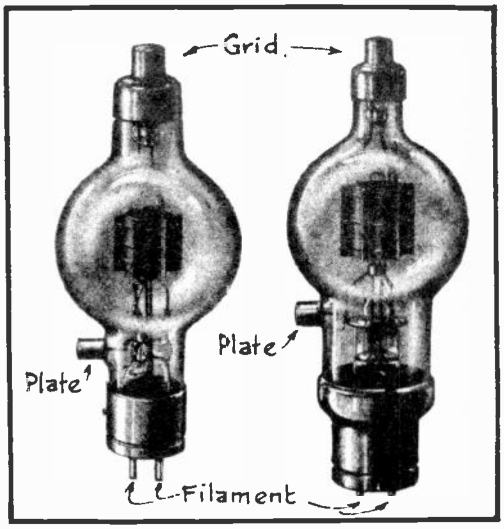

FIG. 4
Another Form of Tube Construction.

I KW. TUBES

A PICTURE OF THE 206 APPEARS IN FIG. 6 AND WHICH YOU WILL NOTE IS MOUNTED SOMEWHAT THE SAME AS THE 204-A, WITH THE EXCEPTION THAT THE GRID CONNECTION IS BROUGHT OUT AT THE SIDE OF THE GLASS ENCLOSURE.

ANOTHER 1000 WATT TUBE, THE 851, IS SHOWN IN FIG. 7. THIS ALSO HAS A THREE PRONG BASE AND A CAP CONNECTION. THE TWO LARGE BASE PRONGS ARE FOR THE FILAMENT AND THE SMALLER CENTRALLY LOCATED ONE IS FOR THE GRID. THE PLATE CONNECTION IS MADE AT THE METAL CAP AT THE OPPOSITE END OF THE TUBE. THIS TUBE IS MOUNTED SIMILARLY TO THAT METHOD WHICH IS ILLUSTRATED FOR THE 204-A AND THE 206 TUBES. THE OVERALL LENGTH OF THE 851 IS $17\frac{1}{2}$" AND ITS MAXIMUM DIAMETER IS $6\frac{1}{8}$".

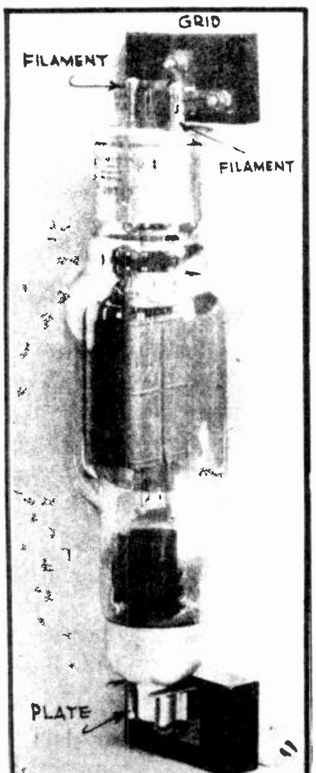

FIG. 5
The 204-A

THE EXPLANATIONS AS SO FAR GIVEN SHOULD HAVE SERVED TO GIVE YOU SOMEWHAT OF AN IDEA REGARDING THE GENERAL SHAPE AND APPEARANCE OF TRANSMITTER TUBES. TO ILLUSTRATE EVERY SINGLE TYPE OF TRANSMITTER TUBE WOULD NOT ONLY BE UNNECESSARY BUT ALSO A WASTE OF TIME. THE ONES SHOWN ARE TYPICAL OF THOSE WHICH YOU WILL FIND IN THE INDUSTRY, AS IN APPEARANCE THEY NEARLY ALL FOLLOW THE SAME SHAPE AS THOSE WHICH HAVE BEEN ILLUSTRATED.

OUR NEXT STEP WILL BE TO CONSIDER SOME OF THE DESIGN FEATURES OF TRANSMITTER TUBES.

DETAILS OF DESIGN

TRANSMITTER TUBES OF HIGHER POWER RATING MUST BE DESIGNED AND CONSTRUCTED WITH UTMOST CARE AND PRECISION.

THE ELECTRON EMITTER IN TUBES OF THIS TYPE IS NEARLY ALWAYS A TUNGSTEN FILAMENT. OXIDE-COATED AND THORIATED-TUNGSTEN FILAMENTS ARE CONFINED PRACTICALLY EXCLUSIVELY TO TUBES OF SMALLER SIZE.

THE REASON FOR USING TUNGSTEN FILAMENTS IS

THAT WHEN THE ELECTRONS TRAVEL FROM THE EMITTER TO THE PLATE OF THE TUBE, THEY COLLIDE WITH ANY REMAINING TRACES OF GAS MOLECULES, BREAKING THEM UP INTO SMALL POSITIVE PARTICLES KNOWN AS POSITIVE IONS AND SMALL NEGATIVE PARTICLES KNOWN AS NEGATIVE IONS. WHEN HIGH PLATE VOLTAGES ARE USED, THE POSITIVE IONS TRAVEL TOWARDS THE EMITTER WITH SUCH TERRIFIC SPEED THAT THE IMPACT UPON STRIKING THE EMITTER IS SUFFICIENT TO STRIP THE THORIUM LAYER OFF THE EMITTER.

THE FILAMENT CURRENT AS DRAWN BY THE LARGER TRANSMITTER TUBES IS GENERALLY QUITE HIGH SO THAT ADEQUATE ELECTRON EMISSION MAY BE OBTAINED. WHEN USING SOME OF THE LARGER TUBES, IT IS CUSTOMARY TO PLACE A RESISTANCE IN SERIES WITH THE FILAMENT WHEN THE FILAMENT CIRCUIT IS FIRST CLOSED, SO AS TO LIMIT THE RUSH OF CURRENT THAT WOULD OTHERWISE FLOW BECAUSE OF THE LOW RESISTANCE OF THE COLD FILAMENT. SHOULD THIS STARTING RESISTANCE NOT BE EMPLOYED, THE INITIAL FILAMENT CURRENT IN THE LARGER TUBES WOULD BURN OUT FUSES OR PERHAPS DAMAGE THE TUBE ITSELF.

TO PREVENT TRACES OF GAS WITHIN TRANSMITTER TUBES IS ONE OF THE MOST DIFFICULT PROBLEMS ENCOUNTERED IN THEIR MANUFACTURE. ALTHOUGH IT IS TRUE THAT THE AIR AND TRACES OF GAS CAN BE REMOVED QUITE READILY FROM THE GLASS ENVELOPE, YET THE EXHAUSTING OF GAS STILL INCLUDED IN THE METALLIC PARTS AND OTHER GLASS SUPPORTING MEMBERS IS EXTREMELY DIFFICULT.

THE GAS IS DRIVEN OUT OF THE METAL STRUCTURE WITHIN THE TUBE BY HEATING THE METAL TO A HIGH TEMPERATURE BEFORE PLACING IT IN THE TUBE AND THE PUMPING IS CARRIED OUT WITH THE ENTIRE TUBE IN AN OVEN THAT IS HEATED TO A TEMPERATURE JUST BELOW THE SOFTENING POINT OF THE GLASS. FINALLY, WHILE THE PUMP IS STILL IN OPERATION, THE METAL PARTS ARE BROUGHT UP TO TEMPERATURES ABOVE THOSE WHICH WOULD OCCUR DURING THE NORMAL OPERATION OF THE TUBE. SOME OF THE LARGER TUBES REQUIRE AS LONG AS 24 HOURS OF CONTINUOUS PUMPING IN ORDER TO REMOVE THE GASES WHICH WOULD ORDINARILY BE HELD BY THE VARIOUS PARTS WHICH ARE ENCLOSED IN THE GLASS ENVELOPE.

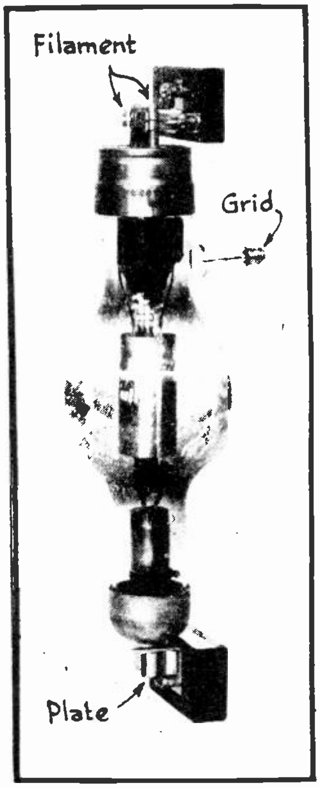

FIG. 6
The 206

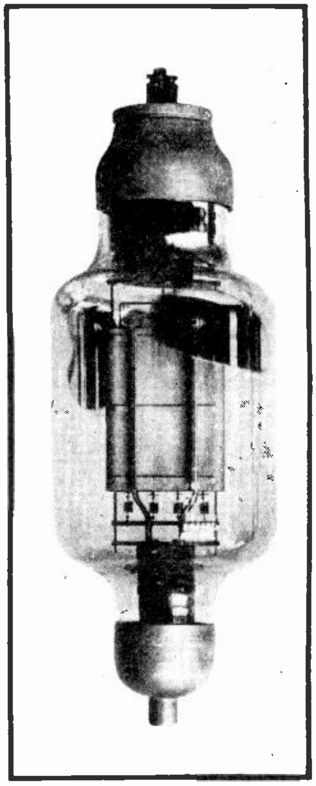

FIG. 7
The 851

THE MATERIALS WHICH ARE SELECTED FOR THE GRIDS AND PLATES MUST BE SELECTED WITH SPECIAL CARE DUE TO THE HIGH TEMPERATURES AT WHICH THESE ELEMENTS FREQUENTLY OPERATE WHEN IN USE. THE GRIDS ARE GENERALLY MADE OF TUNGSTEN ALTHOUGH MOLYBDENUM IS ALSO USED. THE PLATES IN AIR-COOLED TUBES

ARE GENERALLY MADE OF MOLYBDENUM BUT TANTALUM IS ALSO USED.

WHEN TRANSMITTER TUBES ARE IN OPERATION, THEY GENERATE CONSIDERABLE HEAT. THIS HEAT ORIGINATES PRIMARILY AT THE FILAMENT AND PLATE, THE PLATES FREQUENTLY BECOMING RED HOT, ALTHOUGH THIS IS ALSO TRUE OF THE GRIDS IN SOME CASES. SO AS TO PERMIT ADEQUATE RADIATION OF THIS HEAT TO THE SURROUNDING AIR AND THEREBY PREVENT TUBE HEATING OF AN INJURIOUS MAGNITUDE, IT IS CUSTOMARY TO SUPPLY THE TUBE WITH A GLASS ENVELOPE OF CONSIDERABLE SIZE. THE GREATER THE AREA OF THE GLASS IN CONTACT WITH THE SURROUNDING AIR, THE MORE EFFICIENT WILL BE THE COOLING.

TO FASCILITATE COOLING OF THE TUBES THEY SHOULD BE INSTALLED IN SUCH A MANNER THAT THEY WILL BE EXPOSED FREELY TO THE SURROUNDING AIR RATHER THAN BEING CRAMPED IN CLOSE QUARTERS. AN EXAMPLE OF SUCH A TUBE INSTALLATION IS SHOWN IN FIG. 8. ALSO NOTICE IN THIS ILLUSTRATION THAT BEAD INSULATION IS USED ON THE HIGH VOLTAGE CONDUCTORS LEADING TO THE TUBES.

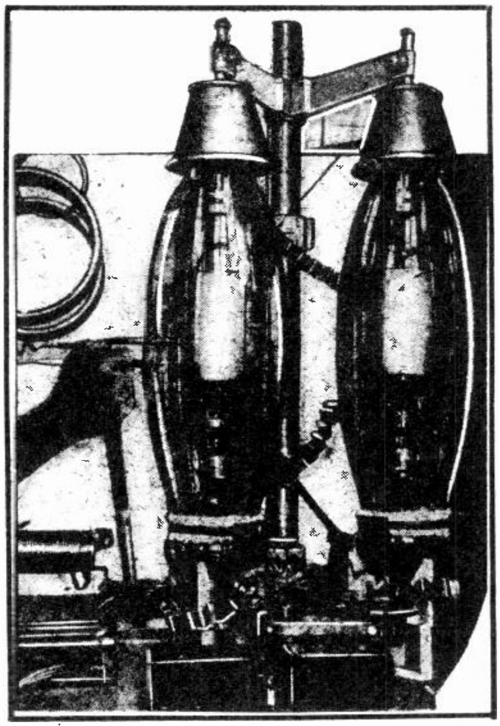

FIG. 8
A Typical High Power Tube Installation.

QUITE OFTEN TO PROVIDE STILL BETTER TUBE COOLING, A DRAFT OF AIR IS CIRCULATED AROUND THEM. THIS CAN BE ACCOMPLISHED WITH THE AID OF LARGE FANS OR BLOWERS WHICH FORCE A DRAFT OF AIR AROUND THE TUBES WHILE THEY ARE IN OPERATION.

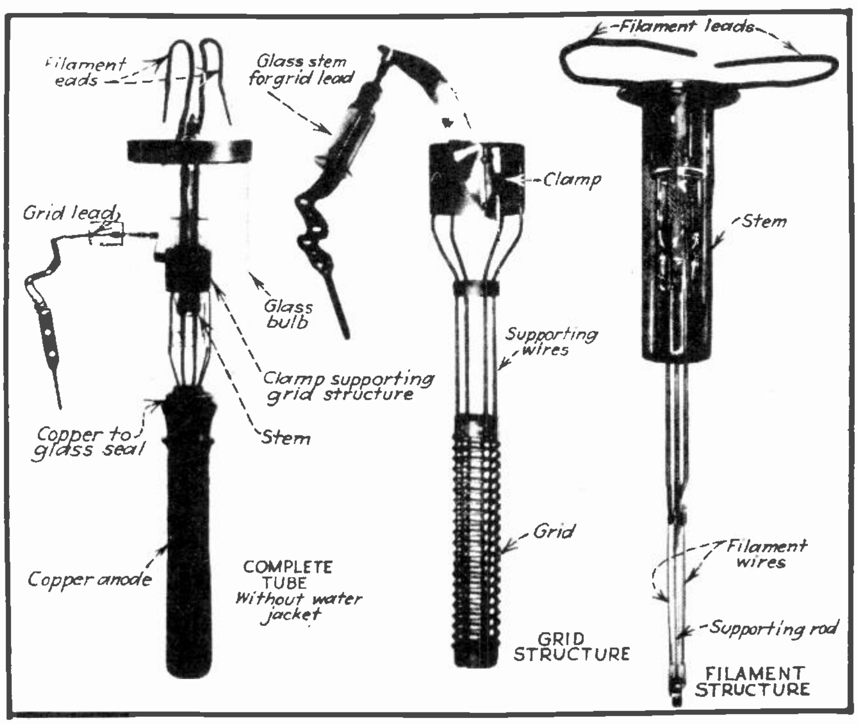

FIG. 9
A Water-Cooled Tube.

WATER-COOLED TUBES

FOR MOST OF THE TUBES OF VERY HIGH POWER RATING, AS USED IN BROADCAST STATIONS, AIR

COOLING IS NOT SUFFICIENT TO KEEP THE TUBE TEMPERATURES AT A SAFE VALUE. IN SUCH CASES, WATER IS USED AS THE COOLING MEDIUM. TO USE WATER FOR THIS PURPOSE, THE TUBE MUST BE SPECIALLY DESIGNED AND AN EXAMPLE OF SUCH A WATER-COOLED TUBE IS SHOWN YOU IN FIG. 9.

HERE THE TUBE IS SHOWN AT THE LEFT IN AN ASSEMBLED CONDITION, WHEREAS THE GRID STRUCTURE IS SHOWN IN DETAIL AT THE CENTER AND THE FILAMENT STRUCTURE AT THE RIGHT.

THIS TUBE USES A HOLLOW, TUBULAR SHAPED, PLATE (ANODE) WHICH IS CLOSED AT ITS LOWER END. THE FILAMENT STRUCTURE IS INSERTED IN THE SPACE WITHIN THE CENTER OF THE GRID STRUCTURE AND THESE TWO STRUCTURES ARE TOGETHER INSERTED INTO THE HOLLOW PLATE. THE UPPER PORTION OF THE TUBE IS SEALED IN A GLASS ENVELOPE.

WHEN IN USE, THE PLATE END OF THE TUBE IS INSERTED INTO A SPECIAL JACKET THROUGH WHICH COOLING WATER IS CIRCULATED, AND WHICH AT THE SAME TIME SERVES AS THE TUBE HOLDER. THIS IS ILLUSTRATED IN FIG. 10.

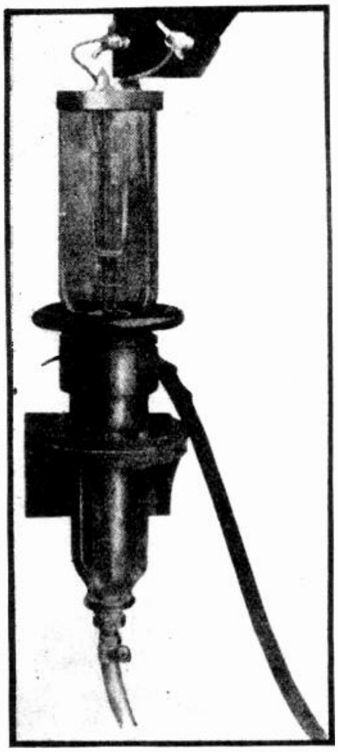

FIG. 10
Water-Cooled Tube Mounted in Jacket.

SUFFICIENT SPACE IS PROVIDED BETWEEN THE INSIDE OF THE JACKET AND THE COPPER PLATE SO AS TO PERMIT A COLUMN OF WATER TO CIRCULATE FREELY AROUND THE PLATE FOR THE EXTRACTION OF HEAT GENERATED AT THIS POINT. HOSE CONNECTIONS LEAD THE WATER INTO AND OUT OF THE JACKET AND A SPECIAL GASKET BETWEEN THE TUBE AND THE JACKET PREVENTS LEAKAGE.

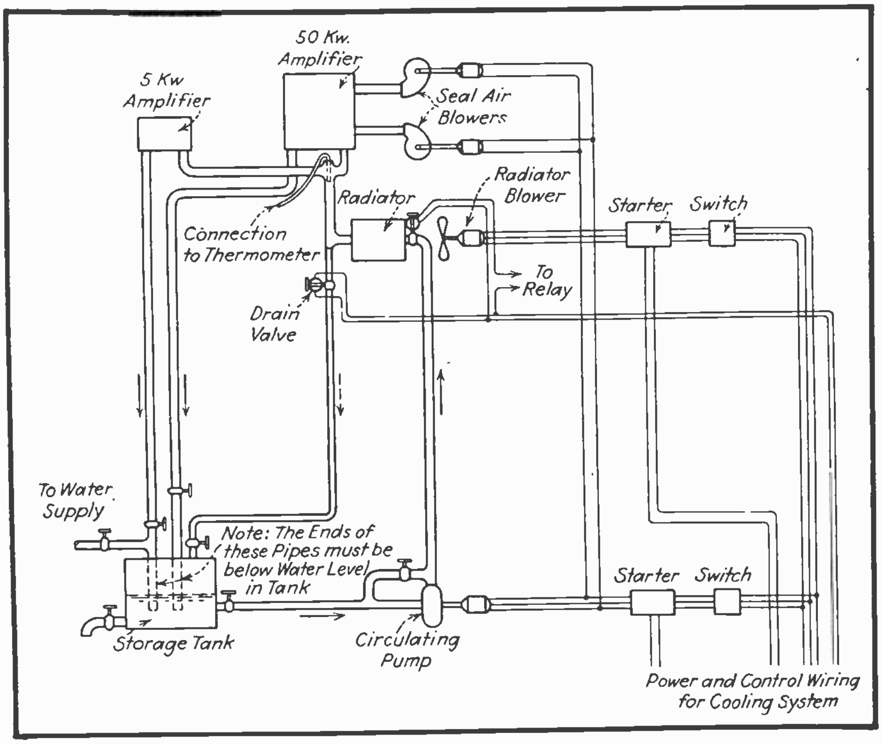

FIG. 11
A Typical Water-Cooling System.

A TYPICAL WATER-COOLING SYSTEM AS USED WITH A 50 KW BROADCAST TRANSMITTER IS SHOWN IN FIG. 11. AS YOU WILL OBSERVE, THIS SYSTEM CONSISTS OF A

STORAGE TANK FROM WHICH THE COOLING WATER IS DRAWN AND FORCED BY THE PRESSURE OF A PUMP THROUGH A RADIATOR, THROUGH THE TUBE JACKETS, AND BACK TO THE STORAGE TANK.

THE RADIATOR IS SIMILAR IN CONSTRUCTION TO AN AUTOMOBILE RADIATOR ONLY THAT IT IS LARGER IN SIZE. A FAN WHICH IS DRIVEN BY AN ELECTRIC MOTOR FORCES AIR THROUGH THE RADIATOR SO AS TO COOL THE WATER BEFORE CIRCULATING IT AROUND THE TUBES. A BANK OF COOLING FANS OF THIS TYPE ARE SHOWN YOU IN FIG. 12. HERE THE AIR IS TAKEN IN FROM OUTSIDE THE BUILDING THROUGH LOUVRES AND FORCED BY THE FANS THROUGH THE RADIATORS WHICH ARE LOCATED DIRECTLY IN FRONT OF THEM.

IN THE SYSTEM OF FIG. 11 ADDITIONAL ELECTRICALLY DRIVEN AIR BLOWERS ALSO FORCE A DRAFT OF AIR AROUND THE TUBES OF THE 50 KW. AMPLIFIER TO STILL FURTHER AID IN THE PROCESS OF COOLING.

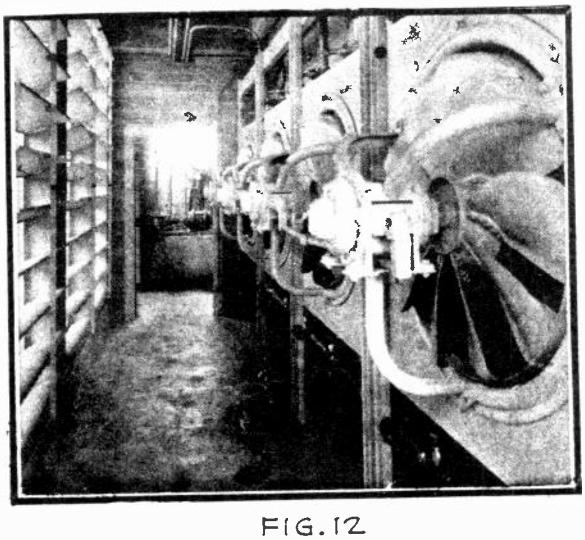

FIG. 12
Cooling Fans and Radiator System.

IN THE LARGE TUBES, ABOUT TWO OR THREE GALLONS OF WATER PER MINUTE IS PUMPED PAST THE PLATE (ANODE). A CIRCUIT BREAKER IS FREQUENTLY INSTALLED BETWEEN THE WATER CIRCULATING SYSTEM AND THE ELECTRICAL CIRCUITS AND IS SET TO OPEN IN CASE THE WATER SUPPLY SHOULD FAIL FOR ANY REASON.

THE TEMPERATURE OF THE WATER IS USUALLY MEASURED AFTER IT HAS PASSED THE HOT ANODE AND AT THIS POINT IS SELDOM PERMITTED TO EXCEED 70° CENTIGRADE (158° FAHRENHEIT). BECAUSE OF THE HIGH PLATE POTENTIAL REQUIRED BY SUCH TUBES, THE PLATE IS CAREFULLY INSULATED FROM THE WATER TANK AND THE METAL TUBING WHICH IS NORMALLY GROUNDED. BY USING A FAIRLY LONG RUBBER HOSE TO CONNECT THE WATER JACKET TO THE WATER SOURCE AND ALSO BY USING PURE WATER IN THE CI CULATORY SYSTEM, THE INSULATION RESISTANCE IS BUILT UP TO THE ORDER OF SEVERAL HUNDREDS OF THOUSANDS OF OHMS, THIS RESISTANCE IS BETWEEN THE HIGH POTENTIAL ANODE WHICH IS IN DIRECT CONTACT WITH THE WATER, AND THE COOLING SYSTEM, AND IN TURN, THE GROUND.

ANOTHER "TRICK" WHICH IS RESORTED TO IN ORDER TO FASCILITATE THE COOLING OF TRANSMITTER TUBES IS TO BLACKEN THE PLATE SO AS TO INCREASE THE RATE OF HEAT RADIATION. ALSO IN SOME OF THE TRANSMITTER TUBES SPECIAL BUILT-IN FEATURES SUCH AS R.F. CHOKES WILL BE FOUND AND WHICH HAVE BEEN PLACED THEREIN WITH THE INTENTION OF REDUCING PARASITIC OSCILLATIONS.

TUBE OPERATING CHARACTERISTICS

NOW THAT YOU ARE FAMILIAR WITH THE CONSTRUCTIONAL FEATURES OF THE DIFFERENT DISTINCTIVE TYPES OF TRANSMITTER TUBES, YOU WILL NEXT BE INTERESTED IN LEARNING HOW THE OPERATING CHARACTERISTICS OF THESE TUBES COMPARE WITH THOSE AS USED IN RECEIVERS.

TABLE I

TRANSMITTING TUBES

TRIODES

Type	Nominal R.F. Output (watts)[1]	Fil. Volts (E_f)	Fil. Amps. (I_f)	Max. Plate Volts[2] (E_b)	Max. Plate Ma. (I_p)	Neg. Grid Bias Volts[3] (E_c)	Max. Grid Ma. (I_c)	Grid Driving Power (watts)	Safe Plate Dissipation (watts)	Amp. Factor (μ)	Interelectrode Capacitances ($\mu\mu$fd.) Grid to Fil.	Grid to Plate	Plate to Fil.	Grid Leak (ohms)
45	10	2.5	1.50	400	50	180		2.0	10	3.5	5.0	8.0	3.0	50,000
46	10	2.5	1.75	400	50	180[4] 22[5]		2.0	10	5.6 30.0				50,000 1,000
59	10	2.5‡	2.0	400	50	135[6] 22[7]		3.0 2.0	10	6.0 30.0				25,000 1,000
843	10	2.5‡	2.5	425	40	90	7.5		15	7.7	5.0	6.0	5.0	10,000
10	15	7.5	1.25	500	60	135	15	3.0	15	8.0	4.0	7.0	3.0	10,000
841	15	7.5	1.25	500	60	30	20	2.0	15	30.0	5.0	8.0	3.0	5,000
801*	25	7.5	1.25	600	65	150	15	4.5	20	8	4.5	6	1.5	10,000
800*	50	7.5	3.25	1000	75	135	25	5.0	35	15.0	2.8	2.5	1.0	10,000
825*	50	7.5	3.25	1000	75	180		5.0	40	10.0	2.0	3.0	1.0	10,000
830	50	10.0	2.15	750	110	180	18	5.0	40	8.0	4.9	9.9	2.2	10,000
RK-18*	50	7.5	2.5	1000	85	135	15	4.0	40	18.0	3.8	5.0	2.0	10,000
304-A*	85	7.5	3.25	1250	100	200	20	8	50	11	2	2.5	0.7	10,000
203-A	100	10.0	3.25	1250	175	100	60	14.0	100	25.0	6.5	14.5	5.5	10,000
211	100	10.0	3.25	1250	175	200	50	14.0	100	12.0	8.0	15.0	7.0	15,000
242-A	100	10.0	3.25	1250	150	150	50	14.0	100	12.5	6.5	13.0	4.0	15,000
852*	100	10.0	3.25	3000	100	350	40	20.0	100	12.0	2.0	3.0	1.0	10,000
354*	150	5	7.75	3000	175	275	40	15.0	150	11.0	9.0	3.7	0.4	10,000
150T*	200	5	10.0	3000	200	300	25	15.0	150	12.0				10,000
F-108-A*	200	10.0	11.0	3000	200	350	50	25.0	175	12.0	3.0	7.0	2.0	15,000
204-A	350	11.0	3.85	2500	275	250	80	60.0	250	25.0	18.0	17.0	3.0	10,000
849	450	11.0	5.0	2500	350	300	125	75.0	300	19.0	17.0	33.5	3.0	10,000
831*	500	71.0	10.0	3000	350	300	100	75.0	400	14.5	3.8	4.0	1.5	10,000
F-100*	500	11.0	25.0	2000	500	300		75.0	500	14.0	4.0	10.0	2.0	10,000

TETRODES AND PENTODES

Type	Nominal R.F. Output (watts)[1]	Fil. Volts (E_f)	Fil. Amps. (I_f)	Max. Plate Volts[2] (E)	Max. Screen Volts (E)	Neg. Grid Bias Volts (E)	Max. Plate Ma.[2] (I_p)	Max. Grid Ma. (I_c)	Grid Driving Power (watts)	Safe Screen Dissipation (watts)	Safe Plate Dissipation (watts)	Interelectrode Capacitances ($\mu\mu$fd.) Grid to Cathode	Grid to Plate	Plate to Cathode
41	5	6.3‡	0.4	300	100	22	40		1.0					
42	10	6.3	0.7	400	100	45	50		2.0					
47	10	2.5	1.75	400	100	45	50		2.0			8.6	1.2	13.0
2A5	10	2.5‡	1.75	400	100	45	50		2.0					
89	10	6.3‡	0.4	400	100	45	40		2.0					
59	10	2.5‡	2.0	400	100	45	50		2.0					
844	5	2.5‡	2.5	500	150	10	30	5	1.0	3	15	10.0	0.07	8.5
865*	15	7.5	2.0	750	150	75	60	15	2.5	3	15	10.0	0.05	7.5
254-A*	20	5.0	3.25	750	175	90	60		3.0	5	20	4.6	0.1	9.4
254-B*	25	7.5	3.25	750	150	135	75		3.0	5	25	11.2	0.085	5.4
282-A*	50	10.0	3.0	1000	250	150	100		5.0	5	70	12.2	0.2	6.8
RK-20*	50	7.5	3.0	1000	300	75	85		3.0	10	40	11.0	0.01	9.5
850	100	10.0	3.25	1250	150	150	175	40	10.0	10	100	17.0	0.2	26.0
860*	100	10.0	3.25	3000	250	200	100	40	15.0	10	100	8.5	0.05	9.0
861*	540	11.0	10.0	3500	500	200	350	100	50.0	35	400	17.0	0.1	13.0

[1] Conservative rating based on normal plate input and operating conditions. The actual output will depend upon the efficiency and the power supplied to the tube plate.
[2] Maximum recommended values, unmodulated d.c. With modulation, d.c. plate voltage should be 25 to 30 per cent lower.
[3] Recommended value for operation as oscillator or Class-C power amplifier.
[4] With outer grid connected to plate.
[5] With grids connected together.
[6] Grids Nos. 2 and 3 connected to plate.
[7] Grids Nos. 1 and 2 connected together; grid No. 3 connected to plate.
‡ Indirectly-heated cathode.
* Especially designed for very high-frequency use.

IN TABLE I, FOR EXAMPLE, YOU ARE GIVEN THE OPERATING CHARACTERISTICS OF THE TRIODES, TETRODES AND PENTODES WHICH ARE MOST EXTENSIVELY USED FOR AMATEUR AND MEDIUM POWER COMMERCIAL TRANSMITTERS. THESE TRIODES ARE SUITABLE AS OSCILLATORS AND POWER AMPLIFIERS. THE TETRODES AND PENTODES WHICH ARE DESIGNED PARTICULARLY FOR TRANSMITTERS ARE INTENDED TO BE USED PRIMARILY AS OSCILLATORS AND RADIO FREQUENCY POWER AMPLIFIERS AND CAN BE USED WITHOUT NEUTRALIZATION. THE OPERATING CHARACTERISTICS OF THE MORE POPULAR RECTIFIER TUBES APPEAR IN TABLE II.

A PAIR OF THE LARGER RECTIFIER TUBES ARE SHOWN YOU IN FIG. 13 WHERE THE 217-C APPEARS AT THE LEFT AND THE 218 AT THE RIGHT. BOTH OF THESE TUBES ARE OF THE HALF-WAVE TYPE. THE OPERATING CHARACTERISTICS OF THE 217-C ARE AS FOLLOWS: FILAMENT VOLTAGE = 10; FILAMENT CURRENT = 3.25 AMPS; PEAK INVERSE VOLTAGE;= 7500 VOLTS MAXIMUM; PEAK PLATE CURRENT =0.6 AMP. MAXIMUM. THE OPERATING CHARACTERISTICS OF THE 218 ARE AS FOLLOWS: FILAMENT VOLTAGE = 11; FILAMENT CURRENT = 14.75 AMPS; PEAK INVERSE VOLTS = 50,000 MAXIMUM; PEAK PLATE CURRENT = 0.75 AMP. MAXIMUM.

THE RECTIFIER TUBES OF LARGER SIZE CAN ALSO BE OF THE AIR-COOLED OR WATER-COOLED TYPE THE SAME AS ALREADY EXPLAINED FOR TRANSMITTER TUBES IN GENERAL.

TUBES OF HIGHER RATING

NOW THAT TABLE I HAS FAMILIARIZED YOU WITH THE OPERATING CHARACTERISTICS OF TRANSMITTER TUBES OF MODERATE SIZE, LET US NEXT TAKE A GLANCE AT THE SPECIFICATIONS OF THE LARGER, WATER-COOLED TUBES. AS AN EXAMPLE, LET US USE THE 848.

WHEN OPERATING AS A PLATE-MODULATED "CLASS C" R.F. POWER AMPLIFIER,

TABLE II

RECTIFIER TUBES

Type No.	Fil. Volts	Fil. Amps.	Max. Voltage per plate (a.c. r.m.s.)	Max. Inverse Peak Voltage	Max. D.C. Output Current (ma.)	Max. Peak Current (ma.)	Type
1	6.3*	0.3	350	1000	50	400	Half-wave M.V.
1-V	6.3*	0.3	350		50		Half-wave H.V.
84	6.3*	0.5	225		50		Full-wave H.V.
12Z3	12.6*	0.3	250		60		Half-wave H.V.
25Z5	25.0*	0.3	125		100		H.V. Voltage-Doubler [1]
80	5.0	2.0	350 400 550[2]		125 110 135		Full-wave H.V.
82	2.5	3.0	500	1400	125	400	Full-wave M.V.
5Z3	5.0	3.0	500		250		Full-wave H.V.
83	5.0	3.0	500	1400	250	800	Full-wave M.V.
81	7.5	1.25	700		85		Half-wave H.V.
RK19	7.5*	2.5	1250	3500		600	Full-wave H.V.
866	2.5	5.0		7500		600	Half-wave M.V.
866-A	2.5	5.0		10,000		600	Half-wave M.V.
872	5.0	10.0		7500		2500	Half-wave M.V.

H.V. — High Vacuum. M.V. — Mercury Vapor.
* Indirectly-heated cathode.

[1] Two independent rectifiers in one bulb.
[2] Only with input choke of at least 20 henrys to filter.

THE 848 HAS THE FOLLOWING CHARACTERISTICS; FILAMENT VOLTAGE = 22 VOLTS A.C. OR D.C.; FILAMENT CURRENT=52 AMPS; D.C. PLATE VOLTAGE = 9000 VOLTS; GRID VOLTAGE = -4000 VOLTS (APPROXIMATELY); POWER OUTPUT = 6000 WATTS (APPROXIMATELY).

WHEN WORKING WITH HIGH POWER TUBES OF THIS KIND, THEIR APPLICATION TO THE TRANSMITTER CIRCUIT FROM AN ELECTRICAL STANDPOINT IS PRACTICALLY THE SAME AS ALREADY DESCRIBED TO YOU IN PREVIOUS LESSONS RELATIVE TO TRANSMITTER TUBES OF MEDIUM POWER RATING. THE ONLY ESSENTIAL DIFFERENCES ENCOUNTERED WHEN USING THE HIGHER POWER TUBES IS THE COOLING MEDIUM USED, THE USE OF A POWER SUPPLY OF HIGHER OUTPUT ABILITY, THE EXERCISING OF GREATER PRECAUTIONS IN THE ARRANGEMENT AND DESIGN OF THE CIRCUIT SO THAT THE VERY HIGH VOLTAGES AND POWERS CAN BE HANDLED WITH SAFETY. YOU WILL BE TOLD MORE ABOUT THE USE OF THESE TUBES OF HIGH POWER RATING IN YOUR STUDIES WHICH TREAT WITH BROADCAST TRANSMITTERS.

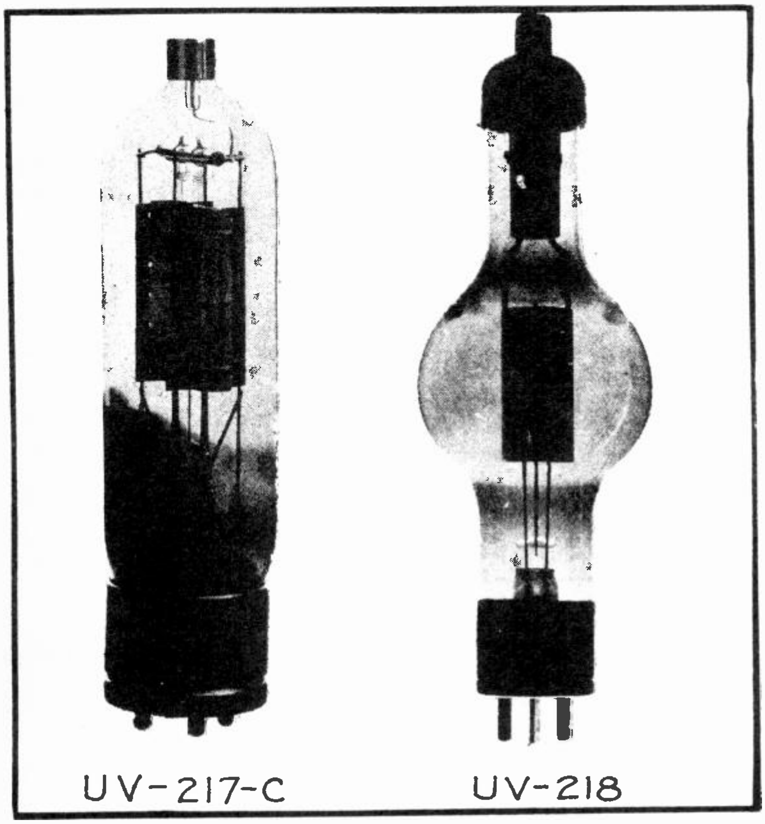

FIG. 13
Typical Rectifier Tubes

ANOTHER IMPORTANT POINT WHICH IT WILL BE WELL TO REMEMBER REGARDING TRANSMITTER TUBES IS THAT THEIR POWER OUTPUT RATING AS SPECIFIED BY THE MANUFACTURERS IS A MORE OR LESS AVERAGE VALUE AND THAT THE POWER OUTPUT REALIZED IN ACTUAL PRACTICE IS GOVERNED LARGELY BY THE DESIGN OF THE PARTICULAR CIRCUIT IN WHICH THE TUBE IS USED.

TUBE DATA FOR MODULATORS

IN TABLES III AND IV OF THIS LESSON, YOU ARE FURNISHED WITH ADDITIONAL TUBE DATA WHICH SPECIFIES THE CHARACTERISTICS FOR OPERATING SOME OF THE MORE POPULAR TUBES AS CLASS A AMPLIFIERS AND MODULATORS, AS WELL AS CLASS B MODULATORS.

HAVING COMPLETED THIS LESSON, YOU SHOULD NOW HAVE A GOOD GENERAL KNOWLEDGE OF THE CONSTRUCTION AND OPERATING CHARACTERISTICS OF TYPICAL TRANSMITTER TUBES. PERHAPS YOU MAY STILL BE WONDERING JUST EXACTLY HOW ALL OF THE TUBE DATA AS PRESENTED IN THIS LESSON IS APPLIED TO THE ACTUAL DESIGN OF TRANSMITTER EQUIPMENT. THESE DETAILS, HOWEVER, WILL ALL BE TAKEN CARE OF IN LESSONS WHICH YOU WILL RECEIVE A LITTLE LATER ON.

BEFORE WE GO INTO THE VARIOUS TRANSMITTER DESIGN CALCULATIONS, HOWEVER, THERE IS STILL ONE MORE IMPORTANT MATTER FOR US TO CONSIDER AND

TABLE III

TYPICAL CLASS-A AMPLIFIER AND MODULATOR OPERATING DATA

Type Tube	Fil. Volts, E_f	Plate Volts, E_b	Plate Ma., I_b	Neg. Grid Volts,[1] E_c	Load Imp.,[2] Ohms	Audio Output,[3] Watts
50	7.5	500	50	100	7500	5.5
2A3 (P.P.)[4]	2.5	300	80	62	3000	15.0
211, 242A, 276A	10.0	1000	65	52	7000	10.0
845	10.0	1000	75	150	7500	23.0
284A	10.0	1250	60	228	10,000	41.5
849	11.0	2000 2500 3000	125 110 100	75 104 132	12,000 12,000 20,000	42.5 81.0 100.0

With exception noted, ratings are for a single tube. For tubes in parallel multiply I_b and Output Watts by number used, and divide Load Impedance by number used. For 2 tubes in push-pull, multiply I_b, Load Impedance and Output Watts by 2, taking peak audio grid voltage twice bias value.

[1] Peak audio grid voltage equal to bias value for single tube or tubes in parallel.

[2], [3] To be used in determining Class-C amplifier operating conditions.

[4] Two tubes in push-pull. Peak audio grid voltage twice bias value.

TABLE IV

TYPICAL CLASS-B MODULATOR OPERATING DATA

Class-B Tubes (2)	Fil. Volts, E_f	Plate Volts, E_b	Plate Ma. (Max.), I_b	Neg. Grid Volts, E_c	Load Imp., Ohms [1]	Tube Output, Watts	Input Trans. Turns Ratio (Pri.:Sec.)	Driver Tubes (P.P.)	Driver Plate Volts
46	2.5	400	108	0	7000	25	3:1	45	225
59	2.5	400	124	0	6000	28	3:1	45	225
841	7.5	500	108	13.5	8000	29	5:1	45	250
210*	7.5	600	153	67	8000	57.5	1.6:1	45	250
800	7.5	1000	164	55	12,500	100	1:1	2A3	250
RK18	7.5	1000	164	45	12,000	100	2:1	45	250
830-B*	10.0	1000	280	33	10,000	190	1:1.4	2A3	250
203-A*	10.0	1000	366	40	5800	240	1.6:1	2A3	250

Ratings are for 2 tubes, Class-B.

* Graphite anode types.

[1] Plate-to-plate. Use this load impedance and Output Watts for determining Class-C stage coupling and operating conditions

THAT IS THE CONSTRUCTIONAL FEATURES AND OPERATION OF RECEIVERS WHICH ARE PARTICULARLY SUITABLE FOR COMMUNICATION STATIONS. THIS, THEREFORE, IS THE SUBJECT MATTER TO BE DISCUSSED WITH YOU IN THE NEXT LESSON. AT THIS TIME YOU WILL ALSO HAVE THE OPPORTUNITY OF LEARNING ABOUT CRYSTAL FILTERS AS USED IN RECEIVERS, ABOUT BEAT-NOTE OSCILLATORS FOR C.W. CODE RECEPTION AND OTHER INTERESTING FEATURES OF COMMERCIAL STATION EQUIPMENT.

THIS AMOUNT OF ADDITIONAL INFORMATION WILL GIVE YOU THE BACK-GROUND WHICH IT IS NECESSARY FOR YOU TO HAVE IN ORDER TO DERIVE THE FULLEST VALUE FROM THE LESSONS WHICH ARE TO FOLLOW.

YOU WILL ALSO NO DOUBT BE INTERESTED IN KNOWING AT THIS TIME THAT AFTER YOU HAVE COMPLETED YOUR STUDIES PERTAINING TO THE DESIGNING FACTORS AS APPLIED TO TRANSMITTER CIRCUITS, YOU WILL ENGAGE IN AN EXTENSIVE STUDY OF BROADCAST TRANSMITTERS AND ALL OF THE STUDIO AND CONTROL ROOM EQUIPMENT WHICH IS ASSOCIATED WITH THESE HIGHLY INTERESTING SYSTEMS.

Answered March 23, 1942

LESSON NO. T-14

"The man who watches the clock usually remains one of the hands."

1. – WHAT ARE THE CHIEF CONSTRUCTIONAL DIFFERENCES BETWEEN THE CONVENTIONAL RECEIVER AND TRANSMITTER TUBES?

2. – WHAT IS THE OBJECT OF KEEPING THE GRID AND PLATE TERMINALS WIDELY SEPARATED ON SOME OF THE TRANSMITTER TUBES?

3. – HOW DOES THE SIZE OF A TUBE'S GLASS ENVELOPE AFFECT THE OPERATION OF THE TUBE?

4. – ILLUSTRATE BY MEANS OF A SKETCH AND DESCRIBE FULLY THE CONSTRUCTIONAL FEATURES OF A TYPICAL WATER-COOLED TRANSMITTER TUBE.

5. – DRAW A DIAGRAM OF A TYPICAL TUBE-COOLING SYSTEM WHICH IS SUITABLE FOR A BROADCAST TRANSMITTER AND EXPLAIN IN DETAIL HOW IT OPERATES.

6. – WHAT ARE THE OPERATING CHARACTERISTICS OF THE TYPE 204-A TUBE?

7. – WHAT SPECIAL FEATURE IS SOMETIMES INCORPORATED IN THE FILAMENT CIRCUIT OF HIGH POWER TRANSMITTER TUBES IN ORDER TO PREVENT TOO MUCH FILAMENT CURRENT BEING DRAWN BEFORE THE FILAMENT TEMPERATURE COMES UP TO NORMAL?

8. – WHAT MATERIAL IS GENERALLY USED FOR THE CONSTRUCTION OF THE FILAMENT IN THE LARGER TRANSMITTER TUBES AND WHY IS THIS PARTICULAR MATERIAL SELECTED?

9. – DESCRIBE SOME OF THE MOST COMMONLY USED METHODS OF MOUNTING OR SUPPORTING TRANSMITTER TUBES.

10. – HOW MAY AIR-COOLING OF TRANSMITTER TUBES BE ACCOMPLISHED?

4

RADIO - TELEVISION

Practical • J. A. ROSENKRANZ, Pres. • Training

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Established 1905

Los Angeles, California

Printed in U. S. A.

Transmitters

LESSON NO. 15

COMMUNICATION RECEIVERS AND SPECIAL SYSTEMS

You have already learned a great deal about standard-wave broadcast, short-wave, and all-wave receivers as used by the average radio listener and experimenter. There are, however, a number of features incorporated in communication type receivers as used by commercial operators and about which you have as yet not been told. These additional receiver features consist of beat-note oscillators, crystal filters etc. These, therefore, are all explained in this lesson.

In Fig. 1 you are shown a front view of a typical communication type receiver, while a bird's-eye-view of the same unit, when removed from the metal cabinet, is shown you in Fig. 2. Later in this lesson you will have the opportunity of studying the circuits of this receiver but first it is necessary that you become familiar with the operation and use of the beat-note oscillator.

BEAT-NOTE RECEPTION

From what you have already learned about radio transmission and reception, you realize that if a transmitter were to radiate an unmodulated continuous wave, no resulting signal would be heard in the ordinary receiver even though the receiver be accurately tuned to the transmitter frequency. The reason for this is that the transmitted wave is beyond the frequency of audibility.

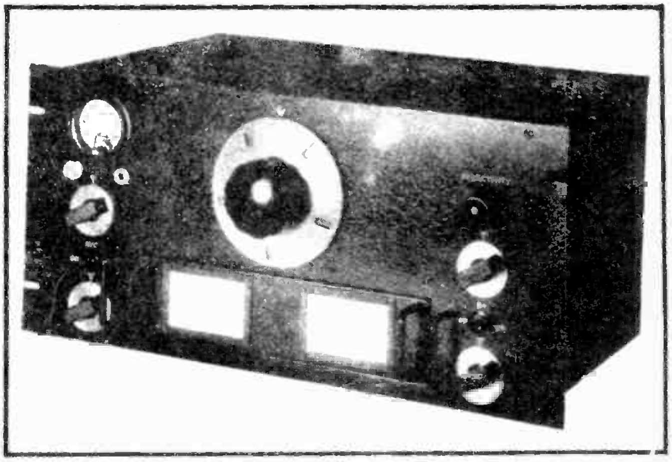

FIG. 1
The National "HRO" Communications Type Receiver.

The only method whereby the continuous wave can ordinarily transmit a signal which is audible is to modulate the carrier frequency (C.W.) at an audio

FREQUENCY RATE. THIS WILL ENABLE THE DETECTOR OF THE RECEIVER TO SEPARATE THE AUDIO COMPONENT FROM THE CARRIER WAVE FORM SO THAT THE DESIRED SIGNAL CAN BE HEARD.

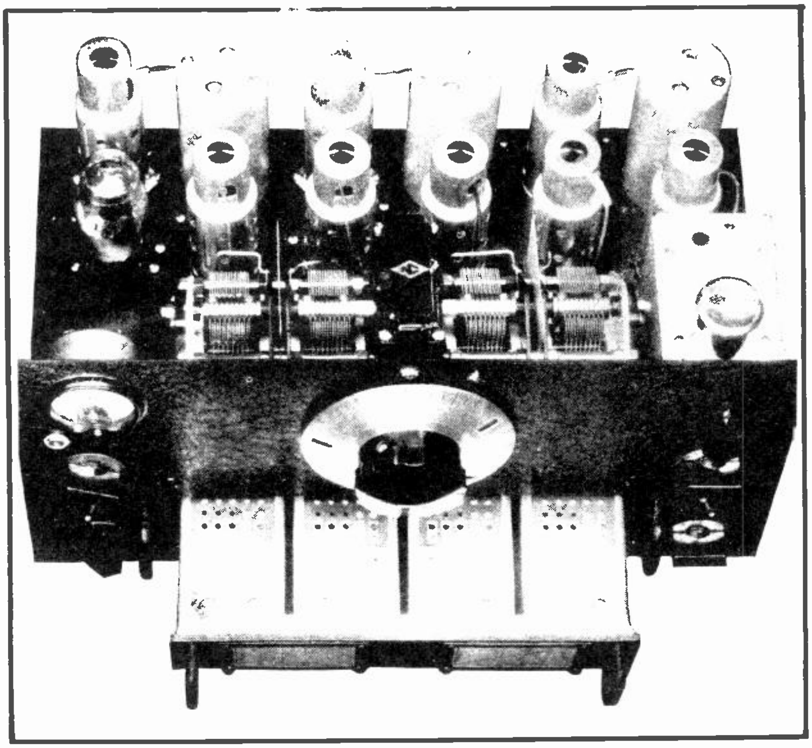

FIG. 2
The National Receiver Removed from the Cabinet

IN THE CASE OF CODE COMMUNICATION, HOWEVER, THE TRANSMISSION OF AN UNMODULATED CONTINUOUS WAVE IS USED EXTENSIVELY. WHEN THIS IS DONE, THE WAVE RADIATION WILL BE SIMILAR TO THAT ILLUSTRATED IN FIG. 3. HERE YOU WILL OBSERVE THAT THE DOT OF THE CODE IS FORMED BY HOLDING THE KEY CLOSED FOR A SHORT DURATION, WHILE THE DASH IS FORMED BY HOLDING THE KEY CLOSED FOR A SLIGHTLY LONGER PERIOD. WHEN THE KEY IS OPEN, THE WAVE RADIATION CEASES ALTOGETHER.

BY STUDYING FIG. 3 CLOSELY, YOU WILL NOTE THAT THE FREQUENCY OF THE WAVE FORM IN EACH GROUP IS OF RADIO FREQUENCY AND OF CONSTANT AMPLITUDE AND FOR THIS REASON SIGNALS WHICH ARE TRANSMITTED IN THIS MANNER WOULD ORDINARILY BE INAUDIBLE.

UPON CARRYING OUR INVESTIGATION OF THIS PRINCIPLE A LITTLE FARTHER, WE NEXT COME TO THE POINT WHICH IS ILLUSTRATED IN FIG.4. HERE WE ARE ILLUSTRATING AT THE CENTER A CONTINUOUS SIGNAL WAVE HAVING A FREQUENCY OF 7,205 KC.(7,205,000 CYCLES PER SECOND) AND WHICH YOU WILL IMMEDIATELY REALIZE AS BEING INAUDIBLE.

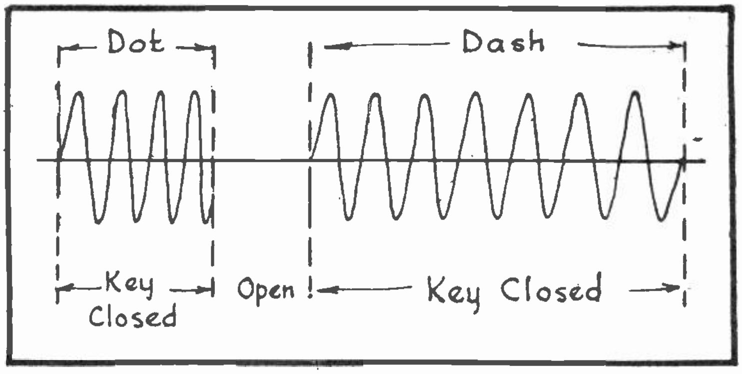

FIG. 3
C. W. Code Transmission.

DIRECTLY ABOVE THIS 7,205 KC. SIGNAL WAVEFORM, WE HAVE ILLUSTRATED ANOTHER WAVE FORM WHICH IS GENERATED BY AN OSCILLATOR WHICH IS LO-

CATED AT THE RECEIVER. THIS PARTICULAR OSCILLATOR ALSO PRODUCES A CONTINUOUS WAVE FORM BUT ITS FREQUENCY IN THE PARTICULAR CASE ILLUSTRATED IS 7,200 KC. OR 7,200,000 CYCLES PER SECOND.

NOW IF WE WERE TO TUNE IN ON THE RECEIVER THE 7,205 KC SIGNAL AND COUPLE TO THIS SAME RECEIVER CIRCUIT THE OUTPUT OF THE LOCAL OSCILLATOR WHOSE FREQUENCY IS 7,200 KC., THEN THROUGH HEATERODYNE ACTION, A BEAT-FREQUENCY WOULD BE PRODUCED IN THE SAME MANNER AS IN A SUPERHETERODYNE RECEIVER. THE BEAT-FREQUENCY IN THIS PRESENT CASE, HOWEVER, WILL BE EQUAL TO THE ARITHMETICAL DIFFERENCE BETWEEN 7,205 KC. AND 7,200 OR 7,205 MINUS 7,200 = 5KC. OR 5000 CYCLES PER SECOND. IN THIS INSTANCE, YOU WILL NOTE THAT THE BEAT FREQUENCY IS OF AN AUDIO FREQUENCY WHILE THE BEAT OR INTERMEDIATE FREQUENCY AS PRODUCED IN THE SAME MANNER IN AN ORDINARY SUPERHETERODYNE RECEIVER IS TOO HIGH TO BE AUDIBLE.

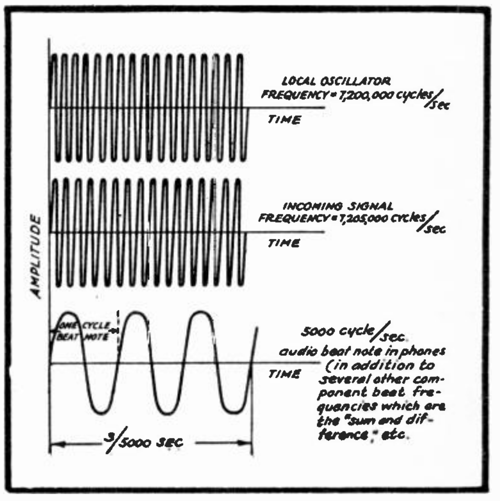

FIG. 4

Producing a Beat-Note By Means of the Heterodyne Principle.

FROM THE EXPLANATION AS SO FAR GIVEN, IT WILL BE APPARENT THAT C.W. CODE TRANSMISSION CAN BE ATTAINED IF THE SIGNAL IS USED AT THE RECEIVER IN SUCH A MANNER SO AS TO PRODUCE A BEAT NOTE OF AUDIBLE FREQUENCY.

C.W. RECEPTION WITH REGENERATIVE RECEIVER

AMATEUR RADIO OPERATORS USE REGENERATIVE RECEIVERS QUITE EXTENSIVELY FOR C.W. CODE RECEPTION, A CIRCUIT OF SUCH DESIGN BEING ILLUSTRATED IN FIG.5. TO ACCOMPLISH THIS, THE REGENERATION CONTROL OF THE RECEIVER IS ADVANCED FAR ENOUGH SO THAT THE DETECTOR CIRCUIT IS ADJUSTED TO THE POINT OF SELF-OSCILLATION. WHEN THIS IS DONE, THE FREQUENCY WHICH IS DUE TO THIS LOCAL SOURCE OF OSCILLATION WILL HETERODYNE WITH THE INCOMING SIGNAL FREQUENCY SO THAT A BEAT FREQUENCY WILL APPEAR IN THE PLATE CIRCUIT OF THE DETECTOR. FOR EXAMPLE, IF THE INCOMING SIGNAL FREQUENCY IS 3000 KC. AND THE SELF-SUSTAINED OSCILLATION IN THE DETECTOR CIRCUIT HAS A FREQUENCY OF 3001 KC., THEN THE

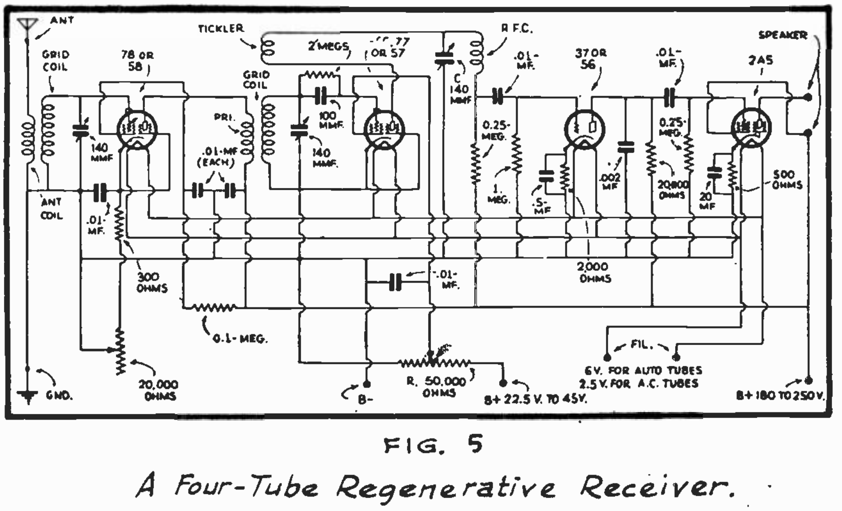

FIG. 5

A Four-Tube Regenerative Receiver.

BEAT FREQUENCY APPEARING IN THE PLATE CIRCUIT OF THE DETECTOR WILL HAVE A FREQUENCY OF 1Kc. OR 1000 CYCLES PER SECOND AND WHICH WHEN REPRODUCED BY THE HEADPHONES OR SPEAKER WILL BE AN AUDIBLE NOTE.

SINCE THE OSCILLATIONS IN THE RECEIVER ARE CONTINUOUS AND WITHOUT INTERRUPTION, WHILE THE CONTINUOUS WAVE OF THE INCOMING SIGNAL ENTERS IN THE FORM OF SUCCESSIVE TRAINS WITH INTERRUPTIONS BETWEEN THEM, THE RATE AT WHICH THE BEAT NOTE OCCURS, AS WELL AS THE LENGTH OF EACH BEAT NOTE, WILL BE DEPENDANT UPON THE TIME INTERVAL BETWEEN THE VARIOUS WAVE GROUPS WHICH ARE RADIATED BY THE TRANSMITTER AND THE LENGTH OF EACH WAVE GROUP WITH RESPECT TO TIME. THUS THE CHARACTERS OF THE CODE ARE HEARD AS THE FAMILIAR DIT-DAH SOUNDS.

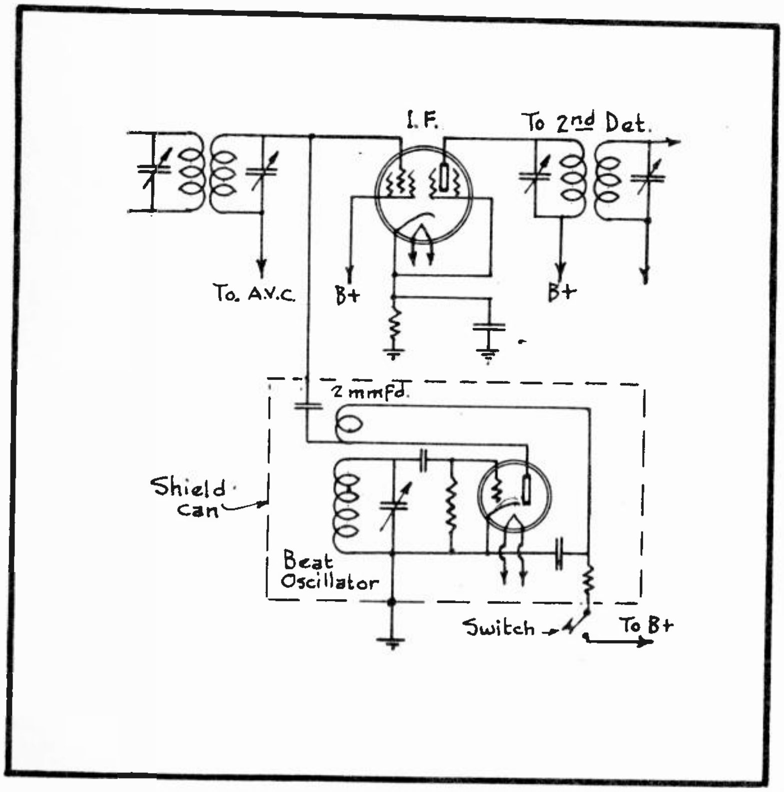

FIG. 6
Application of the Beat-Oscillator.

WHEN A DETECTOR OF A RECEIVER OPERATES BOTH AS A DETECTOR AND AN OSCILLATOR AS JUST DESCRIBED, THE METHOD IS GENERALLY REFERRED TO AS THE AUTODYNE METHOD OF BEAT RECEPTION.

THE BEAT OSCILLATOR

MOST COMMUNICATION TYPE RECEIVERS ARE OF SUPERHETERODYNE DESIGN AND SO AS TO MAKE THE RECEPTION OF C.W. CODE SIGNALS POSSIBLE IN THIS CASE, A SECOND OSCILLATOR IS INCORPORATED INTO THE RECEIVER. THIS SECOND OSCILLATOR IS THEN COUPLED TO THE CIRCUITS OF THE RECEIVER IN SOME SUCH MANNER AS ILLUSTRATED IN FIG.6. AN OSCILLATOR WHICH IS USED FOR THIS PURPOSE IS KNOWN AS A BEAT OSCILLATOR OR A C.W. OSCILLATOR.

A C.W. OSCILLATOR, AS THIS, IS CONSTRUCTED THE SAME AS A CONVENTIONAL OSCILLATOR SUCH AS USED IN SUPERHETERODYNE RECEIVERS IN ORDER TO AID IN PRODUCING THE I.F. FREQUENCY. THE C.W. OSCILLATOR DIFFERS FROM THE REGULAR OSCILLATOR OF THE SUPERHETERODYNE, HOWEVER, IN THAT ITS TUNING CIRCUIT IS DESIGNED SO THAT THE FREQUENCY AS GENERATED BY THE C.W. OSCILLATOR WILL BE FROM ONE TO TWO KILOCYCLES HIGHER OR LOWER THAN THE FREQUENCY TO WHICH THE I.F. AMPLIFIER OF THE RECEIVER IS TUNED.

BY REFERRING TO FIG.6, YOU WILL NOTE THAT THE C.W. OSCILLATOR IS FULLY SHIELDED FROM THE REST OF THE RECEIVER CIRCUITS AND ITS OUTPUT IS LOOSELY COUPLED THROUGH A 2 MMFD. CONDENSER TO THE CONTROL GRID CIRCUIT OF THE I.F. TUBE WHICH PRECEDES THE SECOND DETECTOR OF THE RECEIVER. A

SWITCH IS INCLUDED IN THE PLATE CIRCUIT OF THE BEAT OSCILLATOR SO AS TO PREVENT THIS UNIT FROM OPERATING AT ALL TIMES EXCEPT DURING THE RECEPTION OF C.W. SIGNALS.

QUITE OFTEN, THE C.W. OSCILLATOR IS COUPLED TO THE SECOND DETECTOR OF THE RECEIVER IN SOME SUCH MANNER AS ILLUSTRATED IN FIG.7.

OPERATION OF THE SYSTEM

ASSUMING THAT C.W. SIGNALS ARE BEING RECEIVED AT A FREQUENCY OF 7000 KC. WHEN USING SUCH A SYSTEM AND THE SUPERHETERODYNE IN QUESTION HAS AN INTERMEDIATE FREQUENCY OF 465 KC., THEN THE OPERATION OF THE COMPLETE SYSTEM WOULD BE AS FOLLOWS:

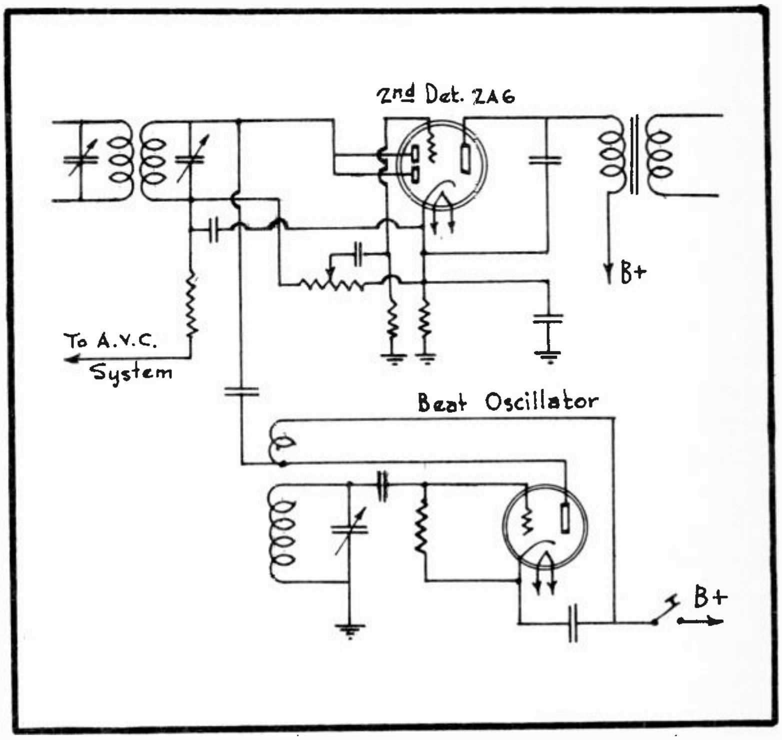

FIG. 7.
Beat Oscillator Coupled to Second Detector

THE INPUT R.F. AND FIRST DETECTOR CIRCUITS WOULD BE TUNED TO 7000 KC. THE REGULAR OSCILLATOR OF THE RECEIVER WOULD AT THE SAME TIME BE TUNED TO A FREQUENCY OF 7000 PLUS 465 OR 7,465 KC. THE RESULTING HETERODYNE ACTION PRODUCES A BEAT FREQUENCY OF 465 KC WHICH IS AMPLIFIED BY THE I.F. AMPLIFIER. ASSUMING THAT A 1000 CYCLE (1KC.) SIGNAL NOTE IS TO BE PRODUCED, THE C.W. OSCILLATOR WOULD BE TUNED TO A FREQUENCY OF 465 PLUS 1 OR 466 KC. THE RESULTING HETERODYNE ACTION BETWEEN THE 465 AND THE 466 KC. FREQUENCY WILL CAUSE A BEAT FREQUENCY OF 1 KC. OR 1,000 CYCLES TO APPEAR IN THE OUTPUT CIRCUIT OF THE TUBE AT WHOSE INPUT THE TWO FREQUENCIES ARE SIMULTANEOUSLY APPLIED. THE 1,000 CYCLE BEAT IS OF AUDIO FREQUENCY AND IS THEN FURTHER AMPLIFIED AND REPRODUCED AS THE EQUIVALENT SOUND BY THE SPEAKER OR HEADPHONES.

EVEN THOUGH THE OUTPUT OF THE C.W. OSCILLATOR BE APPLIED TO THE INPUT OF THE FINAL I.F. TUBE OF A SUPERHETERODYNE, THE FOLLOWING SINGLE I.F. TRANSFORMER IS SUFFICIENTLY BROAD TUNING SO AS TO PERMIT THE 1000 KC. SIGNAL TO PASS THROUGH SATISFACTORILY.

BESIDES MAKING C.W. CODE RECEPTION POSSIBLE, THE C.W. OSCILLATOR ALSO ASSISTS IN LOCATING THE MODULATED SIGNALS FROM DISTANT STATIONS. THIS IS ACCOMPLISHED BY THE HETERODYNING ACTION BETWEEN THE SIGNAL FREQUENCY AND THAT OF THE C.W. OSCILLATOR. THUS WITH A BEAT NOTE BEING AUD-

IBLE, IT IS AN INDICATION THAT A STATION IS BEING TUNED IN. THE C.W. OSCILLATOR CAN THEN BE SWITCHED OFF AND THE RECEIVER VERY SLOWLY AND CAREFULLY TUNED SO THAT THE STATION SIGNALS WILL COME THROUGH IN THE BEST MANNER POSSIBLE.

SINGLE-SIGNAL RECEIVERS

ANOTHER INTERESTING FEATURE WHICH YOU WILL FIND IN SOME OF THE MORE ELABORATE COMMUNICATION TYPE RECEIVERS IS A QUARTZ CRYSTAL WHICH IS INCLUDED IN THE I.F. AMPLIFIER.

ALTHOUGH IT IS TRUE THAT THE SUPERHETERODYNE TYPE OF RECEIVER AFFORDS EXCELLENT SELECTIVITY AS FAR AS THE RECEPTION OF BROADCAST PROGRAMS ARE CONCERNED, YET FOR THE RECEPTION OF C.W. CODE SIGNALS, ESPECIALLY IN THE HIGHER FREQUENCY BANDS WHICH ARE RATHER CROWDED, THE CONVENTIONAL SUPERHETERODYNE IS NOT AS SELECTIVE AS WOULD BE DESIRED.

THE CUSTOMARY I.F. AMPLIFIER OF THE AVERAGE SUPERHETERODYNE WILL PASS A BAND OF FREQUENCIES WHICH IS FROM 5 TO 10 KC. WIDE.

A VARIETY OF COMBINATIONS OF SIGNAL FREQUENCIES WITH WHICH THE R.F. OSCILLATOR OF THE RECEIVER MAY BEAT, MAY BE SUCH THAT SIGNALS VARYING BY 2 KC. ABOVE AND BELOW THE RESONANT FREQUENCY OF THE I.F. AMPLIFIER MAY FIND THEIR WAY THROUGH THE I.F. AMPLIFIER AND THEREBY CAUSE INTERFERENCE UNLESS THE I.F. AMPLIFIER BE TUNED VERY SHARP. ANY ONE OF THESE FREQUENCIES WHICH FIND THEIR WAY THROUGH THE I.F. AMPLIFIER MAY HETERODYNE WITH THE FREQUENCY GENERATED BY THE C.W. OSCILLATOR AND THEREBY CAUSE A MOST DISTURBING INTERFERENCE. TO PREVENT THIS, A QUARTZ CRYSTAL IS USED TO MAKE THE CIRCUIT VERY SHARP TUNING AND PERMIT ONLY THE DESIRED FREQUENCY TO PASS THROUGH THE I.F. AMPLIFIER

A QUARTZ CRYSTAL, YOU WILL RECALL, POSSESSESS PIEZO-ELECTRIC CHARACTERISTICS AND BECAUSE OF THIS FACT PERMITS ONLY CURRENTS TO FLOW THRU

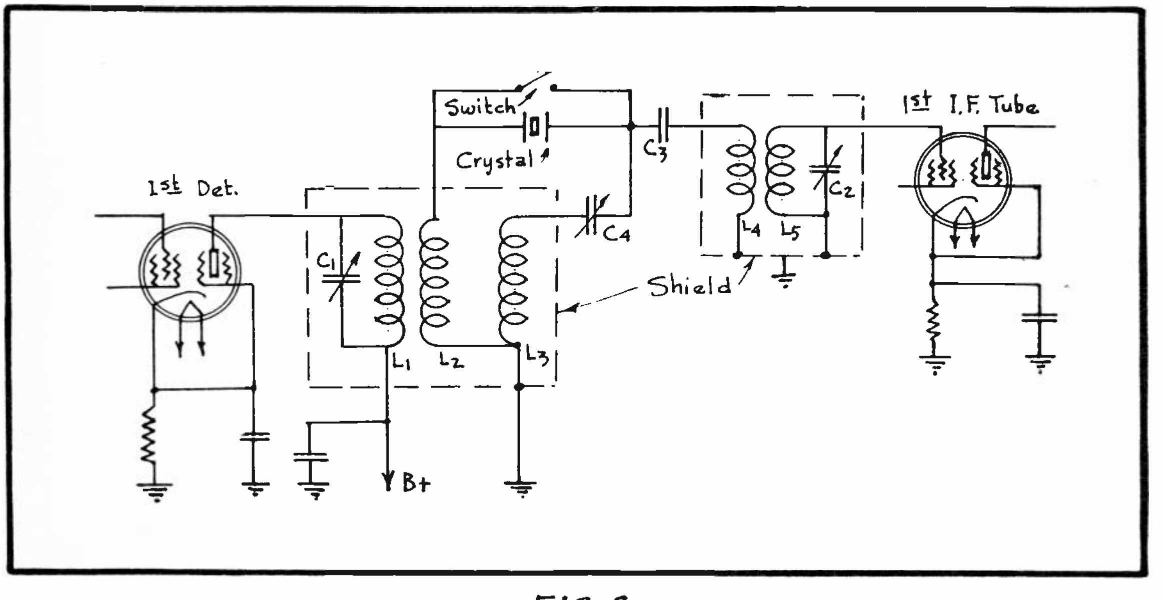

FIG. 8
Application of the Quartz Crystal I.F. Filter.

IT WHOSE FREQUENCY IS IDENTICAL TO THAT FOR WHICH THE CRYSTAL IS GROUND. THIS BEING THE CASE, IT CAN BE READILY SEEN THAT A CRYSTAL OF THIS TYPE WOULD SERVE ADMIRABLY AS A VERY SELECTIVE FILTER IN A RECEIVER CIRCUIT. WHEN USED FOR THIS PURPOSE, THE CRYSTAL IS INSTALLED IN THE RECEIVER CIRCUIT IN A MANNER SOMEWHAT AS ILLUSTRATED IN FIG.8.

IN THIS CIRCUIT, THE TUNED CIRCUIT CONSISTING OF L_1 AND C_1 IS IN REALLITY THE PRIMARY HALF OF THE FIRST I.F. TRANSFORMER, WHILE THE TUNED CIRCUIT CONSISTING OF L_5 AND C_2 IS IN REALLITY THE SECONDARY HALF OF THE FIRST I.F. TRANSFORMER. HOWEVER, INSTEAD OF THESE TWO HALVES OF THE TRANSFORMER BEING PLACED TOGETHER IN THE SAME SHIELD CAN IN THE USUAL WAY, THEY ARE PLACED IN SEPARATE SHIELD CANS AND COUPLING BETWEEN THEM IS ACCOMPLISHED THROUGH THE VARIOUS COUPLING COILS IN CONJUNCTION WITH THE CRYSTAL FILTER. THE CRYSTAL IS GROUND FOR THE FREQUENCY FOR WHICH THE I.F. AMPLIFIER IS DESIGNED.

THE SPLIT WINDINGS L_2 AND L_3 ARE INDUCTIVELY COUPLED TO L_1 AND THEREBY PROVIDE AN INPUT CIRCUIT TO THE CRYSTAL FILTER. THE OUTPUT OF THE CRYSTAL FILTER IS IN TURN COUPLED TO COIL L_5 THROUGH C_3 AND L_4.

AT RESONANCE, L_1 AND L_2, AND L_4 AND L_5 ARE MATCHED IMPEDANCES. THE PURPOSE OF COIL L_3 AND CONDENSER C_4 IS TO NEUTRALIZE THE CAPACITY OF THE CRYSTAL HOLDER PLATES.

COILS L_2 AND L_3 HAVE INDUCED IN THEM E.M.F'S WHICH ARE 180° OUT OF PHASE. THEREFORE, WHEN C_4 EQUALS THE CAPACITY OF THE CRYSTAL HOLDER PLATES, ANY CURRENTS WHICH THESE PLATES MIGHT BYPASS THROUGH THEIR CAPACITY ARE CANCELLED OUT BY CURRENTS IN OPPOSITE PHASE FED THROUGH C_4. CONSEQUENTLY, ONLY THE SIGNAL E.M.F.'S ARE PASSED BY THE CRYSTAL FREE TO REACH THE INPUT CIRCUIT OF THE I.F. AMPLIFIER.

SINCE THE CONDENSER C_4 AFFECTS THE CIRCUIT AS JUST EXPLAINED, IT

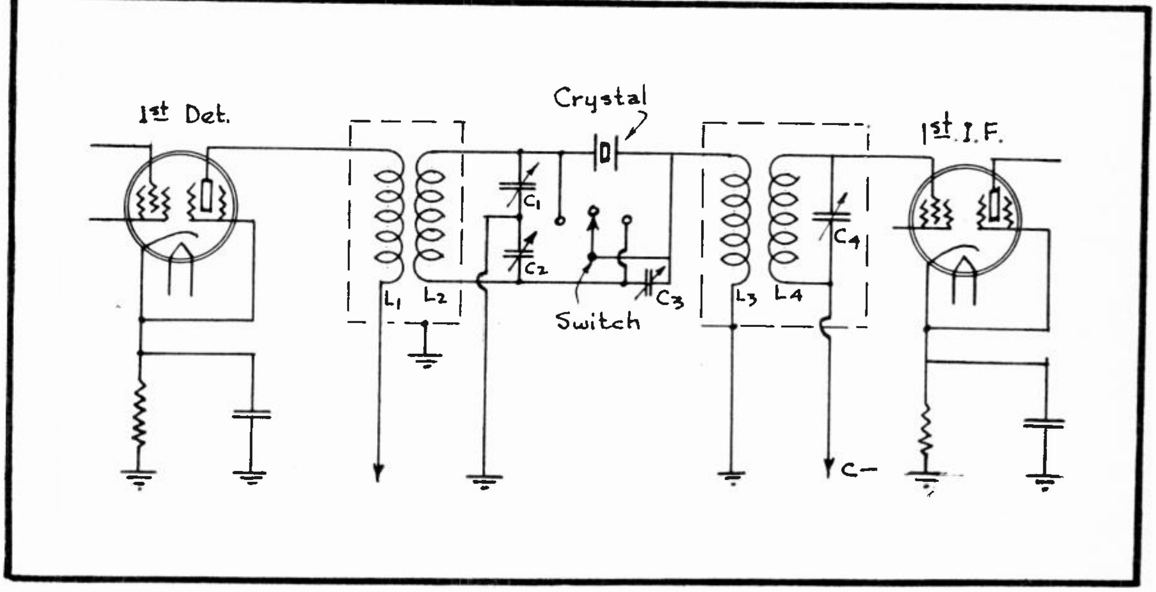

FIG. 9
Another Crystal-Filter Circuit.

CAN READILY BE SEEN THAT THE SETTING OF THIS CONDENSER GOVERNS THE SELECTIVITY OF THE CRYSTAL AND BY THIS METHOD THE BAND PASSED THROUGH THE CRYSTAL CAN BE WIDENED SLIGHTLY.

IN SUPERHETERODYNE RECEIVERS IN WHICH A CRYSTAL FILTER IS EMPLOYED, THE VOLTAGE GAIN OF AN INTERFERRING SIGNAL MAY BE REDUCED AS MUCH AS 97% WHEN THE CIRCUIT IS ADJUSTED APPROXIMATELY 1000 CYCLES OFF THE RESONANT FREQUENCY, WHEREAS IN A SUPERHETERODYNE RECEIVER NOT EQUIPPED WITH A CRYSTAL FILTER, THE INTERFERING SIGNAL MAY BE REDUCED ONLY AS MUCH AS 5% UNDER THE SAME CONDITION OF OPERATION.

THE SHARP TUNING CHARACTERISTIC OF THE CRYSTAL FILTER MAKES ITS USE DESIRABLE FOR THE RECEPTION OF C.W. CODE SIGNALS BUT THIS SAME FEATURE WHEN USED FOR THE RECEPTION OF BROADCAST PROGRAMS WILL MAKE THE FAITHFUL REPRODUCTION OF THE MUSICAL SCALE IMPOSSIBLE. BY THE ADJUSTMENT OF C_4 IN THE CIRCUIT OF FIG.8, HOWEVER, THE WIDTH OF BAND PASSED BY THE CRYSTAL FILTER CAN BE INCREASED TO THE POINT NECESSARY TO PASS THE SPEECH FREQUENCIES SATISFACTORILY. A SWITCH IS ALSO GENERALLY ALWAYS FURNISHED WHEREBY THE CRYSTAL CAN BE SHORT-CIRCUITED AT WILL AND ITS SHARP TUNING CHARACTERISTICS THEREBY BE REMOVED FROM THE CIRCUIT.

ANOTHER BASIC CRYSTAL FILTER CIRCUIT IS SHOWN IN FIG.9. HERE THE SECONDARY CIRCUIT OF THE INPUT TRANSFORMER SUPPLIES A VARIABLE PARALLEL IMPEDANCE AND IS IN SERIES WITH THE CRYSTAL. THIS VARIABLE PARALLEL IMPEDANCE EFFECTS VARIATION IN THE EFFECTIVE RESISTANCE IN THE CRYSTAL CIRCUIT, THEREBY VARYING THE SELECTIVITY IN ACCORDANCE WITH THE PRINCIPLES OF RESONANT CIRCUITS.

THE APPLIED VOLTAGE IS PROPORTIONAL TO THE PARALLEL IMPEDANCE, INCREASING AS THE EFFECTIVE RESISTANCE INCREASES, SO THAT THE EFFECTIVE SENSITIVITY OF THE RECEIVER FOR A SINGLE-FREQUENCY SIGNAL IS BUT LITTLE AFFECTED OVER A CONSIDERABLE BAND WIDTH.

MINIMUM SELECTIVITY OCCURS WITH THE PARALLEL CIRCUIT TUNED TO RESONANCE, AT WHICH TIME IT IS PURELY RESISTIVE, AND MAXIMUM SELECTIVITY OCCURS WHEN THE PARALLEL CIRCUIT IS TUNED SO AS TO BE CONSIDERABLY REACTIVE. THE CRYSTAL IS CONNECTED IN A BRIDGE CIRCUIT THROUGH AN ADJUSTABLE CONDENSER SO AS TO PROVIDE COUNTER-VOLTAGE OF CONTROLLABLE PHASE AND SO AS TO MODIFY THE RESONANCE CURVE AND SHIFT THE ANTI-RESONANT FREQUENCY OF THE CRYSTAL, THEREBY GIVING PARTICULAR REJECTION FOR AN UNWANTED SIGNAL, IN ADDITION TO THE SHARPLY PEAKED RESPONSE GIVEN FOR THE DESIRED SIGNAL.

IN THE CIRCUIT OF FIG.9 THE OUTPUT TRANSFORMER OF THE FILTER CONSISTS OF THE TUNED CIRCUIT L_4-C_4 WHICH IS CLOSELY COUPLED TO THE UNTUNED COIL L_3 THE NUMBER OF TURNS USED ON COIL L_3 ARE CONSIDERABLE LESS THAN THAT USED ON COIL L_4. THE REASON FOR THIS IS THAT THIS TURNS-RATIO AFFORDS THE PROPER IMPEDANCE MATCH BETWEEN THE CRYSTAL FILTER AND THE INPUT CIRCUIT TO THE 1ST I.F. TUBE.

NOW THAT YOU ARE FAMILIAR WITH THE OPERATION AND APPLICATION OF C.W. OSCILLATORS AND CRYSTAL FILTERS, LET US NEXT LOOK AT THE COMPLETE CIRCUIT OF COMMUNICATION OR PROFESSIONAL TYPES OF RECEIVERS WHICH MAKE USE OF THESE FEATURES.

A SEVEN–TUBE SUPERHETERODYNE

In Fig. 10 you are shown the circuit diagram of a seven-tube superheterodyne which by means of a band-switch provides the three following frequency ranges: (1) From 540 to 1700 Kc.; (2) From 1650 to 4300 Kc.; and (3) From 5.5 to 18 megacycles. In other words, this would be classified as an all-wave receiver.

The tubes used are a 78 in the tuned R.F. pre-selector stage; a 6A7 as the first detector and oscillator; a 78 as an I.F. amplifier; a 75 as a combination second detector, triode A.F. amplifier and A.V.C. tube; a 42 as the power output tube; an 80 as the rectifier; and a 78 as an electron coupled C.W. or beat oscillator.

Other interesting features of this same receiver include a switch which permits automatic volume control to be used or not at the will of the operator. A "stand-by" switch is also furnished and which when closed to the "receive position" permits normal reception, whereas when open or in the "send position", the plate supply to the R.F. section of the receiver is cut-off and thereby prevents operation of the receiver while the local transmitter is on the air but yet does not permit the filaments of the receiver's tubes to cool so that the set can come into instant use when reception is to be resumed.

A special jack is provided in the output circuit which permits the insertion of headphones in the circuit and at the same time cuts out the speaker the instant that the phones are put into use. A switch is also provided for turning "on" and "off" the beat oscillator.

The potentiometer which is included in the cathode circuit of the

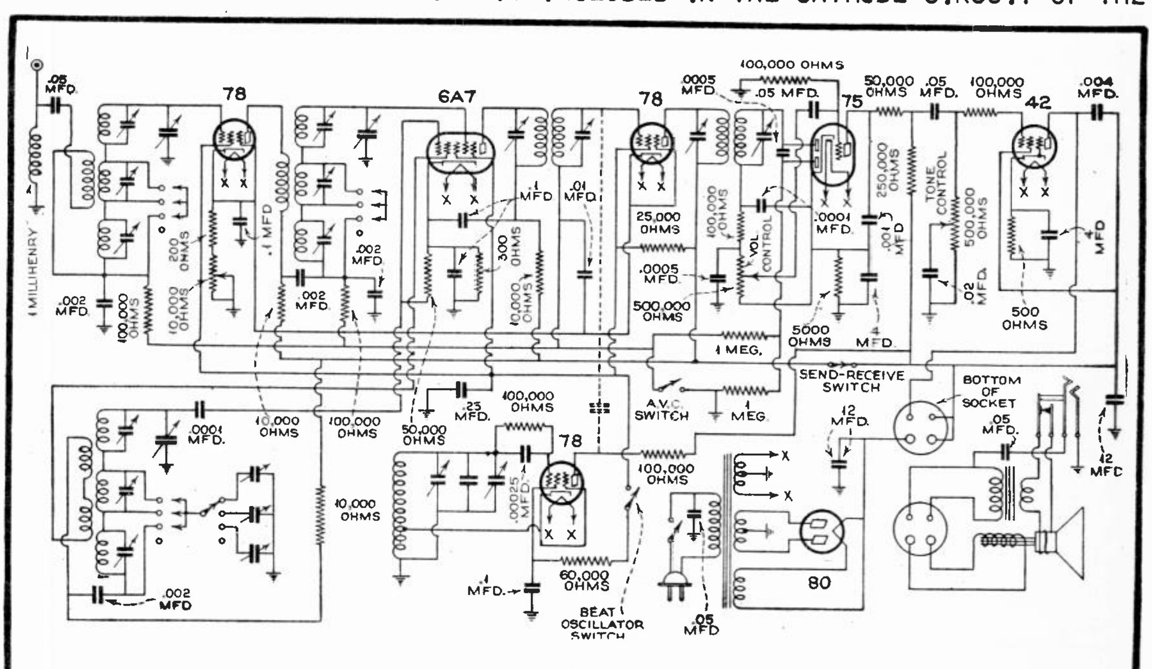

FIG. 10

A 7-Tube Professional Model Receiver.

R.F. TUBE SERVES AS A SENSITIVITY CONTROL, AND WHICH IS USED AS A VOLUME CONTROL WHEN THE A.V.C. SYSTEM IS NOT BEING USED. THE REGULAR VOLUME CONTROL IS INCORPORATED IN THE A.F. CIRCUIT OF THE 75 TUBE.

THE NATIONAL "HRO" CIRCUIT

IN FIG. 11 YOU ARE SHOWN THE COMPLETE CIRCUIT DIAGRAM OF THE NATIONAL "HRO" COMMUNICATION TYPE RECEIVER AND WHOSE PICTURE APPEARS IN FIG. 1 AND 2 OF THIS LESSON. BY STUDYING FIG. 11 CAREFULLY, YOU WILL OBSERVE THAT THIS RECEIVER EMPLOYS BOTH A C.W. OSCILLATOR AND A CRYSTAL FILTER, AS WELL AS MANY OTHER INTERESTING FEATURES.

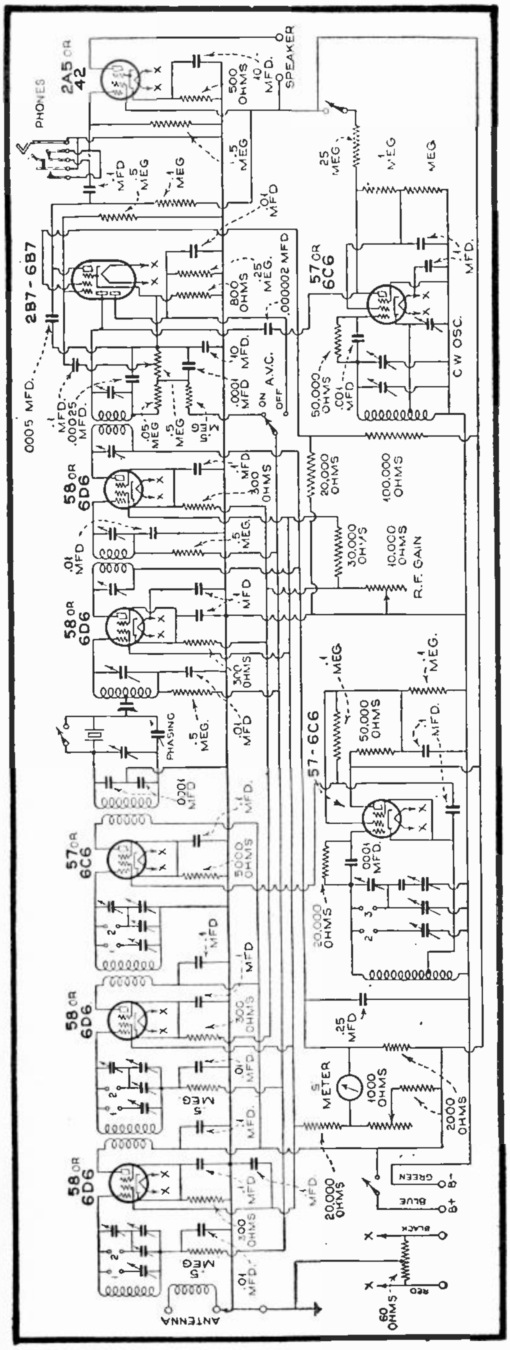

FIG. 11
Circuit Diagram of the National "HRO" Receiver.

THE POWER PACK FOR THIS RECEIVER IS AN INDEPENDENT UNIT, HOUSED SEPARATELY FROM THE RECEIVER AND IS CONNECTED TO THE RECEIVER THROUGH THE HEATER AND "B" TERMINALS WHICH APPEAR IN THE LOWER LEFT HAND CORNER OF FIG. 11.

THE SWITCH WHICH APPEARS IN THE B+ LEAD IN FIG. 11 IS A "STAND-BY" SWITCH AND SERVES THE SAME PURPOSE AS THE EQUIVALENT SWITCH IN THE CIRCUIT OF FIG. 10. A SWITCH IS ALSO HERE PROVIDED SO THAT THE A.V.C. ACTION CAN BE USED OR NOT AS DESIRED. A SENSITIVITY OR R.F. GAIN CONTROL IS SUPPLIED IN THE FORM OF A 10,000 OHM RHEOSTAT WHICH IS CONNECTED IN SERIES WITH THE CATHODE CIRCUITS OF SOME OF THE R.F. TUBES AND B-, WHILE THE REGULAR VOLUME CONTROL IS IN THE FORM OF A .5 MEG. POTENTIOMETER IN THE A.F. CIRCUIT OF THE 2B7 OR 6B7 TUBE. PROVISIONS ARE ALSO MADE FOR THE USE OF EITHER A LOUD SPEAKER OR HEADPHONES.

A SHUNTING SWITCH FOR THE CRYSTAL IS ALSO FURNISHED AND WHICH PERMITS THE CRYSTAL TO BE EXCLUDED FROM THE CIRCUIT WHEN THIS SWITCH IS CLOSED AND THUS MAKE BROADCAST RECEPTION POSSIBLE.

THE PHASING CONDENSER WHICH IS ALSO INCLUDED IN THE CRYSTAL CIRCUIT OFFERS A MEANS OF WIDENING SOMEWHAT THE FREQUENCY BAND PASSED SO THAT SPEECH CAN BE RECEIVED SATISFACTORILY EVEN WHEN THE CRYSTAL IS BEING USED.

NINE TUBES ARE USED IN THIS RECEIVER AND THEY MAY BE EITHER OF THE

2.5 OR 6.3 VOLT SERIES. TWO STAGES OF TUNED RADIO FREQUENCY AMPLIFICATION ACT AS A PRE-SELECTOR AHEAD OF THE FIRST DETECTOR.

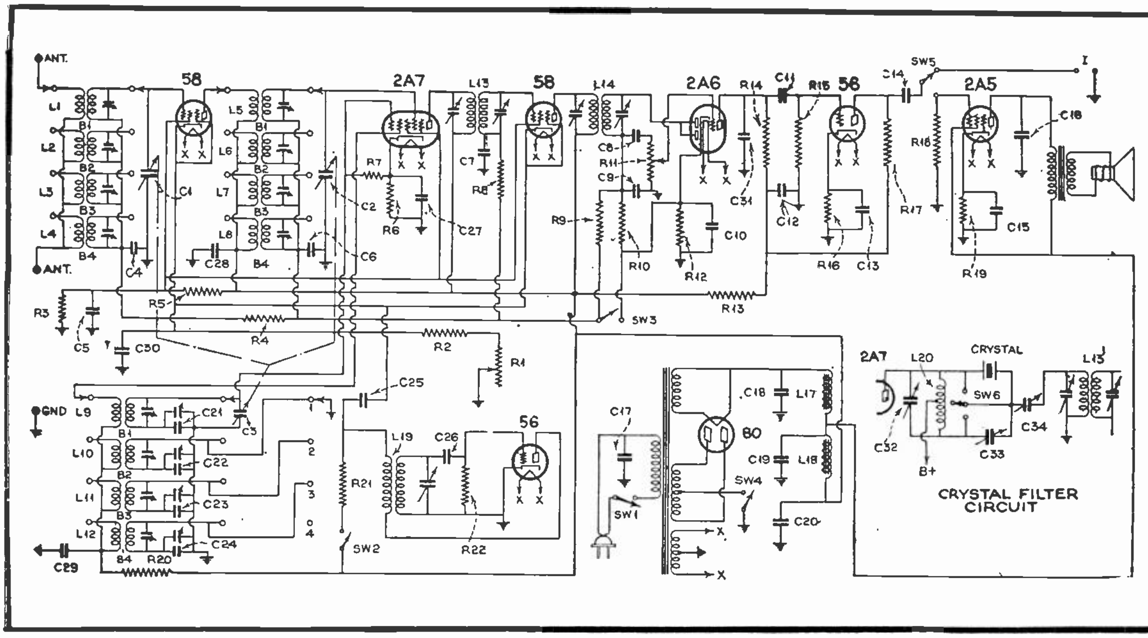

FIG. 12

An 8-Tube Communications Type Receiver.

A SET OF FOUR PLUG-IN COILS ARE USED TO AFFORD FULL BAND COVERAGE AND THEY ARE CONTAINED IN A HANDY DRAWER WHICH CAN BE WITHDRAWN FROM THE CABINET AS SHOWN IN FIG. 2 OF THIS LESSON.

THE "S" METER IS USED AS A MEANS FOR INDICATING THE STRENGTH OF THE SIGNAL WHICH IS BEING RECEIVED.

TABLE I

1—Gen-Ral Coil Kit No. 34 consisting of:
- 1—multi-wave unit—18 to 1.5 megacycles.
- 1—LCX 200D-V-M 507 kc. series wound i.f. unit, input—top grid.
- 1—LCX200D-V-M 507 kc. series wound i.f. unit, output—bottom grid.
- 1—Heterodyne Oscillator—507 kc.

1—Reliance 140 mmfd. band-spread condenser, type 2K140.

C4, C6, C7, C27—.05 mfd., 200 volt.
C5, C8, C10, C11—.01 mfd., 200 volt.
C9—.0001 mfd. mica condensers.
C12, C17—1. mfd. 400 volt.
C13—5. mfd. 25 volt.
C14, C16—.01 mfd. 400 volt.
C15—10. mfd. 25 volt.
C18, C19, C20—8 mfd. 450 volt. Screw type mounting.
C25—.1 mfd., 200 volt.
C26—.00025 mfd. mica condenser.
C28, C29—.10 mfd., 400 volt.
C30—.2 mfd., 200 volt.
C31—.001 mfd. mica condensers.

R1—25,000 ohm volume control with taper.
R2—150 ohm 1 watt carbon resistor.
R3—40,000 ohm 1 watt carbon resistor.
R4, R8, R14—250,000 ohm 1/3 watt carbon resistor.
R5—13,000 ohm 2 watt carbon resistor.
R6—200 ohm 1/3 watt carbon resistor.
R7—25,000 ohm 1/3 watt carbon resistor.
R9—1,000,000 ohm 1/3 watt carbon resistor.
R10—200,000 ohm 1/3 watt carbon resistor.
R11—500,000 ohm pot. type volume control.
R12—5,000 ohm 1/3 watt carbon resistor.
R13, R17, R21, R22—50,000 ohm 1/3 watt carbon resistor.
R15, R18—500,000 ohm 1/3 watt carbon resistor.
R16—3,000 ohm 1/3 watt carbon resistor.
R19—500 ohm 1 watt carbon resistor.
R20—20,000 ohm 1 watt carbon resistor.

AN 8-TUBE RECEIVER

IN FIG. 12 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF AN EIGHT-TUBE RECEIVER WHICH FEATURES A COIL SWITCHING ARRANGEMENT FOR COVERING THE DIFFERENT WAVE-BANDS, A TUNED R.F. INPUT USING A TYPE -58 TUBE, A 2A7 OPERATING AS THE FIRST DETECTOR AND R.F. OSCILLATOR, AND A 56 TUBE OPERATING AS THE BEAT-NOTE OSCILLATOR, FOR C.W. CODE RECEPTION.

THE CRYSTAL FILTER, WHICH IS OPTIONAL WITH THIS CIRCUIT, IS SHOWN IN THE LOWER RIGHT HAND CORNER OF THE DIAGRAM. THE ELECTRICAL VALUES FOR THE VARIOUS PARTS AS USED IN THIS CIRCUIT ARE LISTED FOR YOU IN TABLE I OF THIS LESSON.

SWITCH SW_2 OFFERS A MEANS OF CUTTING IN AND OUT THE BEAT-OSCILLATOR, SW_3 PERMITS THE USE OR REJECTION OF A.V.C.

ACTION, SW_4 IS THE STAND-BY SWITCH, SW_5 PERMITS THE USE OF HEADPHONES WHEN IN THE POSITION HERE ILLUSTRATED AND THE HEADPHONES ARE CONNECTED ACROSS THE TERMINALS AT "I".

A SPECIAL TYPE OF TUNING CONDENSER IS USED WITH THIS CIRCUIT SO AS TO OBTAIN CONTINUOUS BAND-SPREAD FEATURES. THIS CONDENSER CONSISTS OF A THREE-GANG CONDENSER HAVING A CAPACITY RATING OF 140 MMFD. PER SECTION. MOUNTED ON THIS SAME CONDENSER FRAME IS ANOTHER THREE-GANG CONDENSER OF 33 MMFD. PER SECTION AND OPERATED BY A COMMON SHAFT. THE MAIN CONDENSER CONTROL IS HANDLED IN THE USUAL WAY AND THE SMALLER CONDENSER GANG ADJUSTED FOR THE DESIRED BAND-SPREAD EFFECT.

answered March 23, 1942

Examination Questions

LESSON NO. T-15

1. – WHAT ARE SOME OF THE MORE IMPORTANT FEATURES WHICH ARE FOUND IN COMMUNICATION TYPE RECEIVERS AND WHICH ARE NOT FOUND IN THE CONVENTIONAL TYPE OF ALL-WAVE RECEIVER?

2. – EXPLAIN IN DETAIL HOW THE RECEPTION OF C.W. CODE SIGNALS MAY BE ACCOMPLISHED.

3. – HOW IS IT POSSIBLE TO RECEIVE C.W. CODE SIGNALS WITH A REGENERATIVE TYPE RECEIVER?

4. – DRAW A CIRCUIT DIAGRAM WHICH ILLUSTRATES HOW A BEAT-OSCILLATOR MAY BE APPLIED TO A SUPERHETERODYNE RECEIVER FOR THE RECEPTION OF C.W. CODE SIGNALS. EXPLAIN IN DETAIL HOW THIS SYSTEM OPERATES.

5. – DRAW A CIRCUIT DIAGRAM WHICH ILLUSTRATES THE USE OF A CRYSTAL FILTER CIRCUIT IN A SUPERHETERODYNE RECEIVER AND EXPLAIN FULLY HOW THIS SYSTEM OPERATES.

6. – DRAW A COMPLETE CIRCUIT DIAGRAM OF A COMMUNICATIONS TYPE RECEIVER AND POINT OUT THE MORE IMPORTANT FEATURES WHICH IT OFFERS.

7. – WHAT IS THE OBJECT OF INCORPORATING A "STAND-BY SWITCH" IN THE CIRCUIT OF A COMMUNICATION TYPE RECEIVER?

8. – FOR WHAT OTHER PURPOSE MAY A BEAT-OSCILLATOR BE USED OTHER THAN FOR THE RECEPTION OF C.W. CODE SIGNALS? EXPLAIN.

9. – WHAT IS THE CHIEF ADVANTAGE WHICH IS OBTAINED THROUGH THE USE OF A CRYSTAL FILTER IN A COMMUNICATION TYPE RECEIVER?

10. – WHAT WOULD BE THE DISADVANTAGE OF USING A CRYSTAL FILTER CIRCUIT IN A SUPERHETERODYNE RECEIVER OF THE BROADCAST TYPE?

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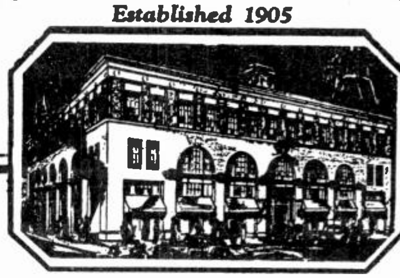

J. A. ROSENKRANZ, Pres.

Transmitters

LESSON NO. 16

TRANSMITTER DESIGN PROBLEMS.

MANY OF THE PROBLEMS WHICH ARE ASSOCIATED WITH THE DESIGN OF TRANSMITTERS ARE HANDLED IN THE SAME MANNER AS HAS ALREADY BEEN DESCRIBED TO YOU IN PREVIOUS LESSONS TREATING WITH RECEIVERS AND AMPLIFIERS. FOR EXAMPLE, THE DESIGNING OF TUNED CIRCUITS, VOLTAGE DISTRIBUTION SYSTEMS IN THE FORM OF RESISTANCE NET-WORKS, A.F. AMPLIFIERS, ETC., WOULD BE CARRIED OUT ACCORDING TO THE SAME ROUTINE OF CALCULATION REGARDLESS IF THE SYSTEM OR CIRCUIT IN QUESTION BE EMPLOYED IN A RADIO RECEIVER, A PUBLIC- ADDRESS AMPLIFIER, OR IN A TRANSMITTER. THIS BEING THE CASE, WE SHALL NOT TREAT DESIGN PROBLEMS OF THIS NATURE IN THIS LESSON.

THE FIRST TYPE OF PROBLEM WHICH WE SHALL NOW CONSIDER IS THAT OF CALCULATING THE OUTPUT IMPEDANCE OF A MODULATING AMPLIFIER.

CALCULATING OUTPUT IMPEDANCE OF MODULATING AMPLIFIER

IN FIG. 2 WE HAVE THE FUNDAMENTAL OUTPUT CIRCUIT OF A MODULATING AMPLIFIER AND WHICH YOU WILL NOTE CONSISTS OF C_1, L_1, AND R_1. WHEN THIS CIRCUIT IS TUNED TO RESONANCE WITH THE OPERATING FREQUENCY, THE INDUCTIVE AND CAPACITIVE REACTANCE IN THE CIRCUIT WILL PRACTICALLY CANCEL EACHOTHER.

WHEN SERIES RESONANCE HAS THUS BEEN ESTABLISHED, WE FIND THAT WITH RESPECT TO THE ASSOCIATED CIRCUITS, MAXIMUM IMPEDANCE WILL OCCUR IN THE PLATE CIRCUIT AND ACROSS WHICH THE SIGNAL VOLTAGE IS DEVELOPED, AND AT THE SAME TIME MINIMUM PLATE CURRENT WILL FLOW THROUGH THE TUBE.

FIG. 1 *Adjusting a Transmitter.*

UNDER THE CONDITIONS HERE DESCRIBED, THE OUTPUT IMPEDANCE OF THE CIRCUIT WITH RESPECT TO THE TUBE CAN BE DETERMINED APPROXIMATELY BY APP-

LYING THE FORMULA $Z = \frac{X_L^2}{R}$ WHERE X_L IS THE INDUCTIVE REACTANCE OF COIL L_1 AT THE FREQUENCY BEING HANDLED AND R_1 THE TOTAL RESISTANCE OF THE CIRCUIT.

FOR EXAMPLE, ASSUMING THAT THE CIRCUIT WILL NORMALLY OPERATE AT A FREQUENCY OF 1000 KC., THAT THE INDUCTANCE VALUE OF $L_1 = 160$ MICROHENRIES, THAT $R_1 = 30$ OHMS AND THAT THE TUNING CONDENSER IS SET FOR A CAPACITY OF 0.000158 MFD. WHEN TUNED TO RESONANCE, THEN THE IMPEDANCE OF THIS CIRCUIT WILL WORK OUT IN THE FOLLOWING MANNER:

$$X_L = 2\pi f L = 2 \times 3.14 \times 1{,}000{,}000 \times 0.000160 =$$
$$1004.8 \text{ OHMS (APPROXIMATELY)}$$

THEN $$Z = \frac{X_L^2}{R} = \frac{1004.8^2}{30} = \frac{1{,}009{,}623.04}{30}$$

$$Z = 33{,}654 \text{ OHMS (APPROXIMATELY)}$$

IN ORDER TO REALIZE THE MAXIMUM OF LINEAR AMPLIFICATION FROM THE MODULATING STAGE, THE OUTPUT IMPEDANCE OF THIS TUBE'S CIRCUIT AT THE FREQUENCY OF OPERATION SHOULD BE EQUAL TO THE PLATE IMPEDANCE OF THE TUBE OR SOME VALUE GREATER THAN THIS AMOUNT UP TO AS MUCH AS TWICE THE PLATE IMPEDANCE OF THE TUBE.

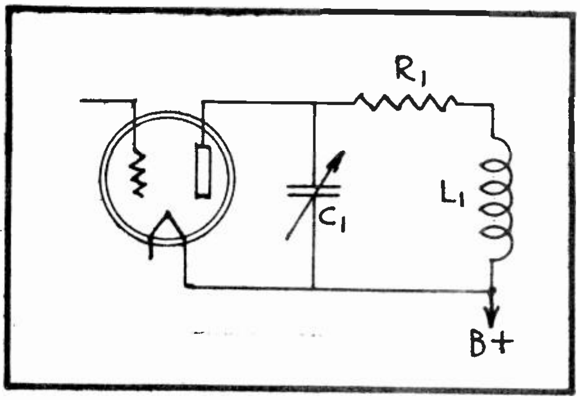

FIG. 2
The Fundamental Circuit.

AFTER WORKING OUT THE OUTPUT IMPEDANCE OF THE TUBE AS JUST EXPLAINED AND IT IS FOUND THAT THE IMPEDANCE IS TOO LOW WITH RESPECT TO THE PLATE IMPEDANCE, THEN THE OUTPUT IMPEDANCE CAN BE INCREASED AS NECESSARY BY ADDING MORE TURNS TO THE COIL, OR ELSE BY WORKING OUT THE DESIGN SO THAT THE RESISTANCE OF THE CIRCUIT IS REDUCED WITHOUT A REDUCTION IN THE INDUCTIVE REACTANCE. ON THE OTHER HAND, IF THE OUTPUT IMPEDANCE VALUE TURNS OUT TO BE TOO HIGH, THEN THE NUMBER OF TURNS ON THE COIL CAN BE REDUCED OR ELSE THE RESISTANCE OF THE CIRCUIT INCREASED. IN OTHER WORDS, THE CONSTANTS OF THE CIRCUITS CAN BE VARIED UNTIL THE PROPER COMBINATION IS ARRIVED AT SO THAT THE OUTPUT IMPEDANCE WILL PROPERLY MATCH THE PLATE IMPEDANCE OF THE TUBE FOR BEST OPERATION AT THE FREQUENCY WHICH IS TO BE HANDLED.

REFLECTED RESISTANCE

IN THE ACTUAL TRANSMITTER, THE LOAD IS NOT QUITE SO SIMPLY ARRANGED AS THAT WHICH IS ILLUSTRATED IN FIG. 2 BECAUSE THE OUTPUT CIRCUIT OF THE TUBE IS GENERALLY COUPLED TO ANOTHER CIRCUIT IN SOME SUCH MANNER AS ILLUSTRATED IN FIG.3, WHERE WE HAVE AN INDUCTIVELY COUPLED CIRCUIT.

BY STUDYING FIG.3 CLOSELY, YOU WILL OBSERVE THAT HERE WE HAVE THE PRIMARY COIL L_1 INDUCTIVELY COUPLED TO THE SECONDARY COIL L_2 AND WITH THE MUTUAL INDUCTANCE BETWEEN THEM REPRESENTED BY M. COIL L_1 IS TUNED BY CON

DENSER C_1 WHILE COIL L_2 IS TUNED BY CONDENSER C_2. IN THE SECONDARY CIRCUIT R_2 REPRESENTS THE LOAD RESISTANCE IN WHICH THE RADIO FREQUENCY POWER IS TO BE DISSIPATED.

WHEN BOTH OF THESE CIRCUITS ARE TUNED TO RESONANCE, THE ENTIRE SECONDARY CIRCUIT IN FIG. 3 MAY BE REDUCED TO THE EQUIVALENT CIRCUIT WHICH IS PICTURED IN FIG. 2 AND IN WHICH CASE, THE SECONDARY CIRCUIT WITH ITS RESISTANCE R_2 IS REPLACED BY L_1 AND AN EQUIVALENT RESISTANCE R_1. THIS PROCEDURE IS KNOWN AS "REFLECTING" THE RESISTANCE INTO THE PRIMARY CIRCUIT AND IT SIMPLIFIES CONSIDERABLY THE IMPEDANCE CALCULATIONS.

THE REASON AS TO WHY THIS LOAD RESISTANCE CAN BE REFLECTED BACK INTO THE PRIMARY CIRCUIT CAN BE EXPLAINED AS FOLLOWS: DUE TO THE ACTION OF THE TRANSFORMER, THE CURRENT WHICH FLOWS THROUGH R_2 IS OF SUCH A VALUE AS TO INDUCE BACK INTO THE PRIMARY CIRCUIT A VOLTAGE OF SUCH VALUE AND PHASE ANGLE THAT THIS REINDUCED VOLTAGE IS EQUIVALENT TO THE VOLTAGE DROP WHICH WOULD OCCUR IN A RESISTANCE OF THE PROPER VALUE IF IT WERE REALLY THERE.

THE NUMERICAL VALUE OF THE REFLECTED RESISTANCE R_1 CAN BE DETERMINED IN THE FOLLOWING MANNER: $R_1 = \frac{X_M^2}{R_2}$

WHERE X_M = THE MUTUAL REACTANCE OF THE PRIMARY AND SECONDARY OF THE TRANSFORMER AND R_2 = THE LOAD RESISTANCE.

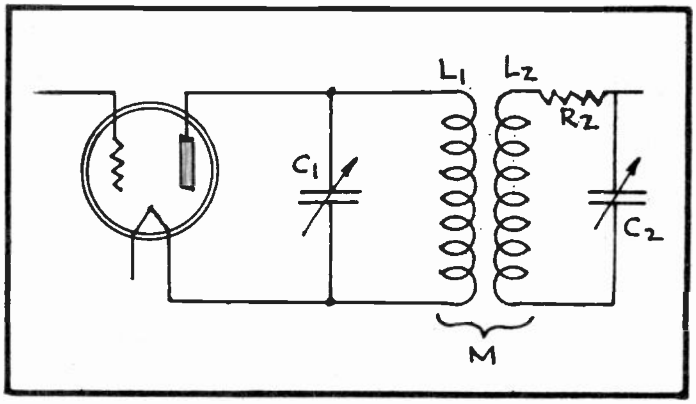

FIG. 3
Inductively Coupled Load.

IN ORDER TO CALCULATE THE IMPEDANCE OF THE EQUIVALENT CIRCUIT, THE SAME FORMULAS AND PROCEDURES ARE USED AS ALREADY EXPLAINED RELATIVE TO THE FUNDAMENTAL CIRCUIT IN FIG. 2. THE ONLY DIFFERENCE IS THAT R IN THE FORMULA $Z = \frac{X_L^2}{R}$ WILL NOW BE EQUAL TO THE REFLECTED RESISTANCE PLUS THE RESISTANCE OF COIL L_1.

DETERMINING GRID EXITATION POWER

IN ORDER TO DERIVE THE GREATEST POSSIBLE POWER OUTPUT FROM AN AMPLIFIER TUBE, IT IS NECESSARY THAT THE PROPER EXITATION BE APPLIED TO ITS GRID. IN PRACTICE, IT WORKS OUT THAT THE POWER REQUIRED TO PROPERLY OPERATE THE GRID OF AN AMPLIFIER TUBE BE APPROXIMATELY EQUAL TO ONE-TENTH THE POWER OUTPUT OF THE SAME TUBE. THAT IS TO SAY, IF THE POWER OUTPUT OF A CERTAIN TUBE IS RATED AT 100 WATTS, THEN APPROXIMATELY 10 WATTS OF POWER SHOULD BE AVAILABLE TO EXITE ITS GRID. THIS THEN MEANS THAT THE DRIVER TUBE MUST BE CAPABLE OF FURNISHING THE REQUIRED 10 WATTS OF POWER TO THE GRID CIRCUIT OF THE TUBE WHICH IT IS DRIVING AND THE TYPE OF DRIVER TUBE AND ITS OPERATION IN THE CIRCUIT MUST THEREFORE BE SELECTED ACCORDINGLY.

DETERMINING GRID EXITATION VOLTAGE

A PRACTICAL METHOD OF DETERMINING THE GRID EXITATION AVAILABLE IS

ILLUSTRATED FOR YOU IN FIG.4. HERE TWO RADIO-FREQUENCY AMMETERS ARE CONNECTED IN THE CIRCUIT AS SHOWN. WHEN THESE TWO METERS INDICATE INDENTICAL VALUES, THEN THE GRID EXITATION VOLTAGE AVAILABLE (E_G) IS DETERMINED WITH THE AID OF THE FOLLOWING FORMULA : $E_G = IX_L$.

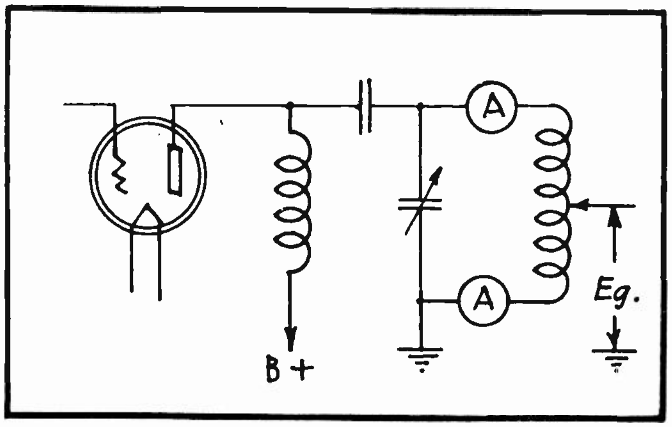

FIG. 4
Determining Grid Exitation Voltage.

IN THE EVENT THAT THE CIRCUIT ARRANGEMENT IS SUCH AS SHOWN IN FIG.5 AND IN WHICH THE GRID EXITATION VOLTAGE IS EQUAL TO THE VOLTAGE DEVELOPED ACROSS THE CONDENSER C_2, THEN WITH THE RADIO-FREQUENCY AMMETER INSTALLED IN THE CIRCUIT AS SHOWN AND THE CIRCUIT TUNED TO RESONANCE, THE GRID EXITATION VOLTAGE WILL BE FOUND FROM THE RELATION $E_G = IX_C$ WHERE I = THE CURRENT INDICATED BY THE METER AND X_C = THE CAPACITIVE REACTANCE OF CONDENSER C_2 AT THE RESONANT FREQUENCY.

APPLICATION OF GRAPHS

THE STATIC AND DYNAMIC CHARACTERISTICS OF A VACUUM TUBE CAN ALSO BE USED TO GOOD ADVANTAGE IN WORKING OUT THE DESIGN OF A TRANSMITTER'S AMPLIFIER WITH RESPECT TO THE GRID EXITATION. THIS METHOD SHALL NOW BE EXPLAINED AS IT WOULD BE APPLIED TO THE CIRCUIT WHICH IS ILLUSTRATED IN FIG. 6.

THIS PARTICULAR CIRCUIT IS A BALANCED PUSH-PULL LINEAR AMPLIFIER AND THE POWER TUBES WHICH ARE USED ARE A PAIR OF WESTERN ELECTRIC TYPE W.E. 279A AND EACH OF WHICH HAS A RATED POWER OUTPUT OF 1 KW. (1000 WATTS). ALTHOUGH THE RATING OF THESE PARTICULAR TUBES IS 1KW YET THEY ARE CAPABLE OF HANDLING A PEAK LOAD OF 2 KW. WITHOUT OVERLOADING.

WHEN ARRANGED IN A BALANCED PUSH-PULL CIRCUIT AS HERE ILLUSTRATED, EACH TUBE WILL HANDLE ONE-HALF OF THE TOTAL POWER OUTPUT. IN OTHER WORDS, IF THE CIRCUIT CONSTANTS AND DESIGN ARE SUCH THAT 1000 WATTS IS TO BE HANDLED BY THE POWER STAGE, THEN EACH OF THESE TUBES WILL DISSIPATE APPROXIMATELY 500 WATTS IN

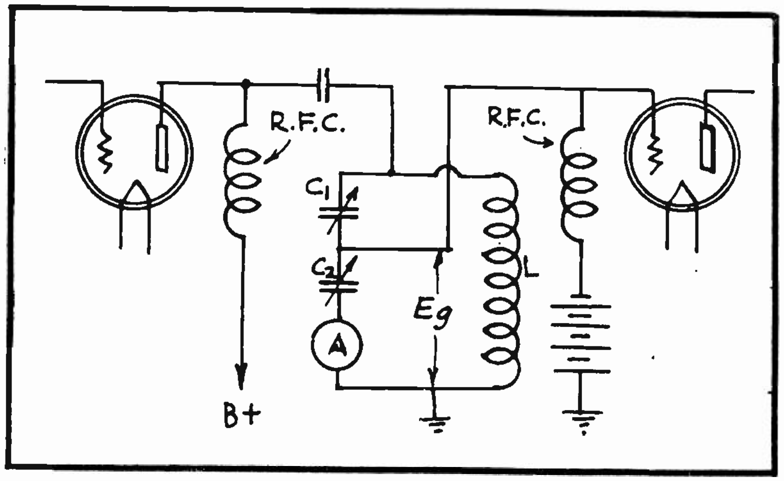

FIG. 5
Another Method of Determining Grid Exitation Voltage.

THIS CIRCUIT, THAT IS TO SAY, 1000 WATTS OF CARRIER OR UNMODULATED POWER. HOWEVER, AT 100 PER CENT MODULATION, THE MODULATED PEAK POWER WILL BE FOUR TIMES THE CARRIER POWER OR 4 X 1000 = 4000 WATTS AND FOR THIS REASON IT IS NECESSARY THAT THESE TUBES BE CAPABLE OF HANDLING THESE SWINGS WITHOUT OVERLOADING. THIS THEY ARE CAPABLE OF DOING ACCORDING TO THE MANUFACTURER'S SPECIFICATIONS.

THE NEXT STEP WILL BE TO REFER TO THE STATIC CHARACTERISTIC CURVE OF THE WE.279A TUBE WHICH APPEARS IN FIG.7. THIS YOU WILL RECOGNIZE AS BEING THE PLATE CURRENT-GRID VOLTAGE CURVE WHEN OPERATING AT ITS NORMAL PLATE POTENTIAL OF 3,000 VOLTS AND A GRID BIAS OF 275 VOLTS ACCORDING TO THE MANUFACTURER'S SPECIFICATIONS.

THE DYNAMIC CHARACTERISTIC CURVES OF TWO W.E. 279A TUBES WHEN OPERATING IN PUSH-PULL IS SHOWN YOU IN FIG.8. THE CHARACTERISTICS OF THE

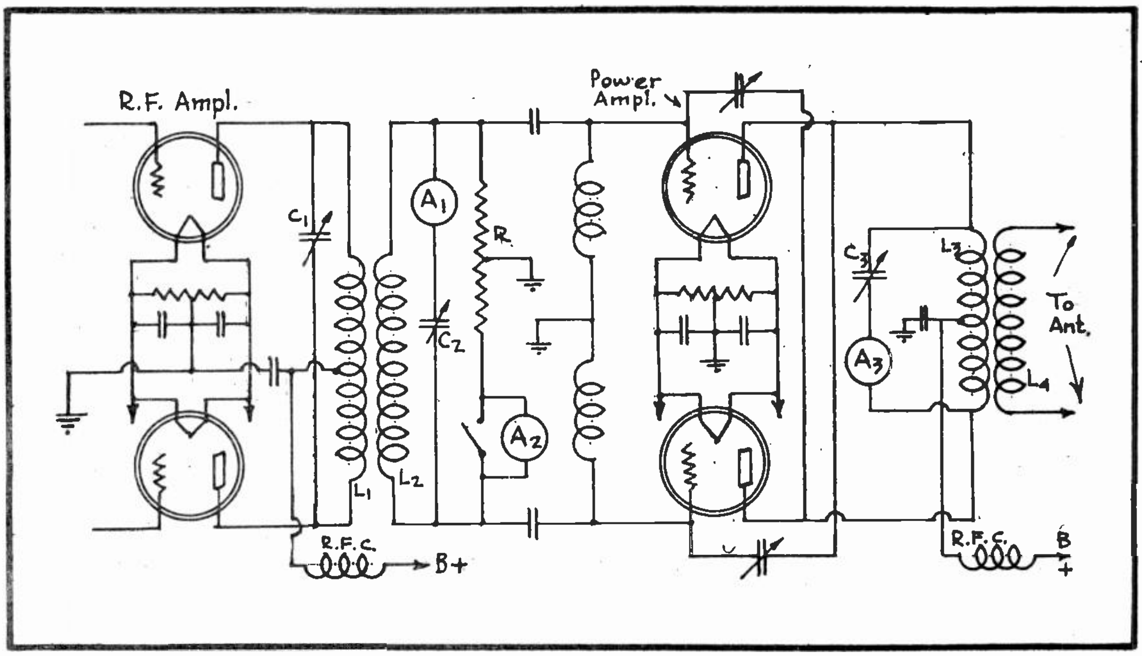

FIG. 6
A Push-Pull Linear Amplifier.

TUBES ARE HERE ILLUSTRATED WHEN OPERATING INTO A LOAD IMPEDANCE OF APPROXIMATELY 3,500 OHMS.

THE UPPER DOTTED CURVE IN THE GRAPH OF FIG.8 REPRESENTS THE APPROXIMATE EFFICIENCY OF THE TUBES WITH RELATION TO THE EXITATION VOLTAGE AND THE LOWER DOTTED CURVE REPRESENTS THE VALUE OF THE TANK POWER IN THE LOAD CIRCUIT C_3 L_3 OF FIG.6.

BY APPLYING A NEGATIVE GRID BIAS OF APPROXIMATELY 275 VOLTS AND A PLATE POTENTIAL OF SLIGHTLY OVER 3000 VOLTS TO THESE TUBES, WE FIND THAT THE TUBES WILL BE BIASED ALMOST TO THE POINT OF PLATE CURRENT CUT-OFF (CLASS B) AND IN THE PLATE LOAD CIRCUIT WILL APPEAR A POWER OUTPUT EQUAL TO THE SQUARE OF THE INPUT GRID VOLTAGE.

IF 100% MODULATION IS USED, THEN THE PEAK OUTPUT WILL BE FOUR TIMES

GREATER THAN THE UNMODULATED CARRIER POWER.

AS WAS STATED PREVIOUSLY, EACH OF THESE POWER TUBES IS EXPECTED TO DELIVER AN UNMODULATED CARRIER OUTPUT OF 500 WATTS OR 1000 WATTS FOR THE TWO TUBES TOGETHER. FOR THIS REASON THE GRID EXITATION POWER MUST BE APPROXIMATELY 1/10 OF THE OUTPUT POWER OR 50 WATTS PER TUBE AND 100 WATTS ACROSS THE GRIDS OF BOTH TUBES. THIS TOTAL GRID EXITATION OF 100 WATTS MUST BE DISSIPATED BY RESISTOR R OF THE CIRCUIT IN FIG.6.

SINCE THE POWER TUBES OF THIS SAME CIRCUIT ARE BIASED AT 275 VOLTS, A GRID EXITATION VOLTAGE OF APPROXIMATELY 265 VOLTS MUST BE APPLIED TO EACH OF THEM IN ORDER TO REALIZE THEIR FULL RATED OUTPUT. THIS MEANS A TOTAL EXITATION VOLTAGE OF 2 TIMES 265 OR 530 VOLTS FOR THE TWO TUBES AND WHICH MUST BE DEVELOPED ACROSS THE EXTREMITIES OF RESISTOR R.

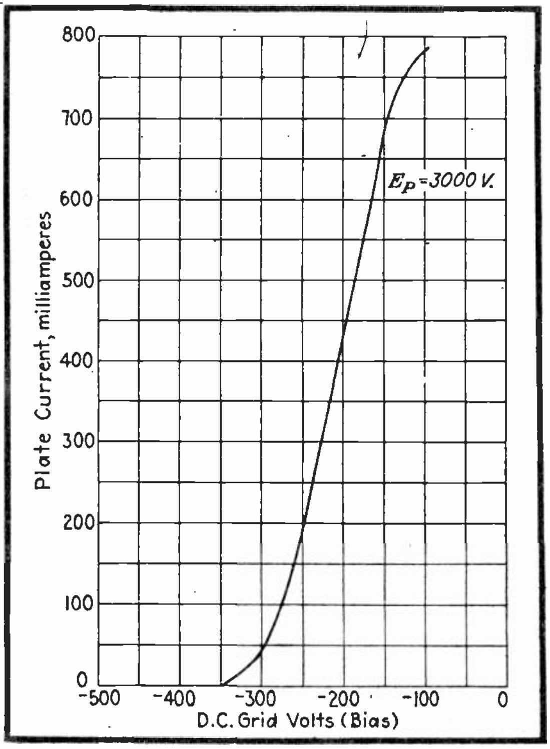

FIG.7
Static Characteristic Curve of the W. E. 279 A.

ASSUMING THAT THE TOTAL RESISTANCE OF R IS 2400 OHMS, WE CAN DETERMINE THE WATTAGE WHICH IS DISSIPATED ACROSS IT BY INSERTING A RADIO-FREQUENCY AMMETER IN SERIES WITH IT AS INDICATED BY A_2 IN FIG.6. THE RADIO-FREQUENCY DRIVE OR INPUT TO THIS CIRCUIT IS THEN VARIED UNTIL THE AMMETER A_2 OFFERS A READING WHICH WHEN SQUARED AND MULTIPLIED BY THE RESISTANCE OF R OR 2400 OHMS WILL BE EQUAL TO APPROXIMATELY 100 WATTS. FOR EXAMPLE, WHEN THIS AMMETER OFFERS A READING OF 0.21 AMP., THEN $I^2R = 0.21 \times 0.21 \times 2400 = 105.84$ WATTS. THEREFORE, WHEN AMMETER A_2 READS 0.21 AMP. THE PROPER GRID EXITATION EXISTS. THE CORRESPONDING GRID EXITATION VOLTAGE IN THIS CASE WILL BE $E = I \times R = 0.21 \times 2400 = 504$ VOLTS, AND WHICH CHECKS CLOSE ENOUGH TO OUR DESIRED VALUES FOR PRACTICAL PURPOSES.

IT IS TO BE UNDERSTOOD THAT THE VARIOUS VALUES AS SO FAR DETERMINED WILL NOT MAKE SATISFACTORY OPERATION POSSIBLE, UNLESS THE LOAD IMPEDANCE C_3 L_3 IN FIG.6 BE OF THE CORRECT IMPEDANCE TO MATCH THE OUTPUT TUBES. IN OTHER WORDS, THE GRAPHS AND DATA WHICH WE HAVE USED IN MAKING THE CALCULATIONS FOR THE CIRCUIT OF FIG.6, HAVE ASSUMED L_3 C_3 AS PROVIDING A LOAD IMPEDANCE OF APPROXIMATELY 14,000 OHMS (4 TIMES 3500 = 14,000) AT THE OPERATING FREQUENCY OF 1000 KC.

SHOULD THIS CIRCUIT BE OPERATED WITH TOO LOW A LOAD IMPEDANCE, THEN THE EXCESSIVE POWER WHICH IS DEVELOPED WILL BE DISSIPATED IN THE TUBE RATHER THAN IN THE LOAD AND THEREBY CAUSE THE TUBE TO OVERHEAT AS WELL AS TO BECOME OVERLOADED. AT THE SAME TIME, THE LOW-LOAD IMPEDANCE MAY CAUSE THE MODULATION PERCENTAGE TO BECOME TOO HIGH AND THUS CAUSE AUDIO-FREQUENCY DISTORTION.

ON THE OTHER HAND, IF THE LOAD IMPEDANCE IS TOO HIGH THEN THE INSUFFICIENT POWER WHICH WILL BE DEVELOPED ACROSS IT WILL CAUSE THE MODULATION PERCENTAGE TO BE TOO LOW.

CALCULATING LOAD IMPEDANCE FOR POWER AMPLIFIERS

ALTHOUGH FOR GENERAL CONDITIONS, THE LOAD IMPEDANCE FOR POWER AMPLIFIERS IS SET AT A VALUE EQUAL TO TWICE THE PLATE IMPEDANCE OF THE TUBE AT THE FREQUENCY BEING HANDLED, YET THIS FACTOR CAN BE DETERMINED WITH STILL GREATER ACCURACY BY APPLYING THE CALCULATIONS AS WILL NOW BE EXPLAINED.

IN FIG. 9, FOR INSTANCE, YOU ARE SHOWN A FAMILY OF CHARACTERISTIC CURVES FOR THE TYPE -10 TUBE, EACH FOR A DIFFERENT GRID BIAS VALUE. THE NORMAL BIAS VOLTAGE FOR THIS TUBE IS -30 VOLTS. THE PROPER GRID SWING FOR THIS TUBE WILL THEN BE PLUS OR MINUS 30 VOLTS WITH RESPECT TO THE NORMAL BIAS OR A TOTAL GRID SWING OF TWICE THE BIAS VOLTAGE OF 30 OR 60 VOLTS.

THE EXTENT OF THE PLATE VOLTAGE SWING AS EXPERIENCED IN THIS CASE CAN BE DETERMINED BY DRAWING A STRAIGHT LINE THROUGH THE NORMAL OPERATING POINT IN THE GRAPH OF FIG. 9 AND EXTENDING THIS LINE SO THAT IT WILL INTERSECT THE CURVE E_c = 0V AT SOME ARBITRARY POINT. THIS SAME LINE IS ALSO EXTENDED TO THE CURVE E_c = -60V. VERTICAL LINES ARE THEN RULED THROUGH THESE POINTS OF INTERSECTION ON THE E_c = 0V AND THE E_c = -60V. CURVES. UPON DOING THIS, IT WILL BE NOTED THAT THESE POINTS CORRESPOND TO PLATE VOLTAGES (E_p) OF 230 AND 548 VOLTS RESPECTIVELY. THESE SAME POINTS ALSO CORRESPOND TO PLATE CURRENT VALUES OF 36 MA. AND 6 MA. RESPECTIVELY.

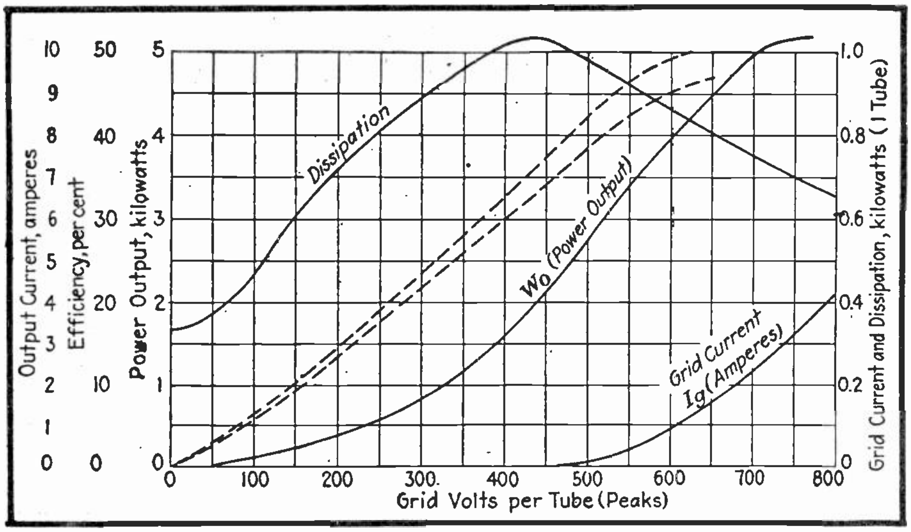

FIG. 8
Dynamic Characteristic Curves of Two W.E. 279A Tubes Operating in Push-Pull.

BY THUS KNOWING THE TOTAL PLATE VOLTAGE SWING E_s AS BEING 548 MINUS 230 OR 318 VOLTS, THE MAXIMUM PLATE CURRENT AS BEING 36 MA. AND THE MINIMUM PLATE CURRENT AS BEING 6 MA., THEN LOAD IMPEDANCE MAY BE CALCULATED BY APPLYING THE FORMULA: $Z_o = \frac{E_s}{I_{P\,MAX} - I_{P\,MIN}}$ WHERE E_s = TOTAL PLATE VOLTAGE SWING; I_{PMAX} = MAXIMUM PLATE CURRENT EXPRESSED IN AMPERES AND I_{PMIN} = MINIMUM PLATE CURRENT EXPRESSED IN AMPERES.

BY SUBSTITUTING INTO THIS FORMULA THE VALUES WHICH WE HAVE SO FAR determined, we have $Z_o = \dfrac{318}{0.036 - 0.006} = \dfrac{318}{0.030} = 10,600$ ohms.

Notice particulary in this case that the load impedance when worked out in this manner checks favorably with the load impedance when assuming the load impedance to be equal to twice the plate impedance of the tubes. That is to say, the type -10 tube at a plate voltage of 400 volts and a grid bias of -30 volts has a plate impedance of approximately 5000 ohms and twice 5000 ohms = 10,000 ohms as the recommended load impedance.

Having determined the load impedance as just explained, we can also proceed to determine the power output of the same tube under these same conditions of operation by applying the formula: Po in watts = $\dfrac{(E_{MAX} - E_{MIN}) \times (I_{MAX} - I_{MIN})}{8}$. Whence Po = $\dfrac{(548-230) \times (0.036-0.006)}{8}$ = 1.192 watts.

The percent distortion can also be determined from the facts which are now available by applying the formula:

$$\text{\% Distortion (2nd Harmonic.)} = \frac{\frac{1}{2}(I_{MAX.} + I_{MIN.}) - I_{NORMAL}}{I_{MAX} - I_{MIN}} \times 100$$

Thus in our particular example, distortion = $\dfrac{\frac{1}{2}(0.036+0.006)-0.018}{0.036-0.006} \times 100 = \dfrac{\frac{1}{2}(0.042)-0.018}{0.03} \times 100 = \dfrac{0.021-0.018}{0.03} \times 100 = \dfrac{0.003}{0.03} \times 100 = 10\%$.

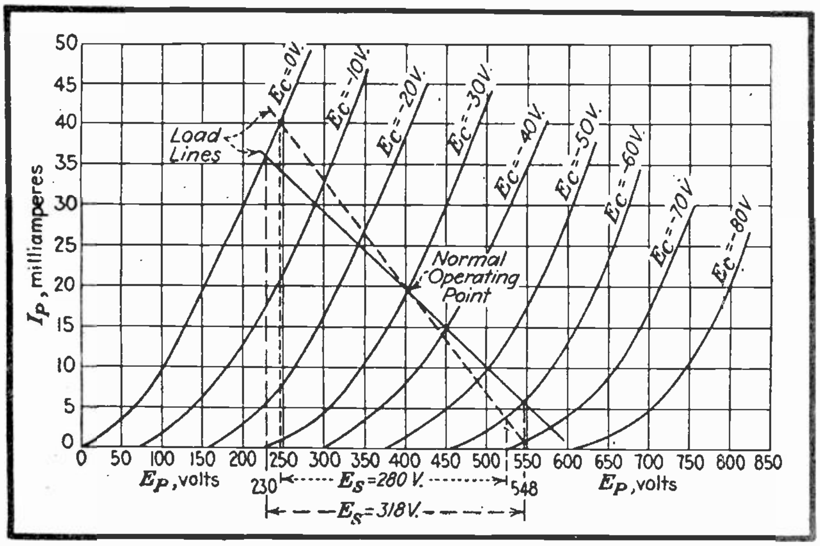

FIG. 9
Load-line Impedance Determination.

Now let us see what would happen if our arbitrary load line in Fig. 9 should have occupied another position, such as indicated by the dotted line, for example. The points where this dotted line intersects the Ec=0V and the Ec=-60V. curves corresponds respectively to the following plate voltage and current values: 525 Volts at 4 ma.; and 245 Volts at 41 ma.

Upon calculating the load impedance in this case, we have:

$$Z_o = \frac{E_s}{I_{PMAX} - I_{PMIN}} = \frac{525-245}{0.041-0.004} = \frac{280}{0.037} = 7,600 \text{ ohms.}$$

Determining the power from Po = $\dfrac{(E_{MAX}-E_{MIN}) \times (I_{MAX}-I_{MIN})}{8} = \dfrac{(525-245) \times (0.041-0.004)}{8}$

= 1.3 WATTS (APPROX.)

$$\text{SECOND HARMONIC DISTORTION} = \frac{\frac{1}{2}(I_{MAX} + I_{MIN.}) - I_{NORMAL}}{I_{MAX} - I_{MIN.}} \times 100 =$$

$$\frac{\frac{1}{2}(0.041 + 0.004) - 0.018}{0.041 - 0.004} \times 100 = \frac{0.0045}{0.037} \times 100 = 12\% \text{ APPROX.}$$

BY COMPARING THESE TWO LOAD LINES IN FIG. 9 TOGETHER WITH THEIR CORRESPONDING CALCULATIONS WE NOTE THAT WITH THE DOTTED LINE, THE POWER OUTPUT IS SOMEWHAT GREATER AS IS ALSO THE PERCENTAGE OF HARMONIC DISTORTION. UPON DRAWING A NUMBER OF LOAD LINES ON THE GRAPH OF FIG. 9 AND WORKING OUT THE CALCULATIONS AS JUST EXPLAINED THE MOST DESIRED COMBINATION BETWEEN THE LOAD IMPEDANCE AND PERCENTAGE OF SECOND HARMONIC DISTORTION CAN BE ARRIVED AT.

THIS METHOD OF CALCULATING THE PROPER LOAD IMPEDANCE CAN BE APPLIED TO SOLVE PROBLEMS OF THIS NATURE IN ALL TYPES OF AUDIO, RADIO-FREQUENCY, OR POWER-AMPLIFIER SYSTEMS.

DETERMINING OPERATING CONDITIONS FOR PLATE MODULATION

IN FIG. 10 YOU ARE SHOWN THE SKELETON DIAGRAM OF A CLASS-A MODULATOR "CHOKE-COUPLED" TO THE PLATE CIRCUIT OF A CLASS C AMPLIFIER ACCORDING TO THE HEISING SYSTEM OF MODULATION.

IN ORDER THAT 100 % MODULATION MAY BE OBTAINED IN THIS CASE, THE CLASS C AMPLIFIER'S D.C. INPUT POWER SHOULD BE TWICE THE MODULATOR'S RATED MAXIMUM UNDISTORTED POWER OUTPUT. THIS D.C. INPUT IS EQUAL TO THE CLASS C AMPLIFIER'S MEAN (AVERAGE) D. C. PLATE VOLTAGE AND PLATE CURRENT. IT IS ALSO TRUE THAT THE MEAN PLATE VOLTAGE DIVIDED BY THE PLATE CURRENT WILL RESULT IN THE MODULATING IMPEDANCE AND WHICH IN THIS CASE SHOULD EQUAL THE MODULATOR'S RATED LOAD IMPEDANCE.

THE FOLLOWING RELATIONS ALSO APPLY IN CIRCUITS OF THIS TYPE: $I_B = \sqrt{\frac{P_O}{R_P}}$ AND $E_B = \frac{P_O}{I_B}$ WHERE I_B = MEAN D.C. CURRENT TO R.F. AMPLIFIER PLATE EXPRESSED IN AMPERES; P_O = UNMODULATED D.C. POWER INPUT TO R.F. STAGE AND WHICH IS EQUAL TO TWICE THE MODULATOR POWER OUTPUT EXPRESSED IN WATTS; R_P = OPTIMUM LOAD RESISTANCE FOR MODULATOR EXPRESSED IN OHMS AND E_B=MEAN

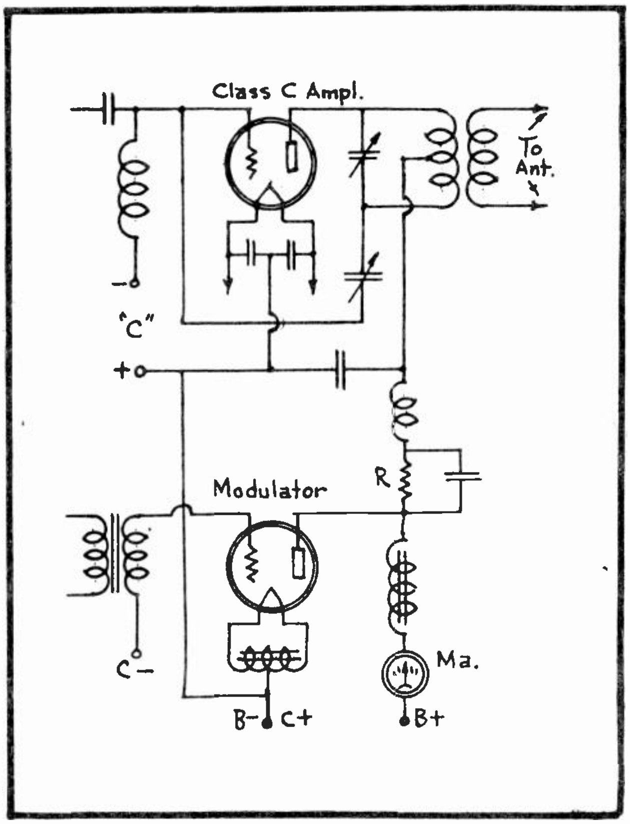

FIG. 10
The Modulation Circuit.

D.C. PLATE VOLTAGE OF R.F. AMPLIFIER.

AS A PRACTICAL EXAMPLE, LET US CONSIDER A TYPE 845 TUBE OPERATING AS A CLASS A MODULATOR WITH A PLATE SUPPLY OF 1000 VOLTS AT 75 MA. WE SHALL FURTHER ASSUME THAT THE POWER OUTPUT OF THIS TUBE IS 23 WATTS FOR A LOAD RESISTANCE OF 7500 OHMS. THE MEAN PLATE CURRENT FOR THE CLASS C R.F. AMPLIFIER IS THEN DETERMINED AS FOLLOWS:

$I_B = \sqrt{\frac{Po}{R_p}} = \sqrt{\frac{2 \times 23}{7500}} = 0.078$ AMP. = 78 MA. THE MEAN D.C. PLATE VOLTAGE FOR THE CLASS C AMPLIFIER IS SOLVED AS: $E_B = \frac{Po}{I_B} = \frac{2 \times 23}{0.078} = 590$ VOLTS.

THE PLATE VOLTAGE DROP FOR THE CLASS C AMPLIFIER IS THEREFORE 1000 MINUS 590 = 410 VOLTS AND WHICH MUST BE DEVELOPED ACROSS RESISTOR R IN FIG. 10. THE VALUE OF RESISTOR R IS DETERMINED BY APPLYING OHM'S LAW IN THE FORM $R = \frac{E}{I} = \frac{410}{0.078} = 5256$ OHMS. THE WATTAGE WHICH THIS SAME RESISTOR MUST DISSIPATE IS EQUAL TO E x I = 410 X 0.078 = 32 WATTS. AS A MATTER OF SAFETY, THE RESISTOR USED SHOULD NOT BE RATED AT LESS THAN 50 WATTS.

FROM THESE CALCULATIONS, IT HAS BEEN DETERMINED THAT THE CLASS C AMPLIFIER TUBE SHOULD BE SELECTED FROM THE STANDPOINT OF BEING CAPABLE OF OPERATING SATISFACTORILY WITH A PLATE INPUT OF APPROXIMATELY 78 MA. AT APPROXIMATELY 590 OR 600 VOLTS.

IN THE EVENT THAT TRANSFORMER COUPLING IS USED BETWEEN THE MODULATOR AND THE CLASS C AMPLIFIER, THEN THE TURNS RATIO OF THE MODULATION TRANSFORMER MUST BE CALCULATED SO AS TO MATCH THE MODULATING IMPEDANCE OF THE CLASS C AMPLIFIER TO THE REQUIRED LOAD IMPEDANCE OF THE MODULATOR. THIS IS ACCOMPLISHED IN THE FOLLOWING MANNER:

A CERTAIN CLASS B MODULATOR HAS A POWER OUTPUT OF 100 WATTS WITH 1000 VOLTS APPLIED TO THE PLATES OF THE TWO TUBES AND OPERATES INTO A SUITABLE LOAD IMPEDANCE OF 14,000 OHMS. TWO SIMILAR TUBES ARE USED IN THE CLASS C AMPLIFIER, ALSO BEING OPERATED AT A PLATE VOLTAGE OF 1000 VOLTS AND WITH AN AVERAGE D.C. POWER INPUT OF TWICE THE MODULATOR'S RATED MAXIMUM OUTPUT OR 2 x 100 = 200 WATTS.

THE PLATE CURRENT FOR THE CLASS C AMPLIFIER IS THEN SOLVED FOR IN THE FOLLOWING MANNER:

$$I_B = \frac{Po}{E_B} = \frac{2 \times 100}{1000} = 0.2 \text{ AMP.} = 200 \text{ MA.}$$

THE MODULATING IMPEDANCE OF THE CLASS C AMPLIFIER IS $Z_M = \frac{E_B}{I_B} = \frac{1000}{0.2} = 5000$ OHMS.

THIS MEANS THAT THE MODULATION TRANSFORMER MUST PROPERLY MATCH THE MODULATOR'S LOAD IMPEDANCE OF 14,000 OHMS TO THE CLASS C AMPLIFIER'S MODULATING IMPEDANCE OF 5000 OHMS. THE CORRESPONDING TRANSFORMER TURNS RATIO WILL BE EQUAL TO THE SQUARE ROOT OF THE PRIMARY-SECONDARY IMPEDANCE RATIO

Or turns ratio $= \sqrt{\frac{14,000}{5000}} = \sqrt{2.8} = 1.6$ to 1 or 1 to 0.62.

This same method of calculation is employed whether the modulator be of the Class A or Class B type. It is also important in this case that the transformer windings be capable of carrying the necessary current without saturating the core.

CHECKING THE MODULATION

A simple method of checking the modulation of a transmitter is to apply a constant modulating frequency to the carrier and note the increase in antenna current. If the carrier is modulated 100%, the antenna current will rise to approximately 1.23 times the carrier value.

The circuit diagram of a modulometer appears in Fig. 11. This device is used for determining the percentage of modulation in the following manner: Coil L_2 is coupled to the output circuit of the transmitter. The R.F. current which passes through this circuit causes a voltage drop across resistor R_1 and which is directly proportional to the current through the resistor.

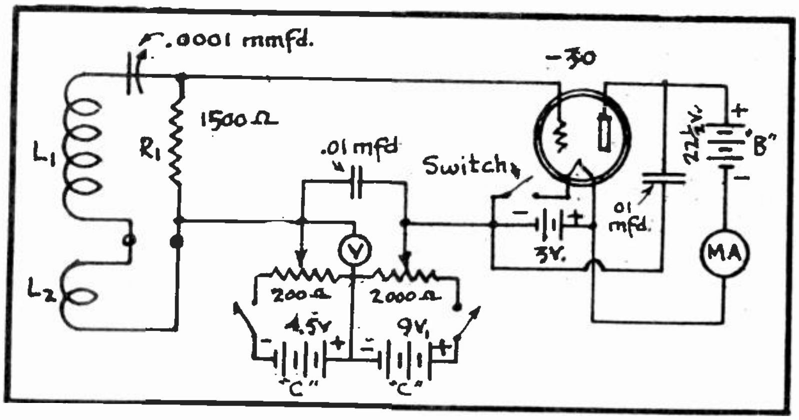

FIG. 11
Circuit of the Modulometer.

Variations in the amplitude of the R.F. current will therefore cause proportionate variations in the R.F. voltage across resistor R_1 and the positive half cycles of this voltage is measured by the peak voltmeter (vacuum tube voltmeter) which is incorporated in the modulometer.

During the time of conducting this test, the transmitting antenna is replaced with a dummy antenna and the coupling is so adjusted that the modulated amplitude of the voltage across R_1 is 5 or 6 volts. The gain control of the speech amplifier is then set at zero so that the carrier is unmodulated and a second measurement is made. The percentage of modulation is then determined from the relation $M = \frac{E\ mod. - E\ car.}{E\ car.} \times 100$

where M is the percentage of modulation, Emod. is the voltage with modulation and Ecar is the voltage of the unmodulated carrier.

The coil L_1 and condenser C_1 are so chosen that this circuit can be tuned to the carrier frequency of the transmitter. The coupling or pick-up coil L_2 may consist of two or three turns of lamp cord of any convenient size.

Answered May 19, 1942

Examination Questions

LESSON NO. T-16

Men are so inclined to content themselves with what is most common, that it is necessary to continually study and nourish in his mind the things which are beautiful and perfect.

1. — WHAT APPROXIMATE RELATION EXISTS BETWEEN THE OUTPUT POWER OF AN AMPLIFIER TUBE AND THE GRID EXITATION POWER FOR THE SAME TUBE? 1/10

2. — WHAT PROCEDURE CAN BE USED IN ORDER TO DETERMINE THE APPROXIMATE GRID EXITING VOLTAGE NECESSARY IN ORDER THAT A CERTAIN AMPLIFIER TUBE MAY DELIVER ITS RATED OUTPUT POWER?

3. — HOW WOULD YOU GO ABOUT THE TASK OF DETERMINING THE OUTPUT IMPEDANCE OF A MODULATING AMPLIFIER?

4. — WHAT IS MEANT BY "REFLECTED RESISTANCE"?

5. — EXPLAIN IN DETAIL HOW THE PROPER LOAD IMPEDANCE FOR A POWER AMPLIFIER MAY BE DETERMINED WITH THE AID OF A FAMILY OF CHARACTERISTIC CURVES CORRESPONDING TO THE SAME TUBE.

6. — EXPLAIN HOW THE PERCENTAGE OF SECOND HARMONIC DISTORTION AT THE OUTPUT OF AN AMPLIFIER MAY BE DETERMINED.

7. — IN ORDER TO REALIZE 100% MODULATION WHEN USING THE HEISING SYSTEM OF MODULATION, WHAT RELATION SHOULD EXIST BETWEEN THE CLASS C AMPLIFIER'S D.C. INPUT POWER AND THE MODULATOR'S RATED MAXIMUM UNDISTORTED POWER OUTPUT?

8. — WHAT METHOD MAY BE EMPLOYED IN ORDER TO DETERMINE THE PERCENTAGE OF MODULATION REALIZED WITH A CERTAIN TRANSMITTER?

9. — IF THE HEISING SYSTEM OF MODULATION IS TO BE EMPLOYED BY USING A MODULATION TRANSFORMER, WHAT STEPS SHOULD BE TAKEN IN ORDER TO DETERMINE THE CORRECT TURNS RATIO FOR THIS TRANSFORMER?

10. — IF THE LOAD IMPEDANCE OF A TRANSMITTER'S POWER AMPLIFIER IS OF TOO LOW A VALUE FOR THE TUBES USED, HOW WILL THIS AFFECT THE OPERATION OF THE TRANSMITTER? HOW WILL THE OPERATION OF THE SAME TRANSMITTER BE AFFECTED IN THE EVENT THAT THE LOAD IMPEDANCE IS OF TOO HIGH A VALUE?

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RADIO - TELEVISION

Practical • J. A. ROSENKRANZ, Pres. • Training

NATIONAL SCHOOLS

Established 1905

Los Angeles, California

Transmitters

LESSON NO 17

·STUDIO AND CONTROL-ROOM EQUIPMENT·

WITH THIS LESSON YOU ARE GOING TO COMMENCE YOUR STUDY OF BROADCAST TRANSMITTERS AND ASSOCIATED STATION EQUIPMENT. THE STUDIO END OF THE SYSTEM SHALL BE CONSIDERED FIRST.

FIG. 2 SHOWS YOU IN A SIMPLIFIED FORM HOW THE STUDIO IS RELATED TO THE OTHER MAJOR UNITS OF THE BROADCAST TRANSMITTER. HERE YOU WILL OBSERVE THAT A NUMBER OF STUDIO MICROPHONES FEED INTO A MIXER AND FROM HERE THE SOUND ENERGY IS DELIVERED TO THE A.F. AMPLIFYING EQUIPMENT WHICH IS LOCATED IN THE CONTROL ROOM. IN THE TRANSMITTER ROOM THIS A.F. ENERGY IS STILL FURTHER AMPLIFIED TO THE VALUE NECESSARY FOR PROPER MODULATION AND FROM THE TRANSMITTER THE MODULATED R.F. ENERGY IS FED INTO THE ANTENNA.

NUMEROUS MODIFICATIONS OF THIS TYPICAL ARRANGEMENT ARE USED BY DIFFERENT STATIONS. FOR EXAMPLE, IN MANY CASES YOU WILL FIND THE MICROPHONES OPERATING DIRECTLY INTO A PRE-AMPLIFIER AND THE A.F. SIGNALS DELIVERED FROM THESE SMALL AMPLIFIERS TO THE MIXER WHICH IS IN SUCH INSTANCES LOCATED IN THE CONTROL ROOM.

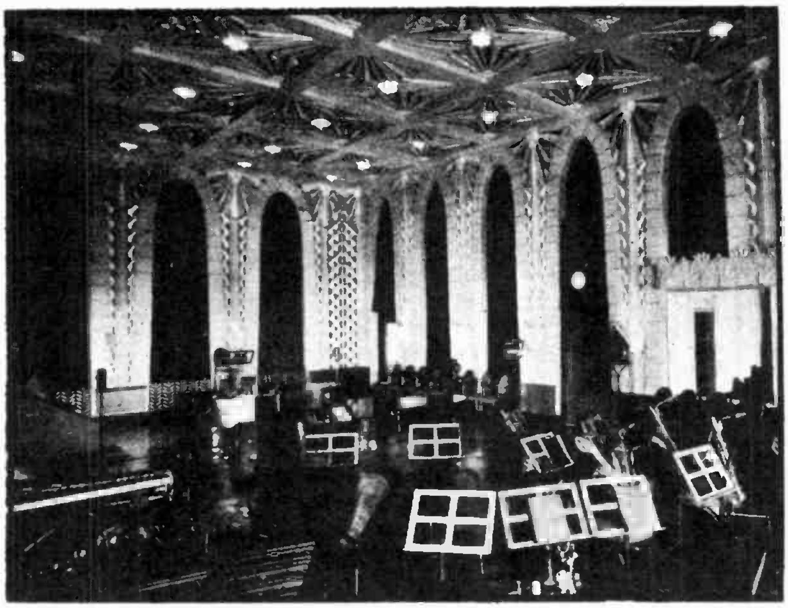

FIG. 1

Main Studio of a Broadcast Station.

IN FIG. 2 YOU ARE ALSO SHOWN HOW PROGRAMS ARE HANDLED BY REMOTE CONTROL. THIS, YOU WILL NOTE, IS ACCOMPLISHED BY PLACING THE NECESSARY MICROPHONES AND MIXER AT THE POINT WHERE THE PROGRAM ORIGINATES — AN AUDITORIUM IN THIS

PARTICULAR CASE. THE A.F. ENERGY IS THEN AMPLIFIED AT THIS SAME LOCATION AND THE OUTPUT TERMINALS OF THIS AMPLIFIER CARRY THE AMPLIFIED A.F. SIGNALS TO THE CONTROL ROOM OF THE STATION OVER SPECIAL TELEPHONE LINES. THESE SIGNALS ARE THEN PASSED THROUGH THE EQUALIZER AND FROM HERE ON, THE PROGRAM IS HANDLED IN THE SAME MANNER AS ALREADY EXPLAINED.

ALSO OBSERVE IN FIG. 2 THAT A SEPARATE TELEPHONE SYSTEM IS INCLUDED BETWEEN THE STATION AND THE DISTANT ORIGIN OF THE PROGRAM SO THAT THE OPERATORS AT BOTH POINTS CAN MAINTAIN PRIVATE COMMUNICATION BETWEEN THEMSELVES REGARDING THE HANDLING OF THE PROGRAM.

FROM THIS BRIEF EXPLANATION, YOU SHOULD NOW HAVE A GENERAL IDEA OF THE ENTIRE BROADCAST SYSTEM. IN THE INSTRUCTION WHICH IS TO FOLLOW YOU WILL HAVE THE OPPORTUNITY OF STUDYING EACH UNIT IN DETAIL, AS WELL AS ALL ACCESSORY EQUIPMENT SUCH AS THE RELAYS, VOLUME INDICATORS, MONITORING DEVICES ETC. WHICH FOR THE SAKE OF CLARITY AND SIMPLICITY HAVE BEEN OMITTED FROM FIG. 2.

B'CAST

STUDIO ARRANGEMENT

IN FIG. 3 YOU ARE SHOWN AN ARTIST'S CUT-AWAY SKETCH OF THE NATIONAL BROADCASTING STUDIOS AND WHICH IS PART OF THE TRAINING EQUIPMENT IN OUR SCHOOL. THIS STUDIO ARRANGEMENT IS TYPICAL OF THAT USED BY THE BETTER BROADCASTING STATIONS OF THIS COUNTRY AND CONSEQUENTLY OUR STUDENTS HAVE THE OPPORTUNITY OF WORKING UNDER THE SAME CONDITIONS AS WOULD EXIST IN ANY OF THE LARGER STATIONS.

YOU WILL NO DOUBT BE INTERESTED IN KNOWING THAT NATIONAL SCHOOLS ALSO CONDUCT THE NATIONAL SCHOOL OF BROADCASTING AND WHICH IS DEVOTED EX-

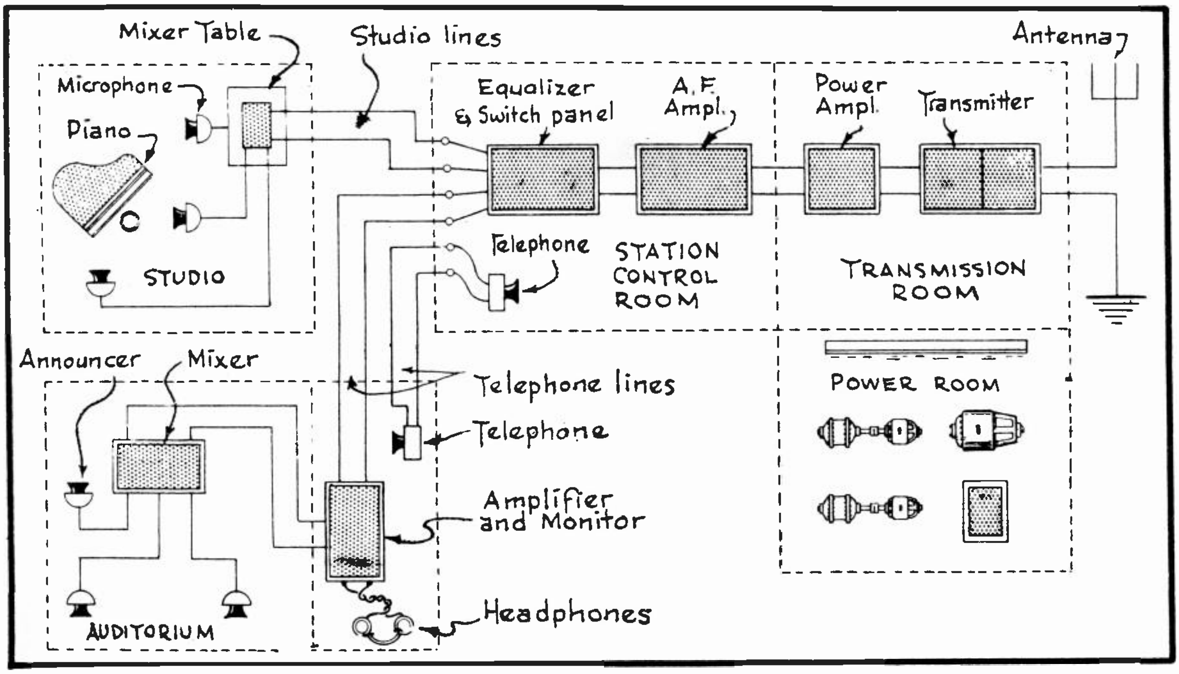

FIG. 2

Typical Arrangement of a Broadcast Station.

CLUSIVELY TO THE TRAINING OF ARTISTS AND OTHER TALENTED PERSONS SO THAT THEY MAY DEVELOP FOR RADIO USE THEIR TALENTS IN THE FIELD OF SINGING, DRAMATICS, ANNOUNCING, CONTINUITY WRITING, ETC. VARIED TYPES OF PROGRAMS WHICH ORIGINATE IN OUR STUDIOS ARE RELEASED ON REGULAR SCHEDULE BY ONE THE MAJOR BROADCASTING STATIONS OF LOS ANGELES.

WHILE THE STUDENTS OF OUR BROADCASTING SCHOOL USE OUR STUDIOS TO THEIR PARTICULAR ADVANTAGE, YET THIS IS OF MUTUAL BENEFIT TO THE RADIO STUDENTS OF OUR TECHNICAL SCHOOL WHO ARE PRIVELEDGED TO ACT AS STUDIO TECHNICIANS, MONITORING MEN, AND STATION TECHNICIANS, IN ADDITION TO GAINING THE MOST VALUABLE EXPERIENCE OF SERVICING ALL THIS EQUIPMENT.

BY AGAIN REFERRING TO FIG. 3 YOU WILL NOTE THAT THE STUDIOS CONSIST OF SEVERAL DEPARTMENTS AND WHICH IS TRUE IN THE MAJORITY OF STATIONS. THE MAIN STUDIO, FOR INSTANCE, IS LOCATED AT "A" — THIS IS A LARGE STUDIO IN WHICH ORIGINATE ALL MAJOR PROGRAMS INVOLVING A NUMBER OF PERSONS.

AT "B", "C" AND "D" WE HAVE THREE SMALLER STUDIOS WHICH ARE USED FOR THE BROADCASTING OF PROGRAMS INVOLVING A MINIMUM OF STUDIO EQUIPMENT AND

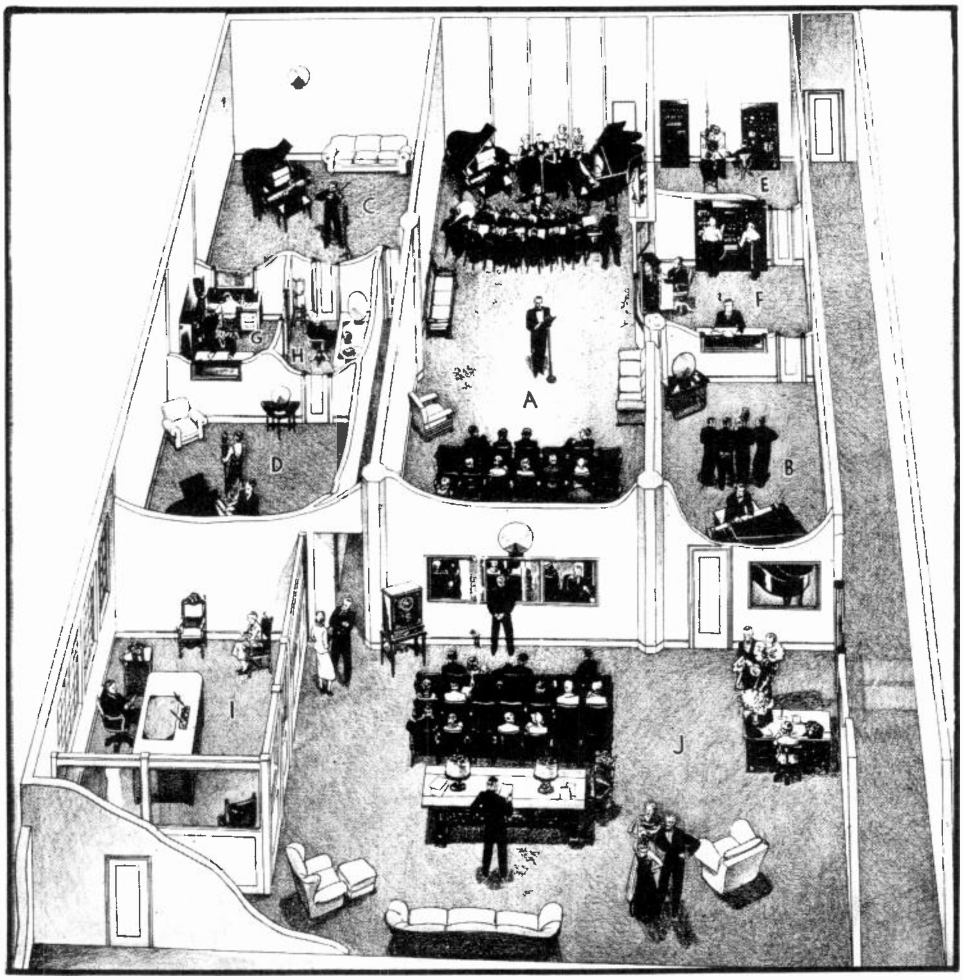

FIG. 3

The National Broadcasting Studios.

IN WHICH ONLY A LIMITED NUMBER OF PERSONS PARTICIPATE. THE SMALLER STUDIOS AS THIS ARE BEST ADAPTED FOR VOICE AND INSTRUMENTAL SOLOIST, SPEAKERS, ETC.

THE TELEVISION STUDIO IS LOCATED AT "E" AND CONTROL ROOMS ARE LOCATED AT BOTH "F" AND "G". SPECIALLY DESIGNED WINDOWS, WHICH ARE INSTALLED IN THE WALLS OF THE CONTROL ROOMS, ENABLE THE CONTROL ROOM OPERATORS TO OBTAIN A FULL VIEW OF THE ACTIVITIES IN ALL OF THE STUDIOS.

AN AUDITION ROOM IS LOCATED AT "H", THE DIRECTOR'S OFFICE AT "I" AND THE RECEPTION ROOM. AT "J". WINDOWS ARE PROVIDED SO THAT THE AUDIENCE IN ROOM "J" CAN WATCH THE ACTIVITIES IN STUDIOS "A" AND "B" AND AT THE SAME TIME HEAR THE PROGRAMS THROUGH SPEAKERS WHICH ARE INSTALLED IN THE RECEPTION ROOM.

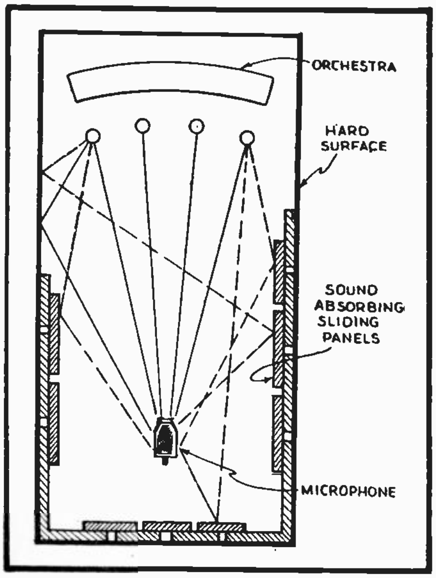

FIG. 4
A "Live and Dead end" Studio.

STUDIO ACOUSTICS

IN THE DESIGN OF BROADCAST STUDIOS, THE ACOUSTIC CONDITIONS ARE OF THE GREATEST IMPORTANCE. FROM WHAT YOU HAVE ALREADY LEARNED IN A PREVIOUS STUDY OF ACOUSTICS, YOU WILL RECALL THAT SOME WALL SURFACES REFLECT SOUND WAVES READILY WHILE OTHERS HARDLY REFLECT SOUND WAVES AT ALL. THOSE SURFACES WHICH REFLECT SOUND WAVES READILY ARE GENERALLY REFERRED TO AS "LIVE" SURFACES WHILE THOSE WHICH DO NOT REFLECT SOUND WAVES READILY ARE REFERRED TO AS "DEAD" SURFACES.

ALL OF THE INSTRUCTION WHICH HAS BEEN GIVEN YOU IN THE LESSON TITLED "ACOUSTICS" OF THE LESSON SERIES TREATING WITH AMPLIFYING SYSTEMS APPLIES TO STUDIO TECHNIQUE EQUALLY AS WELL AS IT DOES TO ACOUSTIC CONDITIONS IN GENERAL. THEREFORE, IF NECESSARY, IT IS ADVISABLE THAT YOU REVIEW YOUR LESSON ON ACOUSTICS AT THIS TIME.

IN STUDIO PRACTICE WE FIND THAT IF THE WALL SURFACES SURROUNDING THE MICROPHONE ARE TOO LIVE, THEN EXCESSIVE REVERBERATION WILL BRING ABOUT UNDESIRABLE ECHOING CONDITIONS AND CAUSE THE SOUND REPRODUCTION TO APPEAR AS THOUGH THE PROGRAM ORIGINATED IN A LARGE AND EMPTY HALL. ON THE OTHER HAND, IF THE WALL SURFACES ARE TOO DEAD, THEN THE REPRODUCTION OF MUSICAL SELECTIONS INVOLVING A LARGE VARIETY OF FREQUENCIES WILL LOOSE SOME OF ITS SPARKLING EFFECT OR BRILLIANCE AND THUS BECOME DULLER THAN IS ADVISABLE.

SO AS TO MEET ALL OF THESE EXTREME CONDITIONS SATISFACTORILY, MOST OF THE LARGER STUDIOS ARE OF THE LIVE END-DEAD END TYPE. AN EXAMPLE OF SUCH A DESIGN IS ILLUSTRATED IN FIG. 4.

IN STUDIOS OF THE LIVE END-DEAD END TYPE, ONE END OF THE STUDIO HAS ITS WALLS FINISHED WITH A HARD, SOUND-REFLECTING SURFACE, WHILE THE DEAD

END OF THE STUDIO HAS ITS WALLS FINISHED WITH A SOUND-ABSORBING MATERIAL. IN SOME CASES, THE NECESSARY SOUND REFLECTION IS OBTAINED BY USING A HARD PLASTER FINISH ON THE WALLS AND CEILING, WHEREAS THE NECESSARY SOUND ABSORBING CHARACTERISTICS CAN BE OBTAINED BY FINISHING THE WALLS AT THE OPPOSITE END OF THE STUDIO WITH ROCK WOOL AND MONK'S CLOTH.

IT IS ALSO THE PRACTICE IN SOME INSTANCES TO FURNISH THIS SOUND ABSORPTION WITH A TAPERING CHARACTERISTIC. THAT IS, THE HARDEST AND BEST REFLECTING SURFACE IS PLACED AT ONE END OF THE STUDIO AND THE WALL SURFACES ARE THEN APPLIED SO THAT THEIR DEGREE OF ABSORPTION IS GRADUALLY INCREASED AS THE OPPOSITE END OF THE STUDIO IS APPROACHED — THE DEAD END OFFERING THE MAXIMUM AMOUNT OF ABSORPTION.

FIG. 5
Interior of one of the Smaller Studios.

FOR DIFFERENT TYPES OF PROGRAMS, A VARYING AMOUNT OF SOUND REFLECTION AND ABSORPTION IS DESIRED AND TO SATISFY THESE CONDITIONS, DIFFERENT POSITIONS IN THE STUDIOS FOR THE MICROPHONES AND ARTISTS ARE TRIED UNTIL THE DESIRED EFFECT IS OBTAINED.

IT IS ALSO A COMMON PRACTICE TO FURNISH THE LARGER STUDIOS WITH SLIDING PANELS OR SCREENS MADE OF SOUND ABSORBING OR SOUND REFLECTING MATERIAL IN THE MANNER SHOWN IN FIG. 4. WITH THIS ARRANGEMENT, THE ACOUSTIC CONDITIONS OF THE STUDIO CAN BE ALTERED CONVENIENTLY SO AS TO BE BEST ADAPTED TO ANY PARTICULAR TYPE OF PROGRAM AND STUDIO SET-UP.

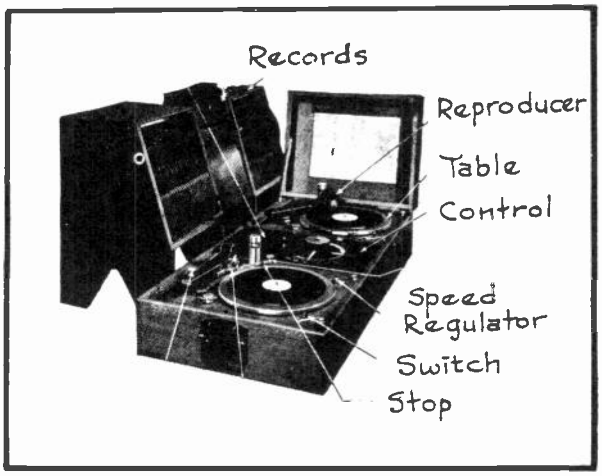

FIG. 6
A Turntable Set.

MICROPHONE PLACEMENT

ANOTHER IMPORTANT PROBLEM WITH WHICH THE STUDIO TECHNICIAN MUST COPE IS "MICROPHONE PLACEMENT". THIS CONSISTS OF PLACING THE MICROPHONE OR GROUP OF MICROPHONES IN THE MOST ADVANTAGEOUS POSITION FOR THE DESIRED PICK-UP.

IN THE CASE OF MICROPHONE

PLACEMENT, WE HAVE SOUND REFLECTION TO CONTEND WITH THE SAME AS ALREADY DESCRIBED RELATIVE TO SPEAKERS AS USED WITH SOUND AMPLIFYING EQUIPMENT. PROVIDED THAT THE SOUNDS ARE NOT COMPARABLE IN INTENSITY, THE TIME LAG BETWEEN THE ORIGINAL AND REFLECTED SOUNDS IS OF NO GREAT IMPORTANCE. HOWEVER, IF THE ORIGINAL AND REFLECTED SOUND INTENSITIES ARE COMPARABLE, THEN IT IS ADVISABLE TO MAINTAIN A SHORT TIME LAG.

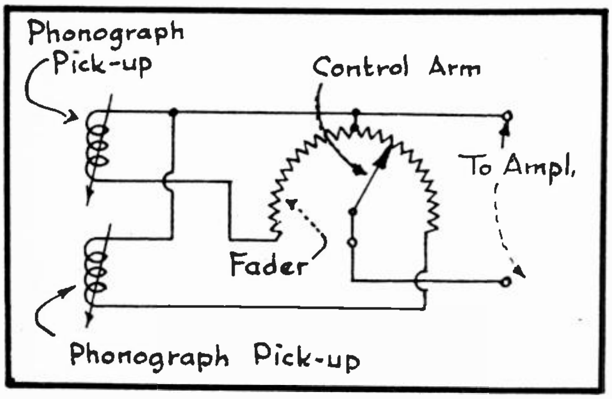

FIG. 7

The Pick-up Fader Circuit.

THE MORE LIVE THE SURROUNDINGS ABOUT THE MICROPHONE, THE SHORTER WILL BE THE TIME LAG AND THIS WILL CAUSE THE REPRODUCTION TO APPEAR AS TINNY. SHOULD THE TIME LAG BE TOO LONG, THEN THE REPRODUCTION WILL TAKE ON A HOLLOW SOUND EFFECT. WHEN A LIVE AND DEAD END STUDIO IS EMPLOYED FOR THE PRODUCTION OF A LARGE PROGRAM IT IS CUSTOMARY TO PLACE THE MICROPHONE OR MICROPHONES IN THE DEAD END OF THE STUDIO AND THE ORCHESTRA IN THE LIVE END OF THE STUDIO AS POINTED OUT IN FIG. 4.

SINCE STUDIO SET-UPS OF THIS NATURE INVOLVE INSTRUMENTS OR VOICES OF DIFFERING QUALITY AND FREQUENCY RANGE, IT IS IMPORTANT THAT THE VARIOUS INDIVIDUALS BE ARRANGED AROUND THE MICROPHONE OR MICROPHONES IN SUCH A MANNER THAT THE SOUND REPRODUCTION AS EMITTED FROM THE LOUD SPEAKER BE WELL BALANCED AND NATURAL IN EFFECT. FOR EXAMPLE, THE WAVES OF CERTAIN FREQUENCIES ARE REFLECTED MORE READILY THAN THOSE OF OTHER FREQUENCIES AND SO THAT CERTAIN SOUNDS DO NOT OVER-POWER OTHERS, THE MORE INTENSIVE SOUND PRODUCERS ARE PLACED FARTHER AWAY FROM THE MICROPHONE.

ANOTHER EFFECT THAT SOMETIMES CAUSES TROUBLE IS THAT WHEN SEVERAL MICROPHONES ARE USED TO PICK UP THE SAME PROGRAM, THE SOUNDS WHICH ARE PRIMARILY INTENDED FOR ONE MICROPHONE ALSO ACT UPON SOME OF THE OTHER MICROPHONES AT SLIGHTLY DIFFERENT TIME INTERVALS AND VOLUMES. WHEN SUCH A CONDITION EXISTS, A SORT OF ECHOING SENSATION APP

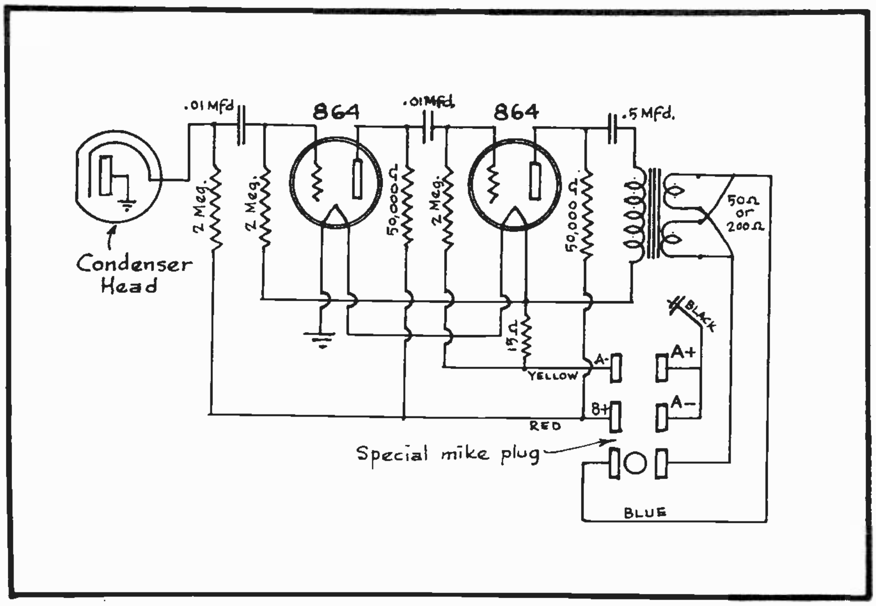

FIG. 8

The Microphone Head Amplifier.

EARS AT THE LOUDSPEAKER, SIMILAR TO THAT EXPERIENCED WHEN THE MICROPHONE IS PLACED IN HIGHLY REFLECTING SURROUNDINGS.

PROPER MICROPHONE PLACEMENT AND THE ADJUSTMENT OF ACOUSTICAL CONDITIONS FOR LARGE STUDIO PRESENTATIONS IS AN ART REQUIRING A SKILL WHICH CAN ONLY BE OBTAINED THROUGH EXTENSIVE EXPERIENCE IN THIS WORK. THIS JOB IS GENERALLY HANDLED BY WHAT ARE KNOWN AS "PRODUCTION MEN" AND WHO ARE HIGHLY SPECIALIZED IN THIS WORK. SINCE THIS IS NOT ALTOGETHER THE WORK OF THE ENGINEER, WE SHALL NOW LEAVE THIS SUBJECT AND TURN OUR ATTENTION TO THE MORE TECHNICAL DETAILS OF THE BROADCAST STATION.

MICROPHONES

THE MICROPHONES AS USED IN BROADCAST STATIONS ARE OF THE HIGHEST QUALITY AND MAY BE OF THE CARBON, CONDENSER, RIBBON, DYNAMIC, OR CRYSTAL TYPE. ALL OF THESE VARIOUS MICROPHONES WERE ALREADY DESCRIBED TO YOU IN A PREVIOUS LESSON OF THE SERIES TREATING WITH AMPLIFYING SYSTEMS AND IT IS THEREFORE NOT NECESSARY TO REPEAT THIS INFORMATION AT THE PRESENT TIME. WE MIGHT POINT OUT, HOWEVER, THAT OF ALL THE MICROPHONE TYPES AVAILABLE, THE CONDENSER AND RIBBON TYPES ARE AT THE PRESENT TIME MOST EXTENSIVELY USED FOR BROADCAST PURPOSES, ALTHOUGH THE DYNAMIC AND CRYSTAL TYPES ARE GAINING IN POPULARITY.

ELECTRICAL EQUIPMENT

BESIDES THE MICROPHONE EQUIPMENT, PROVISIONS ARE ALSO MADE IN MOST BROADCAST STATIONS FOR RELEASING ELECTRICAL TRANSCRIPTION PROGRAMS OVER THE AIR. AN ELECTRICAL TRANSCRIPTION IS A RECORDED COMMERCIAL PROGRAM AND IS EQUIVALENT TO A PHONOGRAPH RECORD OF HIGH QUALTIY.

IN ORDER TO REPRODUCE THESE RECORDINGS, THE STATION EQUIPMENT MUST INCLUDE A SET OF TURN TABLES AND PICK-UP DEVICES AND AN EXAMPLE OF WHICH APPEARS IN FIG. 6. THIS EQUIPMENT IS GENERALLY USED IN PAIRS SO THAT AS THE PROGRAM PROGRESSES AND ONE RECORD IS FINISHED, THE FOLLOWING RECORD CAN BE

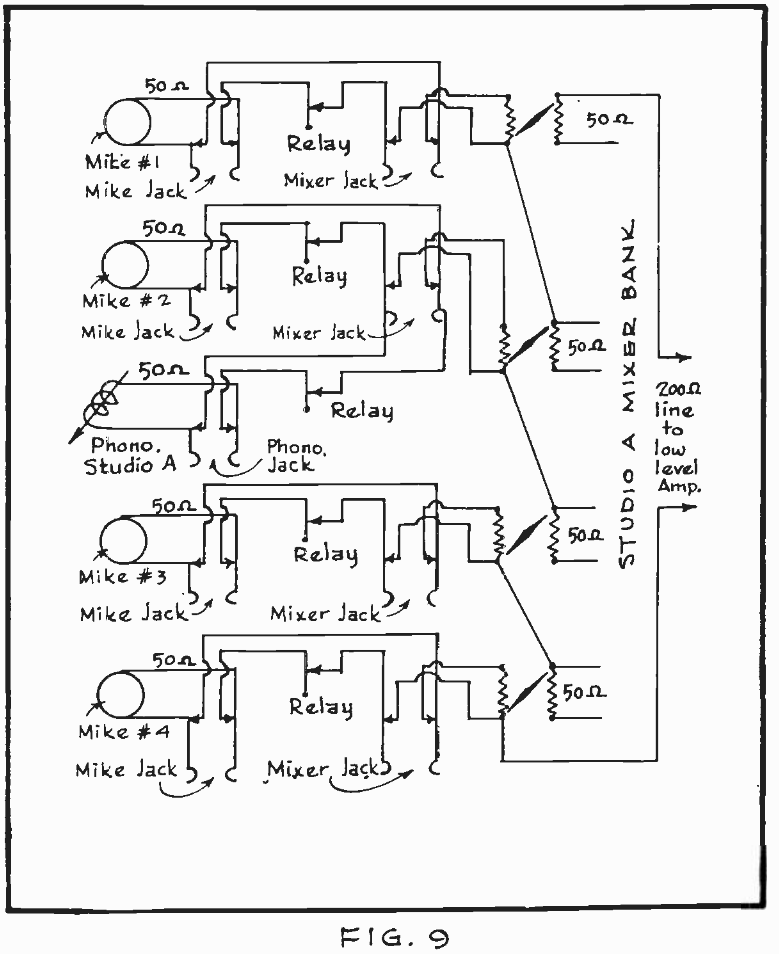

FIG. 9
The Typical Mixer Circuit.

STARTED AND BLENDED INTO THE PRECEDING ONE WITHOUT ANY NOTICEABLE INTERRUPTION. A FADER IS MOUNTED BETWEEN THESE TWO TABLES TO PERMIT THE PROPER SWITCHING OF RECORDS AND THIS CONTROL IS ILLUSTRATED IN FIG.7. THE OPERATION OF THIS FADER CIRCUIT HAS ALREADY BEEN EXPLAINED TO YOU IN A PREVIOUS LESSON TREATING WITH AMPLIFYING SYSTEMS.

TRANSCRIPTION RECORDINGS ARE MADE AT ONE OF TWO SPEEDS, NAMELY 33 R.P.M. AND 78 R.P.M. THE 78 R.P.M. RECORDS ARE GENERALLY 12" IN DIAMETER AND CAPABLE OF PLAYING FOR 5 MINUTES. THE 33 R.P.M. RECORDINGS ARE 16" IN DIAMETER AND ARE CAPABLE OF PLAYING CONTINUOUSLY FOR 15 MINUTES.

ELECTRICAL TRANSCRIPTION PROGRAMS ARE USUALLY OF SHORT DURATION, AT THE MOST LASTING FOR 15 MINUTES. THIS BEING THE CASE, A SINGLE 33 R.P.M. RECORD WILL HANDLE THE ENTIRE PROGRAM WITHOUT THE NEED OF CHANGING RECORDS.

WHEN THE STATION IS EQUIPPED WITH APPARATUS FOR THE REPRODUCTION OF ELECTRICAL TRANSCRIPTIONS, THIS SAME EQUIPMENT CAN ALSO BE USED FOR THE REPRODUCTION OF ORDINARY PHONOGRAPH RECORDINGS FOR TRANSMISSION PURPOSES.

AT THE PRESENT TIME WE SHALL NOT GO INTO DETAILS REGARDING THE PROCESSES INVOLVED IN MAKING THESE RECORDINGS IN THAT THIS IS FULLY COVERED IN LESSONS TREATING WITH SOUND PICTURES. THIS ALSO APPLIES TO THE REFINED TYPES OF PICK-UP HEADS.

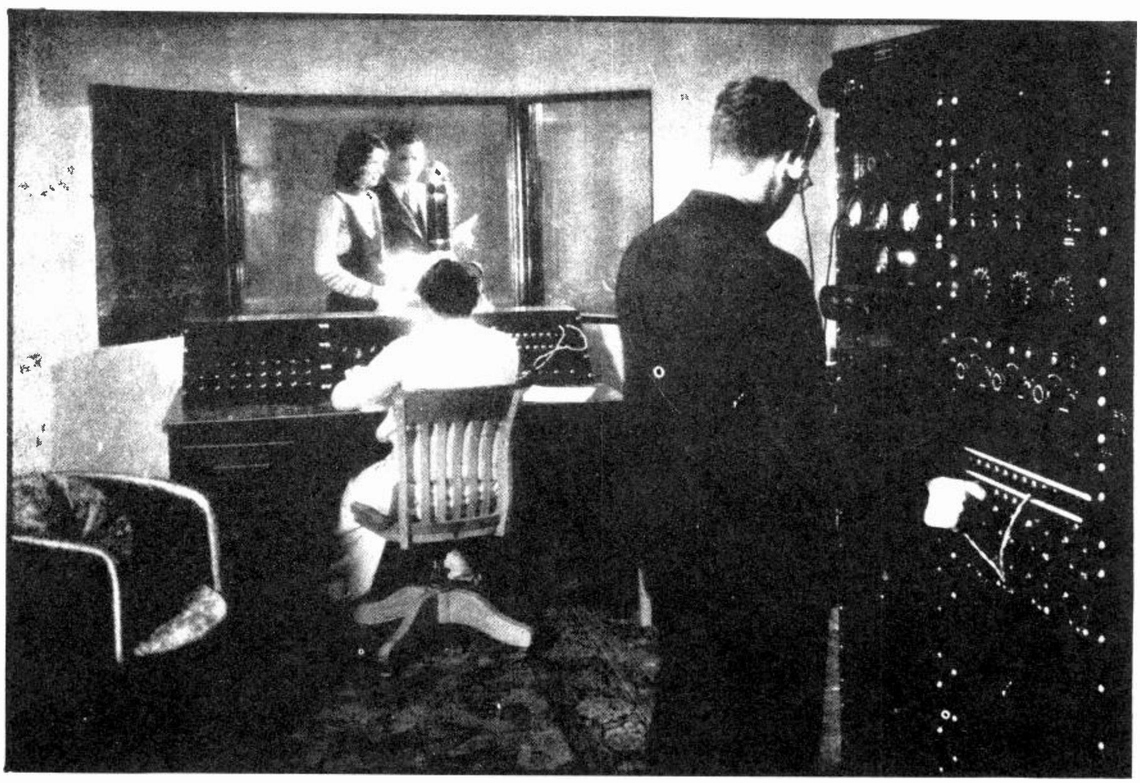

FIG. 10
National's Broadcast Control Room.

ASSUMING THAT CONDENSER MICROPHONES ARE BEING USED IN THE STUDIO, EACH OF THESE MICROPHONES WILL BE FITTED WITH A HEAD OR PRE-AMPLIFIER SIMILAR TO THAT WHICH IS ILLUSTRATED IN FIG.8. EACH OF THESE PRE-AMPLIFIERS IS FITTED WITH AN OUTPUT TRANSFORMER WHICH MATCHES THE INPUT IMPEDANCE OF THE MIXER AND THE HEAD AMPLIFIER OUTPUT OF EACH MICROPHONE IS CONNECTED TO THE MIXER THROUGH A SEPARATE CABLE AND CONDUIT WIRING SYSTEM. THE BATTERY LEADS FOR THE VARIOUS HEAD AMPLIFIERS ARE ALSO FREQUENTLY INCORPORATED INTO THE SAME MICROPHONE CABLE TOGETHER WITH THE A.F. LINE.

FOR THE HEAD AMPLIFIER WHICH IS ILLUSTRATED IN FIG.8 AND WHICH IS USED IN OUR STUDIOS, A 6 VOLT STORAGE BATTERY IS USED FOR THE "A" SUPPLY AND THREE SERIES CONNECTED 45 VOLT "B" BATTERIES FOR THE B SUPPLY. THE WIRING FROM THE CONTROL ROOM TO THE STUDIOS IS CARRIED IN CONDUIT AND THE CONNECTION BETWEEN THE VARIOUS MICROPHONE CABLES AND THE CONTROL ROOM CIRCUITS ARE COMPLETED THROUGH SPECIAL PLUG AND SOCKETS, THE ARRANGEMENT OF WHICH COINCIDES WITH THAT ILLUSTRATED IN FIG.8.

THE OUTPUTS OF THESE VARIOUS HEAD-AMPLIFIERS AND THE OUTPUT OF THE PHONOGRAPH PICK-UP CIRCUIT ARE THEN ALL CONNECTED TO THE MIXER IN SOME SUCH ARRANGEMENT AS ILLUSTRATED IN FIG.9. IT IS OF COURSE ESSENTIAL THAT ALL OF THESE COUPLING DEVICES, AS WELL AS THE MIXER CONTROLS, ALL BE PROPERLY MATCHED WITH RESPECT TO IMPEDANCE AS HAS ALREADY BEEN ADEQUATELY EXPLAINED TO YOU IN PREVIOUS LESSONS.

YOU WILL ACQUIRE A STILL CLEARER CONCEPTION OF THE ACTUAL APPEARANCE OF THE CONTROL ROOM EQUIPMENT BY REFERRING TO FIG. 10. HERE YOU ARE SHOWN A SECTION OF THE CONTROL ROOM IN OUR SCHOOL BROADCASTING STATION. THE MIXER DESK APPEARS AT THE CENTER, WITH THE OPERATOR SEATED IN FRONT OF IT AND IN SUCH A POSITION THAT HE MAY THRU SPECIALLY DESIGNED WINDOWS OBTAIN A FULL VIEW OF THE PERFORMERS IN FRONT OF THE STUDIO MICROPHONES. THE AMPLIFYING EQUIPMENT IS SHOWN AT THE RIGHT, BEING ATTENDED BY A TECHNICIAN.

IN FIG. 11 YOU ARE SHOWN THE MIXER PANEL REMOVED FROM ITS MOUNTING AS TESTS ARE BEING CONDUCTED BY A STUDENT. THIS WILL SERVE TO FAMILIARIZE YOU WITH THE GENERAL APPEARANCE OF THE INTERNAL CONSTRUCTION AND WIRING OF THIS ASSEMBLY.

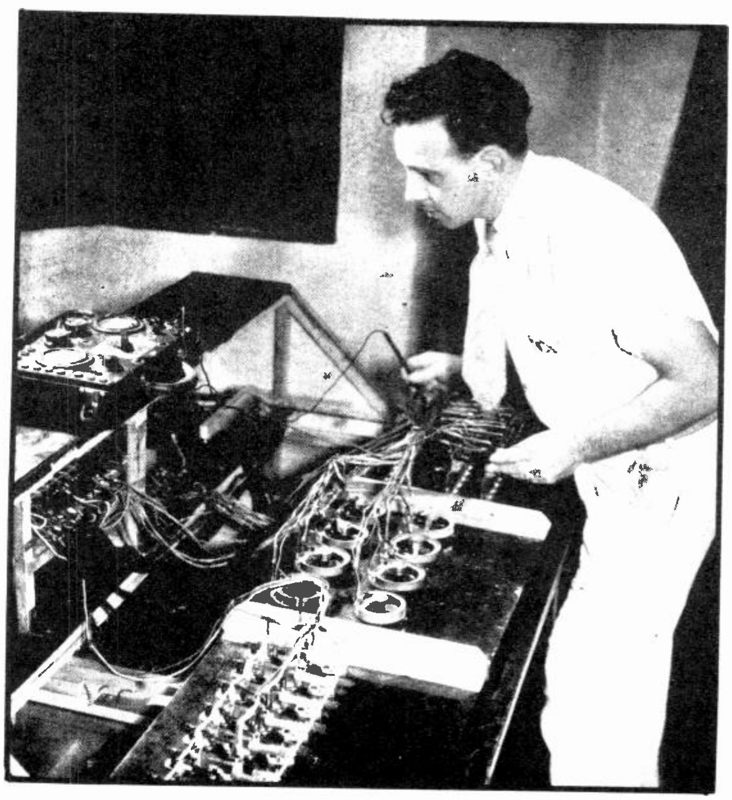

FIG. II
Testing the Mixer in the Broadcast Control Room.

By again referring to Fig. 9 you will note that the 50 ohm line from each of the microphones and the phonograph pick-up units feed through a system of jacks and relays to the inputs of the various L-pad volume controls. These various jacks, relays, and volume controls constitute a part of the mixer panel.

THE LOW-LEVEL AMPLIFIER

The output of the mixer feeds into the input of the low level amplifier through a 200 ohm line. A circuit diagram of the low level amplifier is shown in Fig. 12. This low level amplifier consists of three stages employing type 112A tubes. In the grid circuit of the second stage of this low level amplifier is located a gain or volume control by means of which the over-all gain of this amplifier can be controlled. Low level or low gain amplifiers as this make it possible to amplify the audio frequency energy in a most stable manner. That is to say, this system is not nearly so susceptible to feed-back troubles and oscillation as are amplifiers of high gain per stage. You will also observe in Fig. 12 that jacks are furnished so that the plate and filament current in the various stages of this amplifier can be measured with a minimum of effort.

The filament circuit of the low level amplifier is connected across a 6 volt storage battery, while the B supply for this same amplifier is obtained from the same B power supply as that used for the high level amplifier. The use of a battery filament supply in all of these low level stages reduces the possibility of hum pick-up to a minimum. This is important in that any hum or other extraneous noise which originates in the low level amplifier, or other input equipment, will be greatly magnified by the time it is passed through the following sections of the equipment

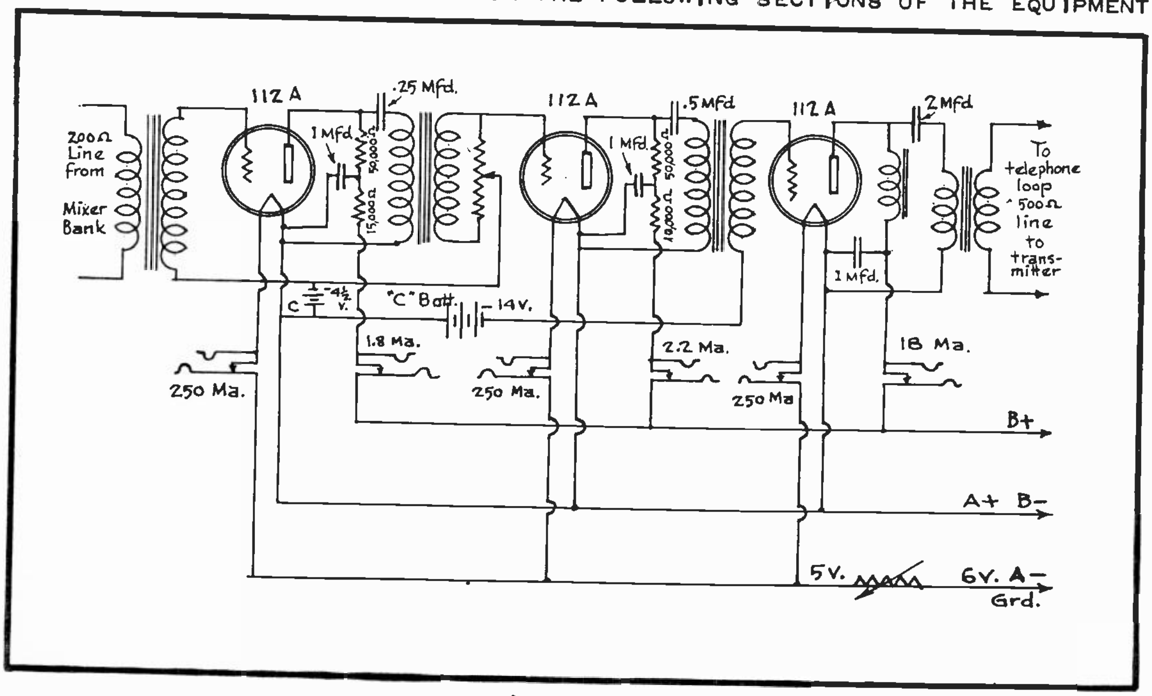

FIG. 12
The Low-level Amplifier.

IT IS ALSO A COMMON PRACTICE TO MOUNT THE TUBES OF THE LOW LEVEL AMPLIFIER IN RUBBER CUSHIONED SOCKETS AND FREQUENTLY TO PROVIDE A COVERING OVER THESE TUBES SO AS TO GUARD AGAINST ANY POSSIBLE CONDITION OF MICROPHONISM.

THE HIGH-LEVEL AMPLIFIER

THE OUTPUT OF THE LOW LEVEL AMPLIFIER IN FIG.12 IS SO ARRANGED THAT IT MAY BE CONNECTED THROUGH A 500 OHM TRANSMISSION LINE TO THE INPUT OF THE A.F. AMPLIFYING EQUIPMENT WHICH IS LOCATED UPSTAIRS IN THE TRANSMITTER ROOM. THIS SAME OUTPUT IS ALSO SO ARRANGED THAT IT CAN BE FED INTO THE SPECIAL TELEPHONE LINE LEADING TO ONE OF THE MAJOR BROADCASTING STATIONS OF LOS ANGELES FOR THE RELEASE OF SPECIAL PROGRAMS. THE THIRD POSSIBILITY

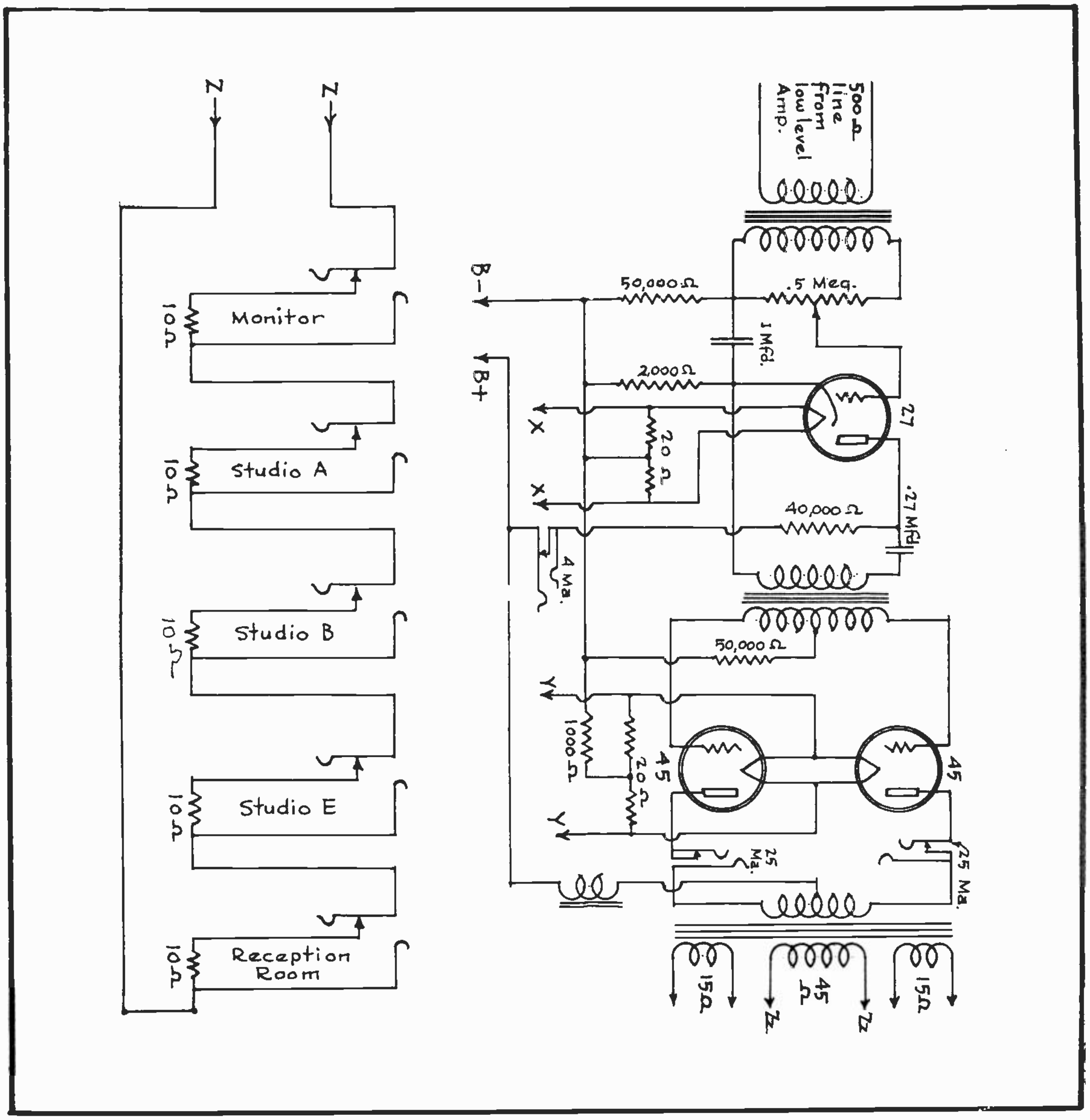

FIG. 13
The High-Level Amplifier.

IS TO CONNECT THE OUTPUT OF THE LOW LEVEL AMPLIFIER TO THE INPUT OF THE HIGH LEVEL AMPLIFIER WHICH IS ALSO INCLUDED IN THE STUDIO CONTROL ROOM. THIS INTER-AMPLIFIER CONNECTION IS MADE THROUGH A 500 OHM LINE.

THE CIRCUIT DIAGRAM OF THE HIGH LEVEL AMPLIFIER IS SHOWN IN FIG. 13 AND THIS UNIT, YOU WILL OBSERVE, CONSISTS OF ONE STAGE EMPLOYING A 27 TUBE AND WHICH IS FOLLOWED BY A PUSH-PULL STAGE IN WHICH A PAIR OF 45'S ARE EMPLOYED. THE INPUT OF THIS HIGH LEVEL AMPLIFIER IS ALSO EQUIPPED WITH A MASTER GAIN CONTROL. THE AUDIO TRANSFORMERS WHICH ARE HERE USED ARE OF THE BEST QUALITY TO INSURE GOOD PERFORMANCE.

ALSO NOTICE IN FIG. 13 THE EXTENSIVE USE OF JACKS FOR THE INSERTION OF A MILLIAMMETER FOR TAKING CURRENT READINGS. YOU WILL ALSO OBSERVE IN THIS SAME ILLUSTRATION THAT PROVISIONS ARE MADE FOR CONNECTING THE VOICE COILS OF FIVE DIFFERENT DYNAMIC SPEAKERS TO THE OUTPUT OF THE HIGH LEVEL AMPLIFIER. THE MONITOR SPEAKER IS MOUNTED IN THE CONTROL ROOM SO AS TO OFFER A MEANS OF CHECKING UP ON THE REPRODUCTION OF THE PROGRAM. ANOTHER SPEAKER IS PLACED IN THE RECEPTION ROOM AND ONE SPEAKER IN EACH OF THE THREE SMALLER STUDIOS. ALL OF THESE SPEAKERS ARE CONNECTED IN SERIES.

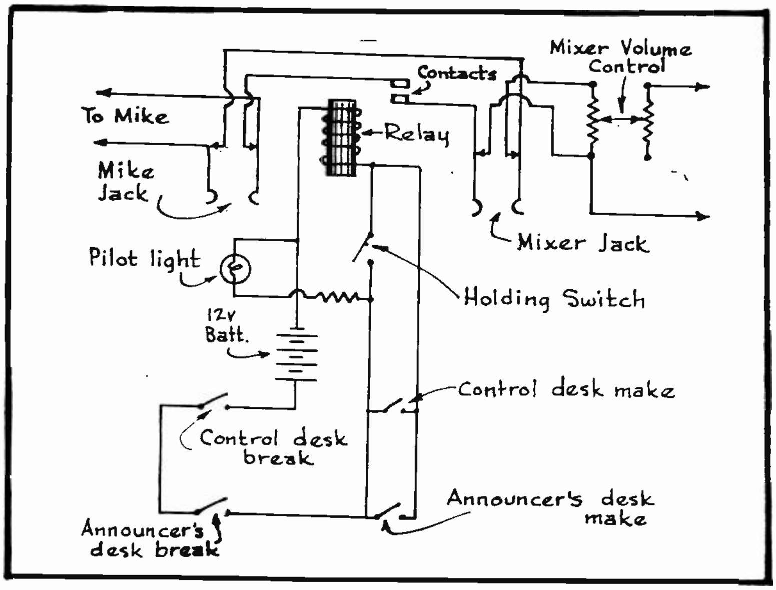

FIG. 14

Details of Microphone Control Circuit.

THE 10 OHM RESISTORS WHICH ARE CONNECTED ACROSS EACH OF THE SPEAKER JACKS ARE CONNECTED IN SERIES WHEN THE SPEAKERS ARE NOT IN USE BUT EACH OF THEM IS AUTOMATICALLY DISCONNECTED FROM THE CIRCUIT AT THE TIME THE SPEAKER IS PLUGGED INTO THE SAME JACK. THIS ARRANGEMENT PERMITS THE SPEAKER CIRCUIT TO MAINTAIN A PRACTICALLY CONSTANT IMPEDANCE VALUE REGARDLESS OF THE NUMBER OF SPEAKERS USED AT ANY ONE TIME. THE SPEAKER FIELDS ARE ENERGIZED BY A 12 VOLT STORAGE BATTERY.

ALTHOUGH THE OUTPUT OF THIS HIGH LEVEL AMPLIFIER ISN'T OF ANY VERY GREAT VALUE, YET IT IS SUFFICIENT FOR THE USE TO WHICH IT IS BEING SUBJECTED. FURTHERMORE, IT IS TO BE REMEMBERED THAT THE GREATER AMOUNT OF AUDIO FREQUENCY AMPLIFICATION OCCURS IN THE MORE POWERFUL AUDIO AMPLIFYING SYSTEM WHICH IS LOCATED IN THE TRANSMITTER ROOM. ALL OF THE AMPLIFYING EQUIPMENT THROUGHOUT IS BUILT ACCORDING TO A RACK AND PANEL DESIGN AS WILL BE APPARENT FROM AN INSPECTION OF FIG. 10, AND WHICH IS THE STANDARD PRACTICE IN ALL BROADCASTING STATIONS.

NATURALLY, YOU WILL NOT FIND THE SAME AMPLIFIER CIRCUITS AS THOSE ILLUSTRATED IN THIS LESSON TO BE USED IN THE CONTROL ROOM OF EVERY STA-

TION. THESE CIRCUITS, YOU WILL REALIZE, MAY VARY CONSIDERABLY AND FOLLOW ANY OF THE VARIETY OF AUDIO AMPLIFIER CIRCUITS WHICH WERE EXPLAINED TO YOU IN PREVIOUS LESSONS. NEVERTHELESS, THE CIRCUITS WHICH ARE PRESENTED TO YOU IN THIS LESSON ARE TYPICAL OF THIS EQUIPMENT.

A BATTERY CHARGER OF THE TUNGAR BULB TYPE IS ALSO USED AS A PART OF THIS CONTROL ROOM EQUIPMENT AND A SWITCH IS PROVIDED IN THE STORAGE BATTERY CIRCUIT SO THAT THESE BATTERIES CAN BE CONVENIENTLY CONNECTED TO THE CHARGER WHENEVER NECESSARY.

THE RELAY SYSTEM

IN FIG. 14 YOU ARE SHOWN IN A MORE DETAILED FORM THE MICROPHONE CONTROL CIRCUIT AND IN WHICH THE APPLICATION OF THE RELAY SYSTEM IS MORE CLEARLY ILLUSTRATED.

AS YOU WILL OBSERVE IN THIS DIAGRAM, THE MICROPHONE CIRCUIT THROUGH THE MIKE JACK, RELAY CONTACTS, MIXER JACK, AND MIXER VOLUME CONTROL CORRESPONDS TO THIS SAME SECTION OF THE CIRCUIT IN THE COMPLETE MIXER SYSTEM WHICH APPEARS IN FIG. 9 OF THIS LESSON.

IN ADDITION, YOU WILL SEE IN FIG. 14 HOW THE WINDING OF THE RELAY IS CONNECTED IN SERIES WITH A 12-VOLT STORAGE BATTERY THROUGH A SERIES OF SWITCHES SO THAT THE MICROPHONE CAN BE CUT IN OR OUT OF THE CIRCUIT BY OPERATING SWITCHES WHICH ARE LOCATED EITHER AT THE CONTROL DESK OR AT THE ANNOUNCER'S DESK. A SMALL PILOT LIGHT, MOUNTED BEHIND A RED GLASS BULLS'-EYE ON THE PANEL OF THE CONTROL DESK, LIGHTS UP WHENEVER THIS MICROPHONE IS IN USE AND IN SOME INSTANCES A SIMILAR SIGNAL LIGHT IS LOCATED AT THE ANNOUNCER'S DESK.

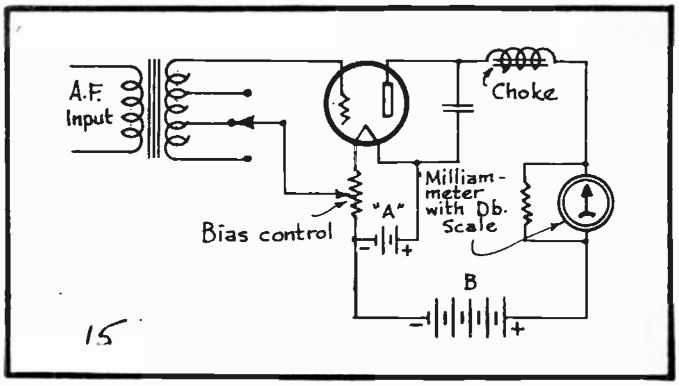

FIG. 15
Application of the V.T. Voltmeter as a Volume Indicator.

VOLUME INDICATORS

IN ORDER SO THAT THE CONTROL ROOM OPERATOR MAY KNOW AT ALL TIMES THE EXACT PROGRAM LEVEL, A METER CALIBRATED IN DECIBELS IS MOUNTED ON THE CONTROL DESK DIRECTLY IN FRONT OF THE OPERATOR. THERE ARE VARIOUS WAYS IN WHICH THIS PROGRAM LEVEL CAN BE ASCERTAINED AND ONE METHOD IS ILLUSTRATED IN FIG. 15. BY REFERRING TO FIG. 15 YOU WILL OBSERVE HOW THE PRINCIPLES OF A VACUUM TUBE VOLTMETER CAN BE USED FOR THIS PURPOSE, WITH THE EXCEPTION THAT THE CUSTOMARY MILLIAMMETER SCALE IN THIS CASE IS REPLACED WITH A SCALE WHICH IS CALIBRATED IN DECIBELS. FROM WHAT YOU HAVE ALREADY LEARNED ABOUT VACUUM TUBE VOLTMETERS, YOU ARE FAMILIAR WITH THEIR PRINCIPLE OF OPERATION AND ALSO REALIZE THAT VERY LITTLE ENERGY IS TAKEN FROM THE CIRCUIT UNDER TEST IN ORDER TO ACTUATE THE INDICATOR.

A POPULAR METHOD OF CONNECTING SUCH A DB. METER TO THE EQUIPMENT IS

IS TO CONNECT IT ACROSS THE 500 OHM LINE BETWEEN THE HIGH AND LOW LEVEL AMPLIFIER. THE INPUT TRANSFORMER OF THE UNIT ILLUSTRATED IN FIG.15 IS TAPPED AND PROVIDED WITH A SWITCH SO THAT THE INSTRUMENT CAN BE MADE TO READ DIFFERENT INPUT LEVELS. THE ARM POSITIONS ARE IN THIS CASE ALSO MARKED IN DECIBELS AND THE ACTUAL DB. LEVEL IS EQUAL TO THE ALGEBRAIC SUM OF THE DB. INDICATION ON THE SWITCH AND THE DB. READING ON THE METER.

THE POINT OF ZERO DB. ON THE METER SCALE IS SOMEWHERES NEAR THE CENTER OF THE SCALE AND THE POINTS IMMEDIATELY BELOW AND ABOVE IT ARE MARKED IN POSITIVE AND NEGATIVE VALUES.

A STILL DIFFERENT TYPE OF DB. VOLUME INDICATOR CONSISTS OF A MILLIAMMETER MOVEMENT WHICH IS FITTED WITH A COPPER-OXIDE RECTIFIER SO AS TO BE SUITABLE FOR TAKING A.C. MEASUREMENTS. THIS LATTER TYPE OF VOLUME INDICATOR IS USED A GREAT DEAL SINCE IT IS NOT AS EXPENSIVE AS THE V.T. VOLTMETER TYPE, REQUIRES NO AUXILIARY EQUIPMENT, AND CAN THEREFORE BE CONSTRUCTED IN A MORE COMPACT FORM AND AT THE SAME TIME IS CONVENIENT TO USE.

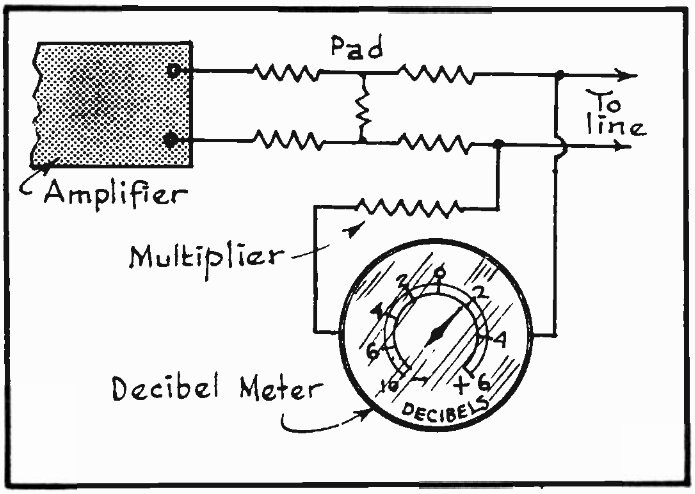

FIG 16
Application of the D.B. Meter.

WHEN USING THE COPPER OXIDE TYPE METER, MULTIPLIER'S ARE GENERALLY CONNECTED IN SERIES WITH THE METER AND THE AMPLIFIER LINE ACROSS WHICH THE METER IS CONNECTED. THE INSTRUMENT THEN FUNCTIONS AS A PEAK-READING VOLTMETER, ONLY THAT THE SCALE IS CALIBRATED IN DECIBELS. WITH THIS ARRANGEMENT, THE IMPEDANCE OF THE METER CIRCUIT IS SUFFICIENTLY HIGH SO THAT WHEN CONNECTED ACROSS THE A.F. LINE, IT DOES NOT NOTICEABLY AFFECT THE PROGRAM LEVEL.

ALTHOUGH IT IS A RATHER COMMON PRACTICE TO CONNECT THE VOLUME INDICATOR DIRECTLY ACROSS THE A.F. LINE WITH ADEQUATE RESISTANCE IN SEREIS SO AS TO PREVENT THE INSTRUMENT FROM ABSORBING A PROHIBITIVE AMOUNT OF ENERGY, YET THIS METHOD OFFERS A DISADVANTAGE IN THAT THE METER READING IS AFFECTED BY CHANGES IN THE FREQUENCY HANDLED BY THE LINE.

TO OVERCOME THIS, THE VOLUME INDICATOR IS FREQUENTLY CONNECTED ACROSS THE OUTPUT END OF A PAD WHICH IS INSTALLED BETWEEN THE OUTPUT OF THE AMPLIFIER AND THE LINE AS ILLUSTRATED IN FIG.16. IN THIS MANNER, THE IMPEDANCE ACROSS THE METER CIRCUIT IS KEPT PRACTICALLY CONSTANT AT ALL FREQUENCIES AND THEREFORE RESULTS IN A MORE ACCURATE INDICATION.

IT IS ALSO POSSIBLE TO CONNECT THE VOLUME INDICATOR ACROSS THE INPUT END OF THE PAD BUT WHEN THIS IS DONE, THE METER READING WILL BE

HIGHER THAN THE ACTUAL LINE LEVEL BY THE VALUE OF THE PAD.

DUPLICATE EQUIPMENT

IN ORDER TO PREVENT A LENGTHY INTERRUPTION IN A BROADCAST PROGRAM IN CASE OF THE FAILURE OF ONE OF THE UNITS, IT HAS BECOME THE PRACTICE TO DUPLICATE STATION EQUIPMENT. FOR EXAMPLE, IN FIG. 17 YOU ARE SHOWN IN DIAGRAM FORM A SERIES OF STUDIO AMPLIFIERS WHICH ARE CONNECTED TOGETHER THROUGH JACKS. THUS IT BECOMES OBVIOUS THAT IF AMPLIFIER #2 SHOULD SUDDENLY BECOME INOPERATIVE WHILE A PROGRAM IS IN PROGRESS, IT IS ONLY NECESSARY TO CONNECT AMPLIFIER #1 TO AMPLIFIER #3 DIRECT BY MEANS OF PATCH CORDS AND THUS ELIMINATE AMPLIFIER #1 ENTIRELY. THE GAIN OF THE

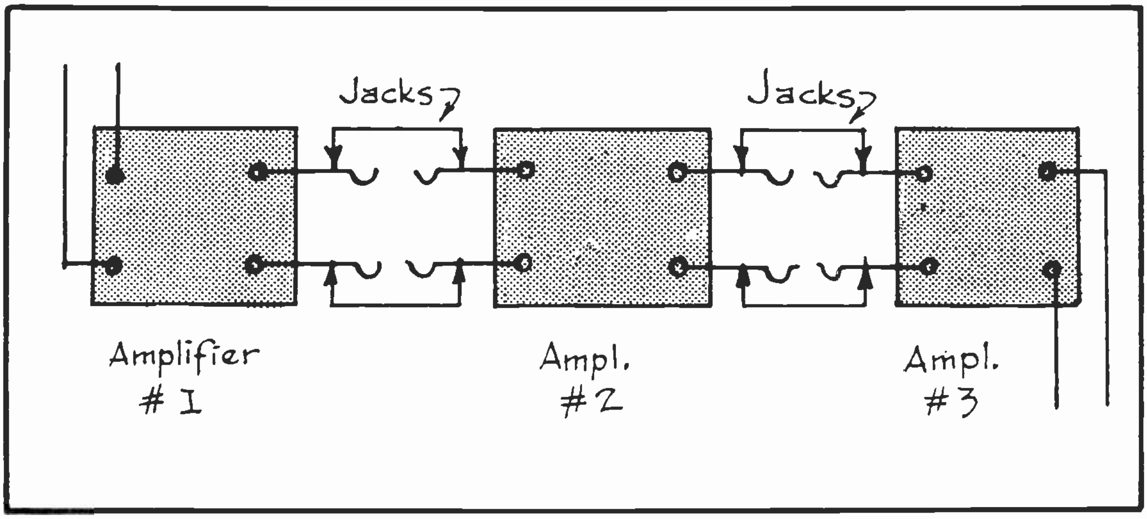

FIG. 17
Jack Connection of Amplifiers.

AMPLIFIERS IN USE CAN THEN BE TURNED UP TO A HIGHER LEVEL TO MAKE UP FOR THE LOSS OF AMPLIFIER #2. (A PATCH CORD IS NOTHING MORE THAN A FLEXIBLE INSULATED WIRE WITH A JACK PLUG ATTACHED TO EACH OF ITS ENDS).

FROM THIS LESSON YOU WILL HAVE OBTAINED A GOOD UNDERSTANDING OF THE EQUIPMENT WHICH IS RELATED TO THE BROADCAST STUDIO. IN THE NEXT LESSON, YOU WILL CONTINUE YOUR STUDY OF BROADCAST STATIONS BY LEARNING ABOUT ALL OF THAT EQUIPMENT WHICH IS LOCATED BETWEEN THE CONTROL ROOM APPARATUS AND THE ANTENNA SYSTEM. THIS WILL INCLUDE EQUALIZERS, BROADCAST TRANSMITTERS, SPEECH INPUT EQUIPMENT AND ALL OTHER APPARATUS WHICH IS DIRECTLY RELATED TO THE TRANSMITTER SECTION OF THE BROADCAST STATION.

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Examination Questions

LESSON NO. T-17

> Cooperation is the foundation upon which every successful business is built. To SUCCEED - COOPERATE!

1. - WHAT EQUIPMENT IS GENERALLY INCLUDED IN A TYPICAL STUDIO CONTROL ROOM?

2. - DRAW A FLOOR PLAN OF THE STUDIOS AND CONTROL ROOM OF A TYPICAL BROADCAST STATION AND LABEL CLEARLY THE VARIOUS SECTIONS OF THE SYSTEM.

3. - WHAT IS MEANT BY A LIVE END-DEAD END STUDIO?

4. - WHAT ARE SOME OF THE MORE IMPORTANT THINGS TO BE CONSIDERED WITH RESPECT TO MICROPHONE PLACEMENT IN A BROADCAST STUDIO?

5. - DESCRIBE A MIXER AS USED WITH RADIO BROADCASTING?

6. - DESCRIBE A LOW-LEVEL AMPLIFIER AND MENTION SOME OF THE MORE IMPORTANT REASONS FOR ITS USE IN CONNECTION WITH RADIO BROADCASTING.

7. - NAME SOME OF THE VARIOUS MATERIALS WHICH ARE USED FORTHE THE ACOUSTIC TREATMENT OF BROADCAST STUDIOS.

8. - DESCRIBE A TYPICAL VOLUME INDICATOR AND EXPLAIN HOW IT MAY BE USED IN RADIO BROADCASTING.

9. - WHAT IS MEANT BY AN ELECTRICAL TRANSCRIPTION AND WHAT EQUIPMENT IS REQUIRED IN THE BROADCAST STATION IN ORDER TO PRESENT PROGRAMS OF THIS TYPE?

10. - DRAW A COMPLETE CIRCUIT DIAGRAM OF ALL THE EQUIPMENT USED IN THE STUDIOS AND CONTROL ROOM OF A TYPICAL BROADCAST STATION AND ALSO SHOW HOW THESE VARIOUS UNITS ARE ALL CONNECTED TOGETHER FROM THE MICROPHONES UP TO THE LINES LEADING TO THE TRANSMITTER ROOM.

RADIO - TELEVISION

Practical • J. A. ROSENKRANZ, Pres. • Training

NATIONAL SCHOOLS

Established 1905

Los Angeles, California

Transmitters

LESSON NO. 18

• BROADCAST TRANSMITTERS •

IN THE PREVIOUS LESSON YOU LEARNED ABOUT THE CONTROL ROOM EQUIPMENT AS USED IN THE TYPICAL BROADCAST STATION, AND SHOULD NOW BE THOROUGHLY FAMILIAR WITH THE MANNER IN WHICH THE AUDIBLE SIGNALS ARE HANDLED FROM THE TIME THEY ORIGINATE IN THE MICROPHONE CIRCUIT UNTIL THEY FINALLY REACH THE CIRCUIT WHICH LEADS FROM THE CONTROL ROOM TO THE TRANSMITTER. THE NEXT LOGICAL STEP, THEREFORE, IS TO LEARN HOW THESE SAME SIGNALS ARE PASSED THROUGH THE TRANSMITTER CIRCUITS PREPARATORY TO THE RADIATION OF THE MODULATED CARRIER WAVE.

AS YOU HAVE ALREADY LEARNED, THE OUTPUT OF THE STUDIO CONTROL ROOM AMPLIFIER IS GENERALLY CONNECTED TO THE INPUT END OF THE TRANSMITTER EQUIPMENT THROUGH A TRANSMISSION LINE AS ILLUSTRATED IN FIG. 1. A TELEPHONE LINE IS ALSO CONNECTED BETWEEN THESE TWO LOCATIONS SO THAT THE OPERATORS CAN COMMUNICATE WITH EACHOTHER WHENEVER NECESSARY. THE LENGTH OF THIS TRANSMISSION LINE WILL NATURALLY VARY ACCORDING TO THE LAYOUT OF THE STATION IN QUESTION -- IN SOME OF THE SMALLER STATIONS THE LENGTH OF THIS LINE MAY ONLY AMOUNT TO A FEW FEET WHILE IN THE CASE OF REMOTE STUDIOS, THIS TRANSMISSION LINE MAY BE SEVERAL MILES IN LENGTH.

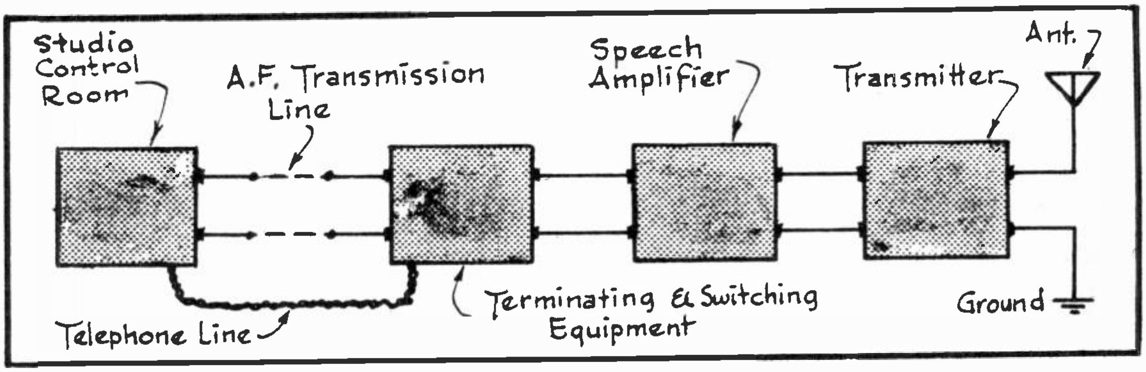

FIG. 1
Arrangement of Broadcast Transmitter Equipment.

EQUALIZERS

LONG TRANSMISSION LINES HAVE A NATURAL CHARACTERISTIC OF PRODUCING A LOSS OF THE HIGHER FREQUENCIES DUE TO THE CAPACITY EFFECT BETWEEN THE CONDUCTORS OF SUCH LINES. IF SUCH A CONDITION WERE PERMITTED TO EXIST, THE LOWER AUDIO FREQUENCIES WOULD BE TOO STRONG IN PROPORTION TO THE HIGHER FREQUENCIES AND THEREBY RESULT IN THE REPRODUCTION OF A PROGRAM WHICH IS NOT IDENTICAL IN QUALITY TO THE ORIGINAL SOUNDS AS PRODUCED IN THE STUDIO. TO OVERCOME THIS DIFFICULTY, EQUALIZERS ARE INSERTED IN THE TRANSMISSION LINE.

IN FIG.2 YOU ARE SHOWN HOW A PARALLEL-RESONANCE EQUALIZER MAY BE INSTALLED IN A TRANSMISSION LINE. THIS EQUALIZER CONSISTS OF A CONDENSER C CONNECTED ACROSS THE ENDS OF AN INDUCTANCE L TO FORM A RESONANT CIRCUIT. THIS RESONANT CIRCUIT IS THEN CONNECTED ACROSS THE TRANSMISSION LINE WITH A VARIABLE RESISTANCE R IN SERIES. AS YOU WILL READILY REALIZE WE HAVE HERE A PARALLEL-RESONANCE CIRCUIT.

TO BETTER ILLUSTRATE THE EFFECT OF THIS EQUALIZER, LET US ASSUME THAT THE NATURAL CHARACTERISTIC OF A CERTAIN TRANSMISSION LINE IS SUCH THAT MOST OF THE FREQUENCIES ABOVE 6000 CYCLES ARE ATTENUATED DUE TO THE DISTRIBUTED CAPACITY BETWEEN THE WIRES OF THE LINES. NOW IF THE PARALLEL-RESONANCE EQUALIZER OF FIG.2 WERE ADJUSTED TO RESONATE AT 6000 CYCLES AND CONNECTED ACROSS THE LINE AS SHOWN IN FIG. 2, IT WILL OFFER A MAXIMUM IMPEDANCE TO ENERGY OF THIS FREQUENCY AND CONSEQUENTLY VERY LITTLE ENERGY AT THE HIGHER FREQUENCIES WILL BE LOST THROUGH THIS CIRCUIT. IN OTHER WORDS, THE FEEBLE ENERGY ORDINARILY DEVELOPED ACROSS IT AT THE 6000 CYCLE FREQUENCY WILL BE INCREASED BY THE E.M.F. DEVELOPED ACROSS THIS HIGH IMPEDANCE.

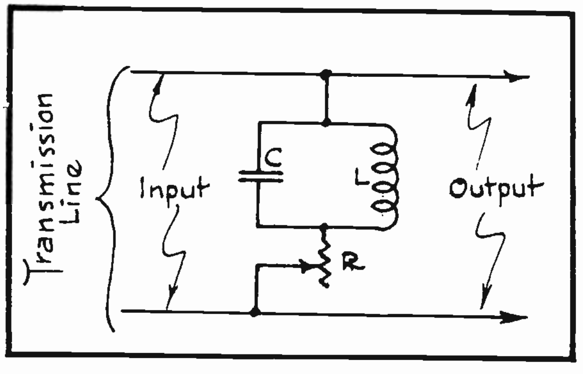

FIG.2
A Parallel-Resonance Equalizer.

FREQUENCIES BELOW THE RESONANT FREQUENCY OF THIS EQUALIZER WILL BE BY-PASSED THROUGH THIS CIRCUIT AND THUS SHUNTED ACROSS THE LINE. THE FARTHER THAT THE FREQUENCY IN QUESTION IS REMOVED FROM THE RESONANT FREQUENCY, THE GREATER WILL BE THE SHUNTING EFFECT AND THIS CAN TO A CERTAIN EXTENT BE CONTROLLED BY THE VALUE OF THE RESISTANCE USED AT R IN FIG.2.

THUS IT CAN BE SEEN THAT BY INCREASING THE TRANSMISSION OF ENERGY AT THE HIGHER FREQUENCIES AND REDUCING IT AT THE LOWER FREQUENCIES, THE OVERALL FREQUENCY CHARACTERISTIC OF THE LINE WILL BECOME MORE UNIFORM.

A SERIES-RESONANCE EQUALIZER IS ILLUSTRATED IN FIG.3. HERE A CONDENSER, INDUCTANCE, AND RESISTANCE ARE ALL CONNECTED IN SERIES AND TOGETHER CONNECTED ACROSS THE TRANSMISSION LINE. THE SERIES-RESONANCE EQUALIZER FUNCTIONS IN JUST THE REVERSE MANNER AS THE PARALLEL- RESONANCE UNIT IN THAT IT OFFERS A MINIMUM IMPEDANCE TO THE FREQUENCY AT WHICH IT RESONATES. THIS BEING TRUE, IT CAN BE SEEN THAT THE SERIES-RESONANCE EQUALIZER OPERATES AS A LOW IMPEDANCE OR ATTENUATING DEVICE.

THE CHARACTERISTICS OF THE SERIES-RESONANCE EQUALIZER BEST ADAPT IT AS A MEANS FOR ATTENUATING SOME LOWER FREQUENCY WHICH IS TOO STRONG IN RELATION TO ALL OF THE OTHER FREQUENCIES BEING HANDLED AND THEREFORE PREDOMINATES TO AN OBJECTIONABLE EXTENT. THUS THE SERIES-RESONANCE EQUALIZER ALSO MAKES THE FREQUENCY CHARACTERISTIC OF THE TRANSMISSION LINE MORE UNIFORM.

ALTHOUGH IT IS POSSIBLE TO PLACE THE EQUALIZER AT ANY POINT OF THE TRANSMISSION LINE, YET IT IS PERFERABLE TO PLACE IT AT THE OUTPUT END, THAT IS, THE END OF THE LINE WHICH IS CONNECTED TO THE TRANSMITTER EQUIPMENT. THIS LOCATION OF THE EQUALIZER PERMITS THE NECESSARY ADJUSTMENT TO BE MADE AT THAT POINT OF THE SYSTEM WHERE THE QUALITY OF TRANSMISSION IS MOST IMPORTANT AND WHERE IT IS ACTUALLY JUDGED. THIS SAME ARRANGEMENT IS ALSO MORE EFFECTIVE IN ATTENUATING ANY NOISE WHICH MAY BE PICKED UP BY THE LINE.

THE FREQUENCY RUN

IN ORDER TO DETERMINE THE FREQUENCY CHARACTERISTIC OF A TRANSMISSION LINE, A TEST IS MADE AND WHICH IS COMMONLY CALLED A FREQUENCY RUN. A TYPICAL SET-UP FOR A TRANSMISSION LINE FREQUENCY RUN IS ILLUSTRATED IN FIG.4.

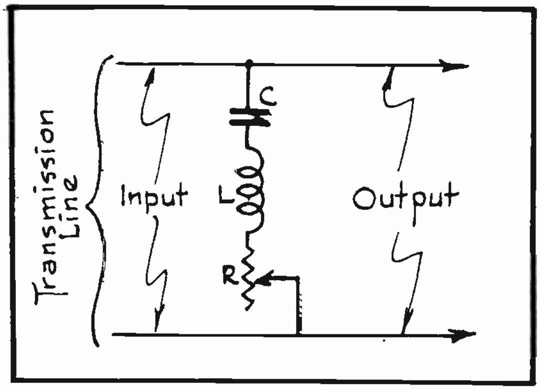

FIG.3
A Series-Resonance Equalizer

BY STUDYING FIG.4 CAREFULLY YOU WILL NOTE THAT AT THE INPUT END OF THE LINE WE HAVE EITHER A PHONOGRAPH PICK-UP OR ELSE AN AUDIO OSCILLATOR WORKING INTO AN AMPLIFIER AND THIS AMPLIFIER IS IN TURN CONNECTED TO THE TRANSMISSION LINE THROUGH A PAD. IN THE EVENT THAT A PHONOGRAPH INPUT IS USED FOR THIS TEST, SPECIAL "FREQUENCY RECORDS" ARE EMPLOYED. RECORDS OF THIS TYPE ARE MADE SPECIFICALLY FOR TESTING PURPOSES AND WILL FURNISH A VARIETY OF KNOWN TONES OR FREQUENCIES. THE AUDIO OSCILLATOR YOU ARE ALREADY FAMILIAR WITH.

BY APPLYING A KNOWN FREQUENCY TO THIS END OF THE LINE, THE VOLUME IS ADJUSTED SO THAT A CONVENIENT READING APPEARS ON THE VOLUME INDICATOR #1 AT THIS LOCATION.

THE OTHER END OF THE TRANSMISSION LINE FEEDS INTO THE EQUALIZER, WHICH IS FOLLOWED BY AN AMPLIFIER AND ACROSS WHOSE OUTPUT ANOTHER VOLUME INDICATOR (#2) IS CONNECTED. WITH A CERTAIN FREQUENCY APPLIED TO THE INPUT END OF THE TRANSMISSION LINE, AS ALREADY EXPLAINED, THE READING OF VOLUME INDICATOR #2 IS NOTED.

A SIGNAL OF A DIFFERENT FREQUENCY IS THEN APPLIED TO THE LINE AND THE EQUIPMENT AT THIS END OF THE LINE IS ADJUSTED SO THAT VOLUME INDICATOR #1 OFFERS THE SAME READING AS BEFORE. THE READING OF VOLUME INDICATOR #2 IS THEN NOTED. THE SAME TEST IS REPEATED FOR AS MANY DIFFERENT FREQUENCIES AS DESIRED -- IT IS COMMON TO MAKE THIS TEST AT 100; 1,000; 3,000; AND 5,000 CYCLES, ALTHOUGH A MUCH GREATER VARIETY OF FREQUENCIES

CAN BE EMPLOYED IF ONE SO CHOOSES.

FROM THE DATA WHICH IS OBTAINED FROM THIS FREQUENCY RUN, A FREQUEN-CY RESPONSE CURVE SIMILAR TO THAT SHOWN IN FIG.5 CAN BE PLOTTED. THE EQUALIZER VALUES CAN THEN BE ADJUSTED AS FOUND NECESSARY IN ORDER TO FLATTEN OR STRAIGHTEN OUT THIS CURVE SO THAT REASONABLY UNIFORM FREQUEN-CY CHARACTERISTICS CAN BE ATTAINED FROM THE LINE.

THE SET UP FOR MAKING THE FREQUENCY RUN IS NOT ALWAYS EXACTLY LIKE THAT WHICH IS ILLUSTRATED IN FIG.4. SOMETIMES, THE LINE OUTPUT, AFTER BE EQUALIZED, IS CONNECTED TO A SUITABLE LINE-TERMINATING COIL AND THE OUT OF WHICH IS PASSED THROUGH A PAD. THE LEVEL AT THE OUTPUT OF THE CAN THEN BE MEASURED WITH A SENSITIVE THERMOCOUPLE TYPE D.B. METER.

WHENEVER A TRANSMISSION LINE AS THIS IS OF EXCESSIVE LENGTH, BOOST-ER AMPLIFIERS ARE INSERTED AT INTERVALS. SUCH BOOSTERS, WHEN USED, ARE US-UALLY INSERTED EVERY 10 OR 20 MILES AND THEY SERVE NOT ONLY TO MAINTAIN

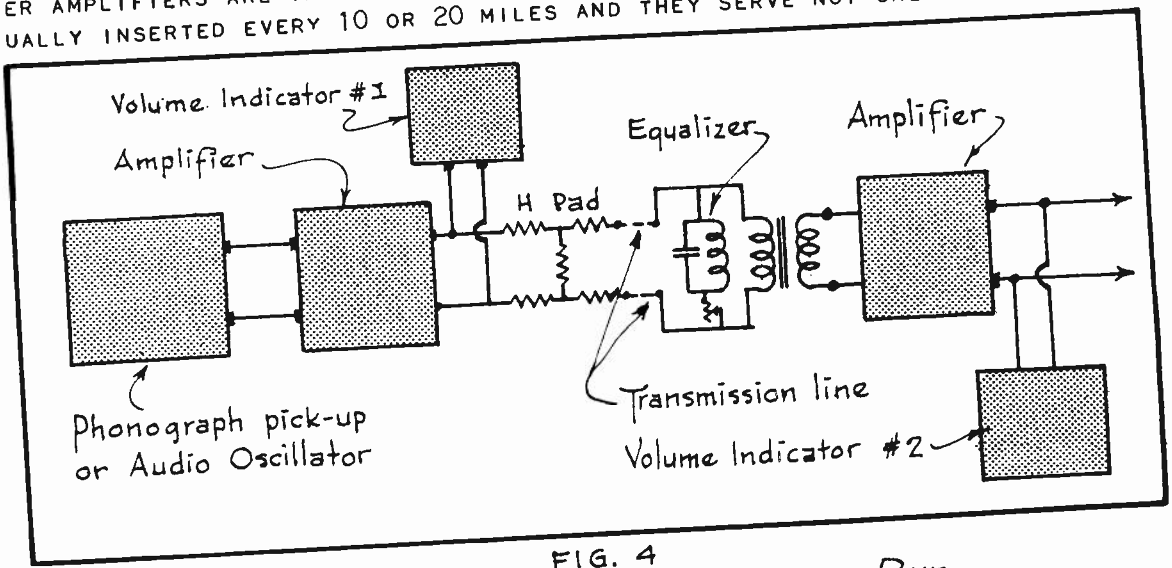

FIG. 4
Set-up for a Transmission Line Frequency Run.

THE PROGRAM LEVEL AT A DESIRED POINT WITH RESPECT TO ATTENUATION DUE TO LONG LINES BUT ALSO PERMIT MAINTAINING THE PROGRAM LEVEL WELL ABOVE THE LINE NOISE.

REMOTE CONTROL EQUIPMENT

THE EQUIPMENT USED FOR REMOTE CONTROL BROADCASTS IS QUITE SIMILAR TO THAT EMPLOYED IN THE STUDIO AND STUDIO CONTROL ROOM, WITH THE EXCEP-TION THAT IT IS USUALLY OF PORTABLE DESIGN. THIS APPARATUS CONSISTS ESS-ENTIALLY OF AN AMPLIFIER, MIXER, VOLUME INDICATOR, AND A BATTERY POWER SUPPLY. CARBON MICROPHONES ARE USED CONSIDERABLY FOR THIS PURPOSE DUE TO THEIR PORTABILITY AND HIGH OUTPUT, ALTHOUGH WHERE CONDITIONS PERMIT, APPARATUS OF STILL MORE ELABORATE DESIGN IS USED.

IN CERTAIN INSTANCES, SUCH AS WHERE A DANCE ORCHESTRA BROADCASTS REGULARLY, NO MIXER OR VOLUME INDICATOR IS USED AND THE ANNOUNCER HIM-SELF PLACES THE EQUIPMENT IN OPERATION AT THE TIME THE PROGRAM GOES ON

THE AIR. UNDER THESE CONDITIONS, NO STATION OPERATOR NEED BE SENT TO THE ORIGIN OF THE REMOTE BROADCAST.

IN THIS LAST MENTIONED CASE, IT IS ALSO THE USUAL PRACTICE TO FEED A CONSIDERABLE OUTPUT FROM THE AMPLIFIER INTO THE SPECIAL PROGRAM TELEPHONE LINE LEADING TO THE STATION SO AS TO SATISFACTORILY COVER UP THE NORMAL LINE NOISE.

BROADCAST TRANSMITTERS

BROADCASTING STATIONS OF SMALL AND MODERATE SIZE USUALLY HAVE THEIR STUDIOS AND ALL TRANSMITTING EQUIPMENT LOCATED ON THE SAME PREMISES AND WHICH SIMPLIFIES THE SYSTEM CONSIDERABLY. MANY OF THE MORE POWERFUL STATIONS, HOWEVER, HAVE THEIR STUDIOS LOCATED IN A METROPOLITAN CITY SO AS TO BE CONVENIENT FOR THE ARTISTS, EXECUTIVES, PUBLICITY STAFF ETC. WHO ARE ASSOCIATED WITH THE STATION. SINCE NEARBY BUILDINGS AND OTHER STEEL STRUCTURES HAVE A TENDENCY TO REDUCE THE EFFICIENCY OF RADIATION, THE TRANSMITTERS OF SUCH STATIONS ARE USUALLY LOCATED AT SOME DISTANCE OUTSIDE OF THE CONGESTED SECTION OF THE CITY AND THE PROGRAMS ARE CARRIED FROM THE STUDIO TO THE TRANSMITTER BUILDING OVER SPECIAL TELEPHONE LINES. IN FACT, SEVERAL OF SUCH TRANSMISSION LINES ARE GENERALLY SUPPLIED BETWEEN THE STUDIO AND TRANSMITTER TO FASCILITATE THE HANDLING OF PROGRAMS, AS WELL AS TO INSURE UNINTERRUPTED SERVICE IF ONE OF THE LINES SHOULD DEVELOPE TROUBLE. IN ADDITION TO THE PROGRAM LINES, PRIVATE TELEPHONE LINES ARE ALSO INCLUDED BETWEEN THE STUDIO AND THE TRANSMITTING QUARTERS SO THAT THE OPERATING PERSONNEL AT BOTH POINTS CAN MAINTAIN CONTINUAL COMMUNICATION BETWEEN EACHOTHER.

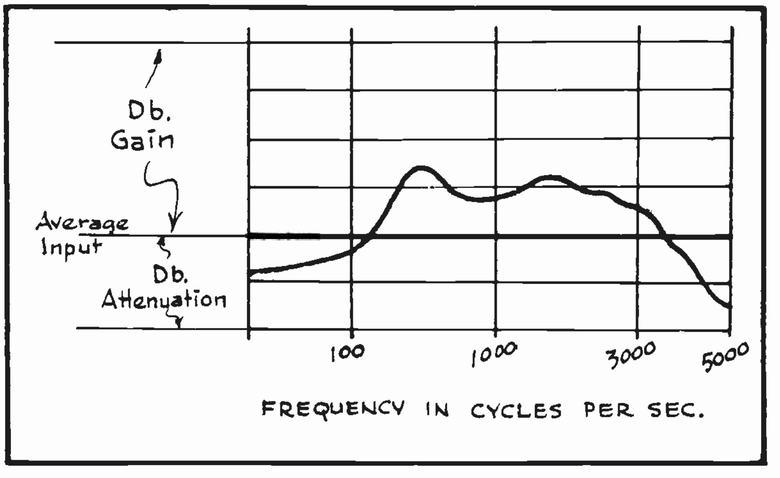

FIG. 5.
A Frequency Response Curve

THE FIRST PIECE OF EQUIPMENT WHICH IS IMMEDIATELY ASSOCIATED WITH THE TRANSMITTER IS THE SWITCHING EQUIPMENT AS POINTED OUT IN FIG.1 OF THIS LESSON. SINCE MOST STATIONS ARE EQUIPPED TO FEED THE MICROPHONES FROM SEVERAL STUDIOS INTO THE TRANSMITTER EQUIPMENT, AS WELL AS HAVING PROGRAM LINES LEADING TO VARIOUS SOURCES FOR REMOTE CONTROL AND CHAIN HOOK-UPS, THE SWITCHING EQUIPMENT AT THE STATION OFFERS A CONVENIENT MEANS OF CONNECTING THE DESIRED LINE TO THE APPARATUS FOR ANY PARTICULAR PROGRAM. THIS SWITCHING EQUIPMENT IS SIMILAR IN APPEARANCE AND OPERATION TO A SWITCHBOARD AS USED FOR TELEPHONE SERVICE. IMPEDANCE MATCHING DEVICES, EQUALIZERS AND ASSOCIATED LINE TERMINATING EQUIPMENT IS ALSO INSTALLED AT THIS POINT.

FOLLOWING THIS PART OF THE TRANSMITTER EQUIPMENT WE HAVE THE SPEECH

AMPLIFIER AND THE PURPOSE OF WHICH IS TO ACCEPT THE COMPARATIVELY FEEBLE A.F. ENERGY COMING OVER THE LINE AND AMPLIFY IT TO THE EXTENT NECESSARY IN ORDER TO PROPERLY MODULATE THE TRANSMITTER. AFTER THE SPEECH AMPLIFIER COMES THE TRANSMITTER ITSELF.

SO THAT YOU MAY OBTAIN A PERFECTLY CLEAR PICTURE OF THE ENTIRE BROADCAST STATION EQUIPMENT COMPLETE FROM THE MICROPHONE TO THE ANTENNA, WE SHALL USE A WESTERN ELECTRIC 1 KW. BROADCAST TRANSMITTER AS A PRACTICAL EXAMPLE.

SPEECH INPUT EQUIPMENT

THE SPEECH INPUT EQUIPMENT FOR THIS TRANSMITTER APPEARS IN FIG. 6. THIS APPARATUS, YOU WILL OBSERVE, CONSISTS OF A DYNAMIC MICROPHONE FEEDING INTO A LOW-LEVEL SPEECH AMPLIFIER.

TRANSFORMER COUPLING IS USED THROUGHOUT THIS LOW-LEVEL SPEECH AMPLIFIER AND SO AS TO PREVENT SATURATING THE CORE OF THESE TRANSFORMERS, THE PLATE CURRENT FOR THE TWO TUBES USED IN THIS AMPLIFIER IS CARRIED BY PLATE LOAD RESISTORS R_P AND ONLY THE ALTERNATING OR SIGNAL VOLTAGES CAN REACT THROUGH THE CONDENSERS C_B AND THUS BECOME EFFECTIVE AT THE PRIMARY WINDING OF THE FOLLOWING A.F. TRANSFORMER. THE CORES OF HIGH-GRADE TRANSFORMERS SATURATE VERY READILY AND THEREFORE THE CIRCUIT ARRANGEMENT AS HERE USED IS NECESSARY.

THE OUTPUT OF THE LOW-LEVEL SPEECH AMPLIFIER IS FED INTO THE INPUT OF THE HIGH-LEVEL SPEECH AMPLIFIER THROUGH AN ATTENUATING DEVICE IN THE

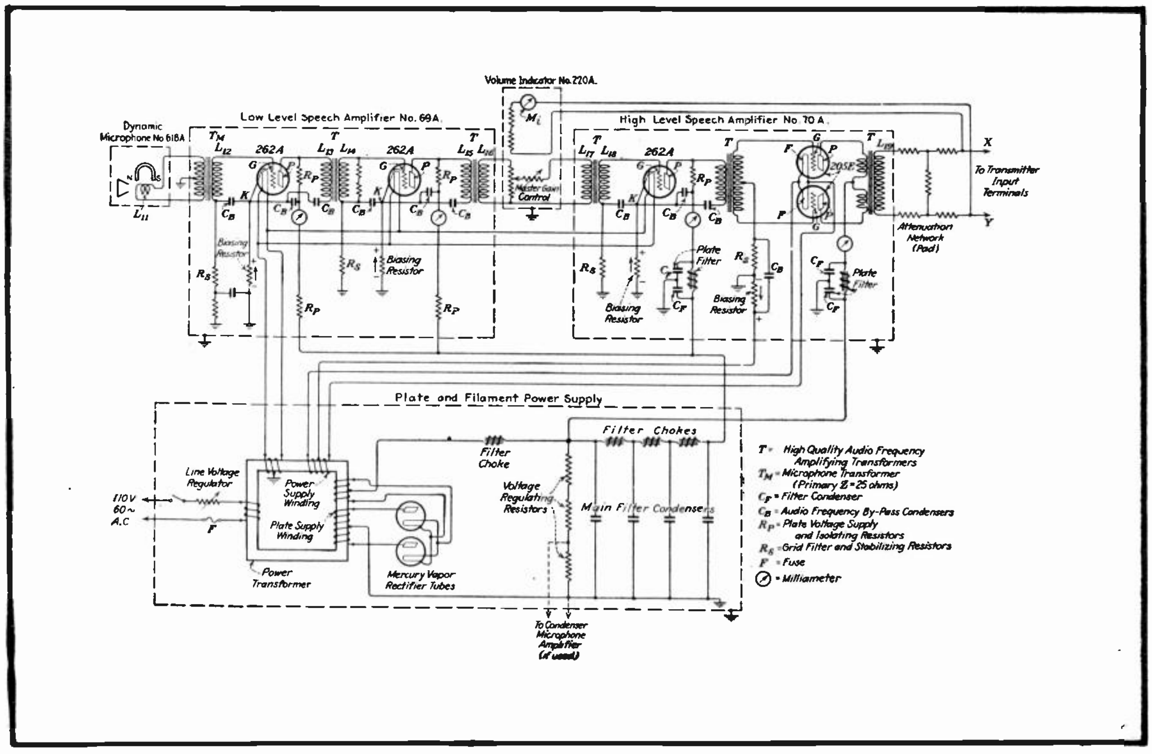

FIG. 6

Diagram of Western Electric Speech Amplifier.

FORM OF A MASTER GAIN CONTROL. THIS GAIN CONTROL IS IN REALLITY A DB. VOLUME CONTROL EQUIPPED WITH 18 STEPS AND 2 DB. PER STEP. THE VOLUME INDICATOR MAKES IT POSSIBLE FOR THE OPERATOR TO KNOW AT WHAT POSITION TO PLACE THE MASTER GAIN CONTROL FOR ANY GIVEN OCCASSION.

THE PUSH-PULL POWER STAGE OF THE HIGH-LEVEL SPEECH AMPLIFIER BY MEANS OF AN OUTPUT TRANSFORMER IS CONNECTED TO A 5 DB. ATTENUATION NETWORK OF THE H-PAD TYPE AND WHICH IN TURN HAS ITS OUTPUT CONNECTED TO A 500 OHM LINE LEADING TO THE TRANSMITTER. A VOLUME INDICATOR OF THE COPPER-OXIDE RECTIFIER TYPE IS CONNECTED THROUGH A MULTIPLIER RESISTANCE ACROSS THE OUTPUT OF THE ATTENUATION NET-WORK.

ALSO NOTE IN FIG.6 THAT THIS SPEECH AMPLIFYING EQUIPMENT HAS ITS INDIVIDUAL PLATE AND FILAMENT POWER SUPPLY APART FROM THE POWER SUPPLY OF THE TRANSMITTER.

THE TRANSMITTER

IN FIG.7 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF THE 1 KW.WESTERN ELECTRIC BROADCAST TRANSMITTER INTO WHICH THE SPEECH AMPLIFYING EQUIPMENT OF FIG.6 OPERATES. BY STUDYING THE DIAGRAM IN FIG.7 CLOSELY, YOU WILL NOTE THAT THE LINE FROM THE SPEECH AMPLIFYING EQUIPMENT IS CONNECTED ACROSS THE PRIMARY WINDING OF TRANSFORMER T_{14} AND WHOSE SECONDARY WINDING IS CONNECTED IN THE GRID CIRCUIT OF THE TRANSMITTER'S THIRD AMPLIFIER SECTION (THE MODULATED R.F. AMPLIFIER). THIS CIRCUIT CONNECTION WILL IMMEDIATELY INFORM YOU OF THE FACT THAT GRID-MODULATION IS USED IN THIS PARTICULAR TRANSMITTER.

THIS TRANSMITTER IS CONSTRUCTED IN TWO DISTINCT SECTIONS, INDEPENDENT OF EACHOTHER. ONE SECTION INCLUDES ALL THAT EQUIPMENT FROM THE OSCILLATOR UP TO THE MODULATED R.F. STAGE IN WHICH THE TWO 270-A TUBES ARE USED. THE OUTPUT OF THIS AMPLIFIER IS 100 WATTS AND IT MAY THEREFORE ACTUALLY BE OPERATED AS A 100 WATT TRANSMITTER BY CONNECTING ITS OUTPUT TO AN ANTENNA SYSTEM. THE 1000 WATT MAIN POWER AMPLIFIER IS AN ENTIRELY SEPARATE UNIT.

POWER CONTROL AND PROTECTION CIRCUITS

FROM WHAT YOU HAVE ALREADY LEARNED IN PREVIOUS LESSONS ABOUT TRANSMITTERS, YOU WILL BE FAMILIAR WITH THE OPERATION OF THE VARIOUS SECTIONS OF THE ASSEMBLY ILLUSTRATED IN FIG.7. THE SYSTEM OF RELAYS, HOWEVER, WHICH IS USED IN THIS INSTALLATION, IS SOMEWHAT DIFFERENT THAN ANY OF THOSE WHICH HAVE BEEN SHOWN YOU UP TO THIS TIME AND FOR THIS REASON WILL NOW BE EXPLAINED IN DETAIL.

THE OPERATION OF THE POWER-CONTROL AND PROTECTION CIRCUITS OF THIS TRANSMITTER IS AS FOLLOWS:

THE MAIN SWITCH SW_1 CONNECTS A THREE-PHASE 220-VOLT 60-CYCLE SOURCE TO THE VARIOUS CIRCUITS OF THE TRANSMITTER AND IS CLOSED WHEN THE TRANSMITTER IS IN OPERATION. THESE CIRCUITS, WITH THE EXCEPTION OF THE TRANSFORMER T_1, WILL, HOWEVER, NOT BE ENERGIZED BY THE CLOSING OF THIS SWITCH. THE TRANSFORMER T_1 MUST BE CONSTANTLY ENERGIZED IN ORDER TO OPER-

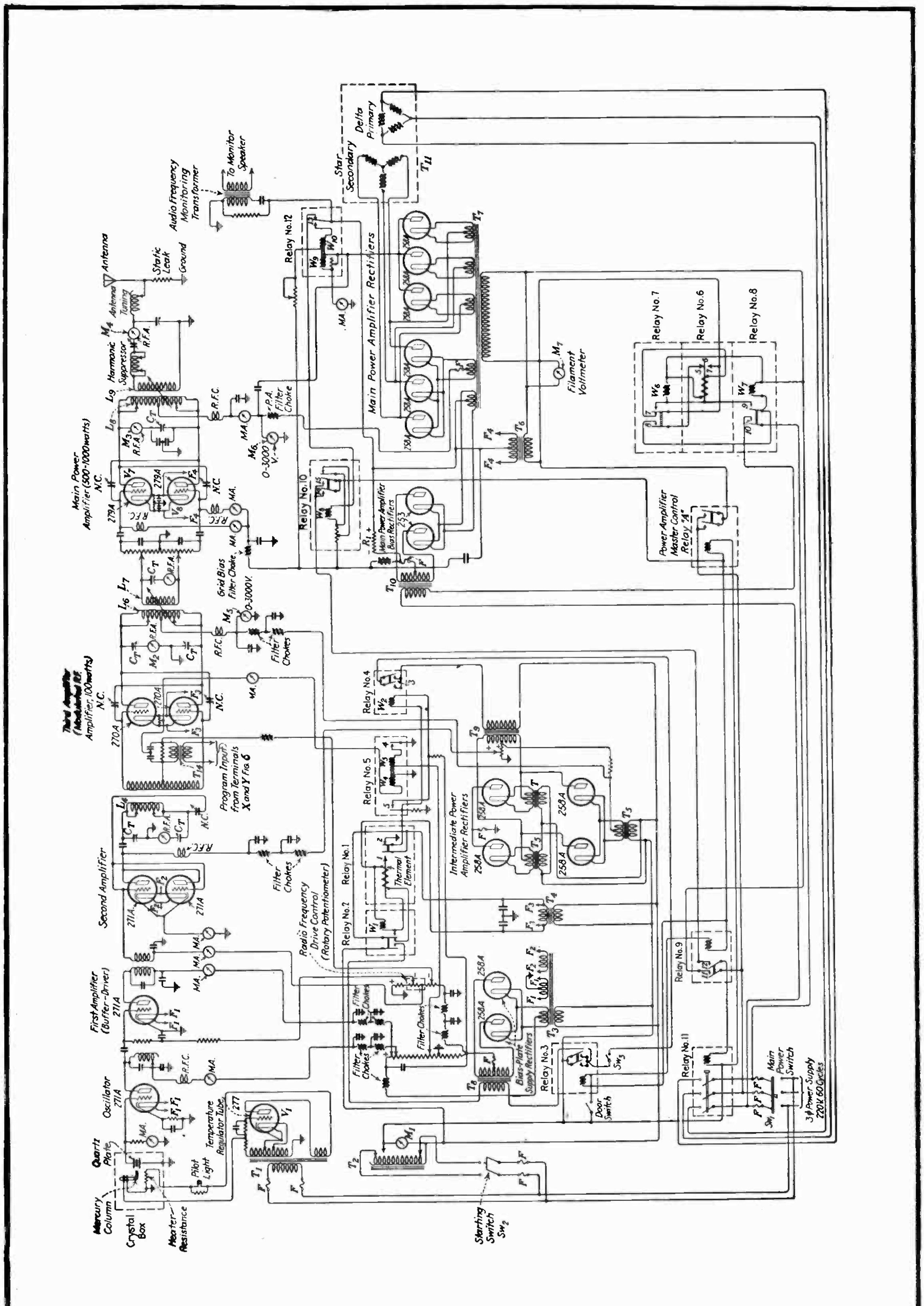

FIG. 7

Diagram of Western Electric Broadcast Transmitter.

ATE THE TEMPERATURE-CONTROL CHAMBER OF THE CRYSTAL BOX TO MAINTAIN A CONSTANT-OPERATING FREQUENCY. THE PRIMARY WINDING IS, THEREFORE, PERMANENTLY CONNECTED ACROSS THE ALTERNATING-CURRENT LINE. IF THIS SWITCH IS LEFT OPEN FOR A CONSIDERABLE TIME THE TEMPERATURE IN THE CRYSTAL CHAMBER WILL BE ALTERED, AND A FREQUENCY DEVIATION OF SEVERAL HUNDRED CYCLES MAY RESULT. THIS TRANSFORMER SUPPLIES THE FILAMENT, PLATE, AND BIAS VOLTAGES FOR THE ARGON REGULATOR TUBE V_1.

THE NEXT SWITCH TO BE CLOSED IS Sw_2. THIS SUPPLIES AN ALTERNATING-CURRENT VOLTAGE ACROSS AN AUTOTRANSFORMER T_2. A TAPPED PORTION OF THIS TRANSFORMER CONNECTS TO A ROTARY SWITCH FOR THE PURPOSE OF SELECTING THE PROPER ALTERNATING-CURRENT VOLTAGE TO BE DELIVERED TO THE OPERATING CIRCUITS. THIS PROVIDES THE PROPER FLEXIBILITY NECESSARY TO MAINTAIN THE DESIRED VOLTAGE TO THE LOAD CIRCUITS TO COMPENSATE FOR LINE-VOLTAGE CHANGES. THIS VOLTAGE MUST BE MAINTAINED AT 220 VOLTS AS INDICATED BY THE ALTERNATING-CURRENT LINE VOLTMETER M_1. ANY VARIATION IN THE SUPPLY-LINE VOLTAGE MAY THEN BE REGULATED BY THE ROTARY SWITCH TO THE REQUIRED VALUE.

THE AUTOTRANSFORMER VOLTAGE EXCITES THE PRIMARY WINDINGS OF THE FILAMENT-LIGHTING TRANSFORMERS T_3, T_4, AND T_5 AND THE MASTER-CONTROL RELAY A WHICH CLOSES AND EXCITES THE PRIMARY WINDINGS OF THE FILAMENT TRANSFORMERS T_6 AND T_7 FOR THE POWER AMPLIFIER AND RECTIFIER TUBES, RESPECTIVELY.

CONNECTED ACROSS THE SECONDARY WINDING OF THE FILAMENT TRANSFORMER T_4 IS A RESISTANCE UNIT WHICH BECOMES HEATED WHEN THE WINDING IS ENERGIZED. THIS UNIT (AND ITS ASSOCIATED CONTACTS) IS KNOWN AS A THERMAL OR HEATER-ELEMENT TIME-DELAY RELAY, (RELAY 1). THIS RESISTANCE IS LOCATED VERY CLOSE TO AN ALLOY STRIP (THERMAL ELEMENT) WHICH, WHEN HEATED, BEGINS TO EXPAND OWING TO THE EFFECT OF HEAT ON THE METAL. AS THIS METAL STRIP EXPANDS SUFFICIENTLY IT FINALLY MAKES CONTACT WITH THE TERMINAL 1 ON THE UNIT AND ENERGIZES ANOTHER RELAY COIL WINDING W_1 OF RELAY 2. THE MAGNETIZED WINDING OF THIS COIL ATTRACTS TWO METAL CONTACT STRIPS WHICH, WHEN CLOSED, OPEN UP THE CONNECTION TO THE HEATER UNIT OF RELAY 1 AND CLOSE THE CIRCUIT LEADING TO THE PRIMARY WINDING OF THE TRANSFORMER T_8. THIS TRANSFORMER SUPPLIES THE PLATE VOLTAGE TO THE OSCILLATOR AND BUFFER-AMPLIFIER STAGES ONLY AND ALSO SUPPLIES THE NEGATIVE BIAS TO THE GRIDS OF THE FIRST AMPLIFIER AND MODULATING RADIO-FREQUENCY AMPLIFIER STAGES. IT IS IMPORTANT TO NOTE, HOWEVER, THAT RELAY 2 CANNOT BE ACTUATED UNLESS RELAY 3 IS ALSO CLOSED. THE LATTER CAN ONLY BE OPERATED WHEN ALL DOOR SWITCHES ARE CLOSED BY TIGHTLY LOCKING ALL COMPARTMENT DOORS.

SINCE THE HEATING RESISTANCE UNIT OF RELAY 1 IS OPEN-CIRCUITED, THE HEATING EFFECT UPON THE METAL STRIP WILL BE DECREASED AND CONSEQUENTLY WILL CAUSE THE STRIP TO RETURN BACK TO ITS NORMAL POSITION. THIS CLOSES THE BACK CONTACTS 2 AND COMPLETES THE CIRCUIT THROUGH THE RELAY 4, WINDING W_2. THIS CLOSES THE CONTACT 3 ON THIS RELAY AND EXCITES THE PRIMARY WINDING OF THE PLATE-VOLTAGE TRANSFORMER T_9. IT IS ASSUMED, OF COURSE, THAT THE PLATE-SUPPLY SWITCH Sw_3 AND THE DOOR-SWITCH RELAY 3 HAVE BEEN PREVIOUSLY CLOSED.

THE OVERLOAD RELAY 5 OF THE TRANSMITTER CONSISTS OF TWO COILS, NAMELY, THE OVERLOAD-COAL WINDING W_4 AND THE OPERATING WINDING W_5. THE OVER

LOAD COIL IS CONNECTED IN SERIES WITH THE CENTER TAPPED FILAMENT RETURN LEAD TO GROUND WHICH COMPLETES THE PLATE-CURRENT CIRCUIT FOR THE MODULATED RADIO-FREQUENCY AMPLIFIER TUBES. IF AN ABNORMAL FLOW OF PLATE CURRENT SHOULD RESULT IN THESE TUBES DUE TO EXCESSIVE MODULATION PEAKS OR LINE-VOLTAGE SURGES, THE WINDING W_4 OF RELAY 5 WILL BE ENERGIZED SUFFICIENTLY TO DRAW OVER THE CONTACTORS AND CLOSE THE CIRCUITS 4 AND 5. THIS ACTION WILL SHORT-CIRCUIT THE WINDING OF RELAY 4 THEREBY DEMAGNETIZING IT AND RELEASING THE CONTACTS 3 ON THE RELAY 4. THUS THE PRIMARY WINDING OF THE PLATE-SUPPLY TRANSFORMER T_9 WILL BE OPENED AND THE HIGH VOLTAGE TO THE MODULATED AMPLIFIER TUBES WILL BE DISCONNECTED.

A SMALL OVERLOAD RESET PUSH-BUTTON (NOT SHOWN) IS PROVIDED TO OPEN THE WINDING W_5 SO THAT THE SHORT CIRCUIT WILL BE REMOVED FROM THE WINDING W_2 ON RELAY 4 AND THEREBY REESTABLISH THE PLATE VOLTAGE TO THE MODULATED AMPLIFIER TUBES.

WHEN THE MASTER CONTROL RELAY A IS CLOSED, THE PRIMARY WINDING OF THE FILAMENT TRANSFORMERS T_6 AND T_7 ARE EXCITED AS STATED BEFORE. AT THE SAME TIME, HOWEVER, ANOTHER THERMAL TIME-DELAY RELAY 6 IS HEATED, SINCE IT IS CONNECTED ACROSS THE PRIMARY WINDINGS OF THE TWO FILAMENT TRANSFORMERS T_6 AND T_7. THIS RESULTS IN THE EXPANSION OF THE THERMAL ELEMENT AND THE CLOSING OF CONTACTS 6 AND 7; AND THIS ALLOWS CURRENT TO FLOW THROUGH THE WINDING W_6 WHICH ENERGIZES RELAY 7. WHEN THIS RELAY IS ENERGIZED, THE CONTACT 7 IS OPENED AND THE HEATER WINDING OF RELAY 6 IS BROKEN, THUS ALLOWING THE THERMAL ELEMENT TO CONTRACT AND REESTABLISH CONNECTIONS 5 AND 6 ON RELAY 6. AT THE SAME TIME, HOWEVER, THE CONTACT 8 IS CLOSED WHICH ALLOWS A CURRENT TO FLOW THROUGH THE WINDING W_7. THIS MAGNETIZES RELAY 8 AND CLOSES THE CONTACTS 9 AND 10. THE CLOSING OF THESE CONTACTS ALLOWS AN ALTERNATING CURRENT TO FLOW THROUGH THE PRIMARY WINDING OF THE TRANSFORMER T_{10} AND ESTABLISH A VOLTAGE BETWEEN THE TWO PLATES OF THE ASSOCIATED MERCURY-VAPOR RECTIFIER TUBES. THIS RESULTS IN A CURRENT FLOW THROUGH THE RESISTANCE R_1 WHICH DEVELOPS A VOLTAGE DROP ACROSS IT. THIS DROP IS USED TO SUPPLY THE BIAS OF -275 VOLTS TO THE GRIDS OF THE TWO POWER-AMPLIFIER TUBES V_7 AND V_8. THIS IS, OF COURSE, PROVIDED THAT THE RELAY 9 IS ALSO CLOSED BY HAVING ALL DOOR SWITCHES LOCKED. OTHERWISE CONTACT 11 WILL BE OPEN AND NO CURRENT WILL PASS THROUGH T_{10}.

AS SOON AS THE GRID-BIAS VOLTAGE IS DEVELOPED ACROSS THE RESISTANCE R_1, A CURRENT WILL PASS THROUGH THE GRID-BIAS RELAY 10 BECAUSE IT IS CONNECTED DIRECTLY ACROSS THE RESISTOR THROUGH CONTACTS 13. THIS ACTUATES THE RELAY WINDING W_8 BY MAGNETIZING THE IRON CORE AND CLOSING THE CONTACTS 14 AND 15. IN SERIES WITH THESE CONTACTS IS A LARGE SOLENOID CONTACTOR, RELAY 11, WHICH BECOMES ENERGIZED AND DRAWS OVER THREE CONTACTORS TO CLOSE THE THREE-PHASE ALTERNATING-CURRENT SUPPLY TO THE HIGH-VOLTAGE TRANSFORMER T_{11}. THIS ACTION SUPPLIES THE ALTERNATING-CURRENT HIGH VOLTAGE TO THE PLATES OF THE MAIN POWER-AMPLIFIER, MERCURY-VAPOR RECTIFIER TUBES, WHERE IT IS THEN RECTIFIED TO THE DESIRED DIRECT-CURRENT POTENTIAL OF 3,000 VOLTS FOR THE PLATE SUPPLY.

ALL CIRCUITS SHOULD NOW BE EXCITED AND THE PROPER PLATE, BIAS, AND FILAMENT VOLTAGES SHOULD BE APPLIED. THESE VOLTAGES MAY NOW BE PROPERLY CHECKED BY THE FILAMENT VOLTMETER M_7 AND THE DIRECT-CURRENT VOLTMETERS M_5 AND M_6. ALL PLATE AND RADIO-FREQUENCY CURRENTS MAY ALSO THEN BE CHECK-

ED BY THE VARIOUS PLATE MILLIAMMETERS MA, AND BY THE RADIO-FREQUENCY AMMETERS RFA, IN THE RESPECTIVE CIRCUITS.

IN THE W.E. INSTALLATION ONLY ONE MILLIAMMETER IS USED TO OBTAIN THE PLATE AND GRID-CURRENT READINGS FOR SEVERAL OF THE LOW-POWER STAGES IN THE 100-WATT UNIT. THIS IS ACCOMPLISHED BY A NUMBER OF RESISTANCE SHUNTS AND A ROTARY-SELECTOR SWITCH WHICH TRANSFERS THE METER INTO THE DESIRED CIRCUIT. IN FIG. 7 THIS SWITCH AND THE ASSOCIATED SHUNTS ARE OMITTED, BUT INDIVIDUAL METERS ARE INSERTED IN THEIR PROPER PLACES TO SIMPLIFY CIRCUIT ANALYSIS.

ALL PLATE AND POWER-SUPPLY CIRCUITS ARE SUITABLY PROTECTED BY FUSES AND OVERLOAD CIRCUIT BREAKERS AS ILLUSTRATED IN THE DIAGRAM. TWO OVERLOAD RELAYS 5 AND 12 ARE PROVIDED IN THE 100-WATT AND POWER AMPLIFIER UNITS TO ENABLE THE OPERATOR QUICKLY TO REESTABLISH TRANSMITTER OPERATION IN THE EVENT OF A CIRCUIT BREAKER "TRIPPING" OWING TO EXCESSIVE MODULATION PEAKS, LINE-VOLTAGE SURGES, OR TEMPORARY CONDENSER FLASHOVERS DUE TO DUST ACCUMULATION.

THE OVERLOAD-COIL WINDING W_9 OF RELAY 12 IS CONNECTED IN SERIES WITH THE NEGATIVE TERMINAL OF THE 3,000-VOLT RECTIFIER AND GROUND. IF AN EXCESSIVE VALUE OF CURRENT FLOWS THROUGH THIS COIL THE CORE IS MAGNETIZED SUFFICIENTLY TO PULL THE RELAY ARM OVER AND BREAK THE CONTACTS 13. THIS OPENS THE WINDING W_8 ON RELAY 10 AND RELEASES THE CONTACT ARM OF THE RELAY, WHICH BREAKS CONTACTS 14 AND 15 AND OPENS RELAY 11. THIS DISCONNECTS THE THREE-PHASE SUPPLY TO THE POWER TRANSFORMERS AND CUTS OFF THE HIGH-VOLTAGE SUPPLY TO THE POWER-AMPLIFIER TUBES. THE WINDING W_{10} ON THE OVERLOAD RELAY 12 SERVES TO HOLD THE ARM IN THIS POSITION UNTIL IT IS DESIRED TO REESTABLISH THE PLATE VOLTAGE.

A PUSH-BUTTON RESET SWITCH (NOT SHOWN) IS CONNECTED IN SERIES WITH WINDING W_{10} TO BREAK THIS CIRCUIT WHEN IT IS DESIRED TO RELEASE THE ARM BACK TO ITS NORMAL POSITION, THEREBY REESTABLISHING CONTACTS 13, 14, AND 15 AND AGAIN ENERGIZING WINDING W_8 OF RELAY 10.

OPERATING THE TRANSMITTER

FROM PREVIOUS LESSONS TREATING WITH TRANSMITTERS, YOU ALREADY LEARNED THE GENERAL PROCEDURE FOR ADJUSTING A TRANSMITTER PREPARATORY TO OPERATION. NEVERTHELESS, YOU SHOULD FIND THE FOLLOWING SPECIFIC INFORMATION REGARDING THE OPERATION AND ADJUSTING OF THE WESTERN ELECTRIC TRANSMITTER ILLUSTRATED IN FIG. 7 TO BE BOTH INTERESTING AND HIGHLY INSTRUCTIVE. THE PROCEDURE IN THIS PARTICULAR CASE IS AS FOLLOWS:

ALL PLATE, FILAMENT, AND BIAS VOLTAGES MUST BE CAREFULLY ADJUSTED TO THEIR REQUIRED VALUES IN ACCORDANCE WITH THEIR CLASS OF OPERATION.

THE CRYSTAL OSCILLATOR USES A TYPE 271-A TUBE AND OPERATES WITH A PLATE POTENTIAL OF 130 VOLTS AT A PLATE CURRENT OF 7 MA. AND A GRID CURRENT OF 0.3 MA. THE FIRST AMPLIFIER USES A TYPE 271-A TUBE AND OPERATES WITH A PLATE POTENTIAL OF 300 VOLTS AND DRAWS A PLATE CURRENT OF 6 MA.

THE SECOND AMPLIFIER STAGE CONSISTS OF TWO 271-A CATHODE-HEATER

TUBES, IN SERIES OR PARALLEL. THESE TUBES OPERATE AT A PLATE POTENTIAL OF 350 VOLTS, A PLATE CURRENT OF 12 MA., AND A GRID BIAS OF -75 VOLTS. THE THIRD AMPLIFIER OR MODULATING RADIO FREQUENCY STAGE USES TWO 270-A TUBES (350 WATTS EACH) OPERATING AS A CLASS C AMPLIFIER AT A PLATE POTENTIAL OF 3,000 VOLTS, A TOTAL PLATE CURRENT OF 125 MA., AND A GRID BIAS OF -250 VOLTS. THESE TUBES ARE ADJUSTED TO A 100-WATT OUTPUT.

THE FINAL, OR POWER AMPLIFIER, STAGE USES TWO TYPE 279-A TUBES (RATED AT 1,200 WATTS EACH) OPERATING AS A CLASS B AMPLIFIER WITH A PLATE POTENTIAL OF 3,000 VOLTS, A TOTAL PLATE CURRENT OF 0.25 AMP., AND A GRID BIAS OF -275 VOLTS.

THE FILAMENTS OF THE ENTIRE TRANSMITTER ARE ALTERNATING CURRENT OPERATED THROUGH THE MEDIUM OF SINGLE PHASE POWER TRANSFORMERS. THE FILAMENT OPERATING VOLTAGE OF THE 271-A TUBES IS 5 VOLTS; AND THE 270-A AND 279-A TUBES ARE ALL OPERATED AT 10 VOLTS.

THE HIGH VOLTAGE RECTIFIER TUBES ARE W.E. TYPE 258-A HAVING A MAXIMUM INVERSE-PEAK POTENTIAL OF 6,500 VOLTS. THE GRID BIAS RECTIFIER TUBES ARE W.E. TYPE 253-A HAVING A MAXIMUM INVERSE-PEAK POTENTIAL OF 3,500 VOLTS. ALL RECTIFIERS ARE OF THE MERCURY VAPOR TYPE. TYPE 253-A TUBES ARE USED IN THIS TRANSMITTER IN THE RECTIFIER UNIT, AND TYPE 258-A TUBES ARE USED IN THE PLATE SUPPLY RECTIFIER UNITS. THE FILAMENT VOLTAGE OF BOTH TYPES IS 2.5 VOLTS. THE PEAK CURRENT OF TYPE 253-A IS 500 MA.; OF TYPE 258-A 1.1 AMP.

USE THE CRYSTAL-OXCILLATOR BOX CORRESPONDING TO THE NEWLY ASSIGNED FREQUENCY. THIS BOX IS ADJUSTED TO WITHIN 25 CYCLES OF THE ASSIGNED FREQUENCY BY THE WESTERN ELECTRIC COMPANY. CARE MUST BE TAKEN THAT THE MERCURY COLUMN IN THE BOX IS FREE TO RISE. THIS MAY BE ASSURED BY SLIGHTLY TAPPING THE REAR EDGE OF THE BOX ON A TABLE.

INSERT A NEW ARGON HEATER REGULATOR TUBE BUT LEAVE THE PLATE VOLTAGE FOR THIS UNIT DISCONNECTED UNTIL ITS FILAMENT HAS BEEN HEATED FOR SEVERAL MINUTES. THEN CLOSE THE PLATE VOLTAGE SUPPLY SWITCH. A PILOT LIGHT WILL SHOW THAT THE HEATER UNIT IN THE CRYSTAL BOX IS BEING PROPERLY HEATED. IT WILL TAKE AT LEAST 2 HOURS BEFORE THE BOX TEMPERATURE IS CORRECT AND THE PILOT LIGHT GOES OUT.

CONNECT COILS, CONDENSERS, AND LINKS TO CORRESPOND TO THE DESIRED FREQUENCY.

CLOSE ALL DOOR SWITCHES BY CLOSING DOORS, AND PLACE THE MASTER SWITCH IN STARTING POSITION. VARIOUS TIME DELAY RELAYS WILL CLOSE IN GRADUAL SUCCESSION BUT ONLY AFTER THE BIAS RECTIFIER TUBES ARE IN OPERATION. THIS PREVENTS ANY POSSIBILITY OF THE PLATE VOLTAGE BEING APPLIED BEFORE THE BIASING CIRCUIT IS COMPLETED.

THE FIRST AMPLIFIER, OR BUFFER STAGE, REQUIRES NO TUNING ADJUSTMENTS OR NEUTRALIZATION BECAUSE OF ITS APERIODICALLY TUNED PLATE CIRCUIT TRANSFORMER. THIS TRANSFORMER EFFECTIVELY COVERS THE BROADCAST FREQUENCIES OF FROM 500 TO 1,200 KILOCYCLES. A VARIABLE RESISTANCE CONTROLS THE BIAS VOLTAGE ON THE GRID OF THIS TUBE AND ALSO IS THE MAIN RA-

RADIO FREQUENCY DRIVE CONTROL FOR THE SUCCEEDING AMPLIFIER TUBES.

PREPARE THE SECOND RADIO FREQUENCY AMPLIFIER FOR NEUTRALIZING BY OPENING THE THIRD AMPLIFIER PLATE SUPPLY SWITCH AND CLOSING THE SECOND AMPLIFIER PLATE SUPPLY SWITCH.

CLOSE THE HIGH VOLTAGE SUPPLY SWITCH ON THE 100 WATT SECTION OF THE TRANSMITTER PANEL AND NOTE THE PLATE CURRENT READING OF THE MILLIAMMETER. ADJUST THE TUNING CONDENSERS WHICH ARE CONNECTED ACROSS L_4 UNTIL THE PLATE MILLIAMMETER SHOWS A MAXIMUM DROP. THIS IS A PRELIMINARY TUNING ADJUSTMENT BEFORE NEUTRALIZING AND, SHOULD DIFFICULTY BE ENCOUNTERED IN THE ADJUSTMENT, THE NEUTRALIZING CONDENSER SHOULD BE SHIFTED SLIGHTLY. IT WAS ASSUMED THAT THE NEUTRALIZING CONDENSER WAS APPROXIMATELY ONE FOURTH ENGAGED.

THE SECOND STAGE IS NOW READY FOR NEUTRALIZING, BUT IT IS ADVISABLE TO PROCEED FIRST WITH THE NEUTRALIZATION OF THE THIRD AMPLIFIER TO SIMPLIFY MATTERS.

TO NEUTRALIZE THE THIRD AMPLIFIER OPEN THE HIGH VOLTAGE SUPPLY SWITCH AND OPEN DOORS. SET THE NEUTRALIZING CONDENSERS ON THE THIRD AMPLIFIER STAGE SO THAT THEY ARE A LITTLE LESS THAN ONE HALF ENGAGED. INSERT A THERMOGALVANOMETER AND THERMO-COUPLE INTO THE PLATE MESH CIRCUIT C_7L_6. CLOSE THE PANEL DOORS AND ADJUST THE RADIO FREQUENCY DRIVE TO A MINIMUM POSITION AND LOOSEN THE MAGNETIC COUPLING OF L_6L_7. CLOSE THE HIGH VOLTAGE SUPPLY SWITCH AND BEGIN TO VARY THE THIRD AMPLIFIER TUNING CONDENSERS ACROSS L_6 UNTIL THE RADIO FREQUENCY AMMETER IN THIS MESH CIRCUIT READS MAXIMUM. IF NO READING IS OBTAINED, INCREASE THE RADIO-FREQUENCY DRIVE. ALSO VARY THE MESH TUNING CONDENSERS. AN EXCESSIVE READING WILL REQUIRE AN INCREASE IN THE CAPACITY OF THE NEUTRALIZING CONDENSERS UNTIL THE READING DROPS TO A LOW VALUE. CONTINUE TO INCREASE THE RADIO FREQUENCY DRIVE BUT KEEP ADJUSTING THE NEUTRALIZING CONDENSERS SO THAT THE MESH CURRENT DOES NOT EXCEED 3/4 AMP.

BOTH THE SECOND AND THIRD AMPLIFIER TUNING CONDENSERS MUST THEN BE VARIED UNTIL A MAXIMUM CURRENT IS INDICATED IN THE RADIO FREQUENCY MESH CIRCUIT AMMETER. THEN VARY THE THIRD AMPLIFIER NEUTRALIZING CONDENSERS UNTIL THE RADIO FREQUENCY AMMETER IN THE MESH CIRCUIT READS ZERO.

THE SECOND AMPLIFIER MAY NOW BE NEUTRALIZED BY OPENING THE HIGH VOLTAGE SUPPLY SWITCH AND REDUCING THE RADIO FREQUENCY DRIVE TO A MINIMUM. OPEN THE PLATE SUPPLY SWITCH TO THE SECOND AMPLIFIER AND CLOSE THE PLATE SWITCH TO THE THIRD AMPLIFIER. CLOSE THE HIGH-VOLTAGE SUPPLY SWITCH AND VARY THE RADIO FREQUENCY DRIVE TOGETHER WITH THE NEUTRALIZING CONDENSER UNTIL THE RADIO FREQUENCY AMMETER IN THE THIRD AMPLIFIER MESH CIRCUIT READS ABOUT 3/4 AMP. ADJUST THE SECOND AND THIRD AMPLIFIER TUNING CONDENSERS UNTIL THE THIRD AMPLIFIER RADIO FREQUENCY MESH METER M_4 READS A MAXIMUM. THEN VARY THE SECOND AMPLIFIER NEUTRALIZING CONDENSER UNTIL THIS METER READS MINIMUM.

THE RADIO FREQUENCY DRIVE SHOULD THEN BE INCREASED TO A MAXIMUM AND THE SECOND AMPLIFIER NEUTRALIZING CONDENSER ADJUSTED UNTIL NO READING IS OBTAINED AT THE RADIO FREQUENCY METER IN THE THIRD AMPLIFIER

MESH CIRCUIT.

THE POWER AMPLIFIER STAGE MAY NOW BE NEUTRALIZED BY OPENING ITS PLATE SUPPLY CIRCUIT AND REDUCING THE MAGNETIC COUPLING BETWEEN L_8 AND L_9 AND INCREASING THE CAPACITY OF THE POWER STAGE NEUTRALIZING CONDENSERS TO ABOUT ONE FOURTH CAPACITY. APPLY THE PLATE VOLTAGE BY CLOSING THE HIGH VOLTAGE SWITCH ON THE 100 WATT UNIT. INCREASE THE RADIO FREQUENCY DRIVE AND VARY THE POWER AMPLIFIER TUNING CONDENSER ACROSS L_8 UNTIL THE RADIO FREQUENCY AMMETER M_3 IN THE PLATE MESH $C_T L_8$ READS ABOUT $1\frac{1}{2}$ TO 2 AMP. INCREASE THE CAPACITY OF THE NEUTRALIZING CONDENSERS UNTIL THE READING OF THE POWER AMPLIFIER RADIO FREQUENCY AMMETER IN THE $C_T L_8$ MESH READS AT, OR VERY NEARLY, ZERO.

THE ENTIRE TRANSMITTER MAY NOW BE TUNED FOR MAXIMUM EFFICIENCY BY ADJUSTING THE VARIOUS AMPLIFIER STAGES TO THE PROPER LOAD AND RESONANT CONDITIONS. ALL STAGES WITH THE EXCEPTION OF THE FIRST AMPLIFIER AND ANTENNA CIRCUITS INDICATE A RESONANT CONDITION WHEN A MINIMUM PLATE CURRENT IS OBTAINED IN THE TUBE WHOSE TUNED CIRCUIT IS BEING ADJUSTED. GREAT CARE SHOULD BE TAKEN IN TUNING THE SECOND AND THIRD AMPLIFIER SO THAT THEY WILL NOT BE RESONANT TO THE SECOND HARMONIC FREQUENCY OF THE CARRIER.

NO TUNING ADJUSTMENTS ARE NECESSARY IN THE FIRST AMPLIFIER CIRCUITS, SINCE ALL CONDENSERS AND COILS ARE OF THE FIXED OR UNTUNED VARIETY. THE SECOND AMPLIFIER CIRCUIT IS TUNED FOR A MAXIMUM DIP IN THE PLATE CURRENT BY VARYING THE CONDENSERS C_T ACROSS L_4. THE THIRD AMPLIFIER OUTPUT CIRCUIT IS THEN ADJUSTED FOR THE DESIRED INPUT TO THE POWER AMPLIFIER TUBES.

OPEN THE PLATE SUPPLY VOLTAGE OF THE 1000 WATT UNIT (POWER AMPLIFIER STAGE), AND INSERT THE FULL POWER INPUT RESISTANCE ACROSS THE GRIDS OF THE POWER AMPLIFIER TUBES. CLOSE THE PLATE SUPPLY VOLTAGE OF THE 100 WATT UNIT AND TUNE CONDENSERS C_T ACROSS L_8 UNTIL THE RADIO FREQUENCY AMMETER IN THIS MESH READS A MAXIMUM VALUE. ADJUST THE RADIO FREQUENCY DRIVE SO THAT THIS METER DOES NOT EXCEED 1.5 AMP. VARY THE COUPLING OF $L_6 L_7$, AND ADJUST THE POWER AMPLIFIER INPUT CONTROL CONDENSER C_T ACROSS L_7 UNTIL THE RADIO FREQUENCY AMMETER IN THE $C_T L_6$ CIRCUIT READS A MINIMUM. INCREASE THE COUPLINGS OF $L_6 L_7$ AND THE RADIO FREQUENCY DRIVE UNTIL THE RADIO FREQUENCY AMMETER IN THE $C_T L_7$ CIRCUIT READS ABOUT 1 AMP. AND THE RADIO FREQUENCY AMMETER IN THE $C_T L_6$ CIRCUIT DROPS BETWEEN 0.8 AND 1.3 AMP. THE PLATE CURRENT OF THE THIRD AMPLIFIER STAGE AT THIS POINT SHOULD READ BETWEEN 125 AND 165 MA. THEN ADJUST C_T ACROSS L_6 FOR A MINIMUM PLATE CURRENT READING IN THIS STAGE.

BEFORE PROCEEDING WITH THE OUTPUT TUNING OF THE POWER AMPLIFIER STAGE, IT WILL BE NECESSARY TO ADJUST THE RADIO FREQUENCY DRIVE SO THAT THE GRIDS OF THE POWER AMPLIFIER TUBES RECEIVE THE PROPER EXCITATION. THIS IS ACCOMPLISHED BY INSERTING A RADIO FREQUENCY AMMETER IN SERIES WITH THE RESISTANCES (2,400 OHMS) WHICH ARE ACROSS THE POWER AMPLIFIER GRIDS. ASSUMING 100 WATT EXCITATION, THE RADIO FREQUENCY DRIVE IS INCREASED UNTIL THE RADIO FREQUENCY AMMETER IN THE RESISTANCE CIRCUIT READS A LITTLE LESS THAN 0.22 AMP. THUS, $W = I^2R$ OR APPROXIMATELY 100 WATTS. ACCURATE POWER AMPLIFIER GRID EXCITATION MAY THUS BE OBTAINED FOR ANY POWER UP TO 1,000 WATTS IN THIS TRANSMITTER.

THE OUTPUT CIRCUIT OF THE POWER AMPLIFIER MAY THEN BE TUNED AS FOLLOWS. ADJUST THE HARMONIC SUPPRESSION COIL TO THE REACTANCE VALUE WHICH WILL OFFER A MINIMUM IMPEDANCE TO THE DESIRED CARRIER FREQUENCY AND A MAXIMUM IMPEDANCE TO THE SECOND HARMONIC FREQUENCY. THIS VALUE IS OBTAINED BY REFERRING TO THE CALIBRATION CHART ACCOMPANYING THE TRANSMITTER. CLOSE THE POWER AMPLIFIER PLATE SUPPLY CIRCUIT. THE PLATE CURRENT IN THIS CIRCUIT SHOULD READ VERY NEARLY 0.3 AMP.

VARY THE RADIO FREQUENCY DRIVE UNTIL THE RADIO FREQUENCY AMMETER IN THE C_TL_8 MESH READS APPROXIMATELY 2 AMP. AT THIS POINT RECHECK THE THIRD AMPLIFIER PLATE CURRENT BY VARYING C_T ACROSS L_6 UNTIL THE PLATE CURRENT IN THIS STAGE IS OF MINIMUM VALUE.

VARY C_T ACROSS L_8 FOR MAXIMUM CURRENT IN THE C_TL_8 RADIO FREQUENCY MESH. INCREASE THE OUTPUT COUPLING SLIGHTLY, AND VARY THE ANTENNA TUNING CONDENSER IN SERIES WITH THE HARMONIC SUPPRESSION COIL UNTIL THE RADIO FREQUENCY AMMETER IN THE PLATE MESH READS A MINIMUM.

INCREASE THE COUPLING L_8L_9, AND VARY THE RADIO FREQUENCY DRIVE UNTIL ALL METER READINGS IN THE POWER AMPLIFIER OUTPUT CIRCUIT CORRESPOND WITH THE REQUIRED MANUFACTURER'S RATINGS FOR A GIVEN POWER OUTPUT.

WHEN THE TRANSMITTER HAS BEEN PROPERLY TUNED AND NEUTRALIZED AS DESCRIBED, THE PROPER MONITORING LEVEL MAY BE DETERMINED FOR THE AMOUNT OF POWER TO BE USED.

THE COMPLETE ADJUSTMENT OF THE RADIO AND AUDIO FREQUENCY CIRCUITS ARE CARRIED ON INTO A DUMMY ANTENNA LOAD HAVING A RESISTANCE OF APPROXIMATELY THE SAME VALUE AS THAT OF THE ANTENNA. THIS PERMITS THE THOROUGH TESTING OF ALL THE CIRCUITS TO INSURE THEIR COMPLIANCE WITH THE RIGID REQUIREMENTS OF THE LICENSING AUTHORITY BEFORE CONNECTING THE TRANSMITTER TO THE ANTENNA OR RADIATING SYSTEM, THEREBY GREATLY REDUCING INTERFERENCE DURING THE TEST HOUR PERIODS.

SLIGHT RETUNING OF THE OUTPUT COUPLING CIRCUITS MUST AGAIN BE MADE WHEN THE ANTENNA CIRCUIT IS CONNECTED FOR PROGRAM RADIATION.

ALTHOUGH THE TANK CIRCUITS ARE TUNED TO RESONANCE WHEN ADJUSTED FOR A MAXIMUM DIP IN THE PLATE CURRENT READING AS INDICATED BY THE DIRECT CURRENT MILLIAMMETER, THE FULL POWER OUTPUT CANNOT BE SECURED UNLESS THE TUNING ADJUSTMENTS ARE SLIGHTLY ALTERED. IN REALITY THE CIRCUIT IS NOT DETUNED BUT MERELY CHANGED FROM A MAXIMUM IMPEDANCE TO A UNITY POWER FACTOR CONDITION. THIS IS PARTICULARLY IMPORTANT IF THE CIRCUIT IS ADJUSTED BY THE INDUCTIVE REACTANCE X_L SINCE THE RESISTIVE COMPONENT OF THE INDUCTANCE L PREVENTS AN ABSOLUTE ADJUSTMENT TO THESE CONDITIONS. IF, HOWEVER, THE TANK CIRCUIT IS TUNED BY A CONDENSER, AS IN FIG. 7, THE CAPACITIVE REACTANCE MAY BE MORE EASILY ADJUSTED SO THAT THE COMBINED REACTANCES ARE EQUAL, THEREBY RESULTING IN A UNITY POWER FACTOR CONDITION. THIS ADJUSTMENT GIVES A GREATER TRANSFER OF POWER BECAUSE THE LOAD CIRCUIT RESISTANCE WILL DECREASE, THEREBY REDUCING THE POWER DISSIPATION, DUE TO THE RESISTANCE, AND GIVING MORE USEFUL POWER OUTPUT. MODULATION AND FREQUENCY MEASUREMENTS MUST THEN BE MADE TO INSURE THE PROPER PERCENTAGE OF MODULATION AND FREQUENCY STABILIZATION IN ACCORDANCE WITH THE REQUIREMENTS OF THE FEDERAL LICENSING AUTHORITY.

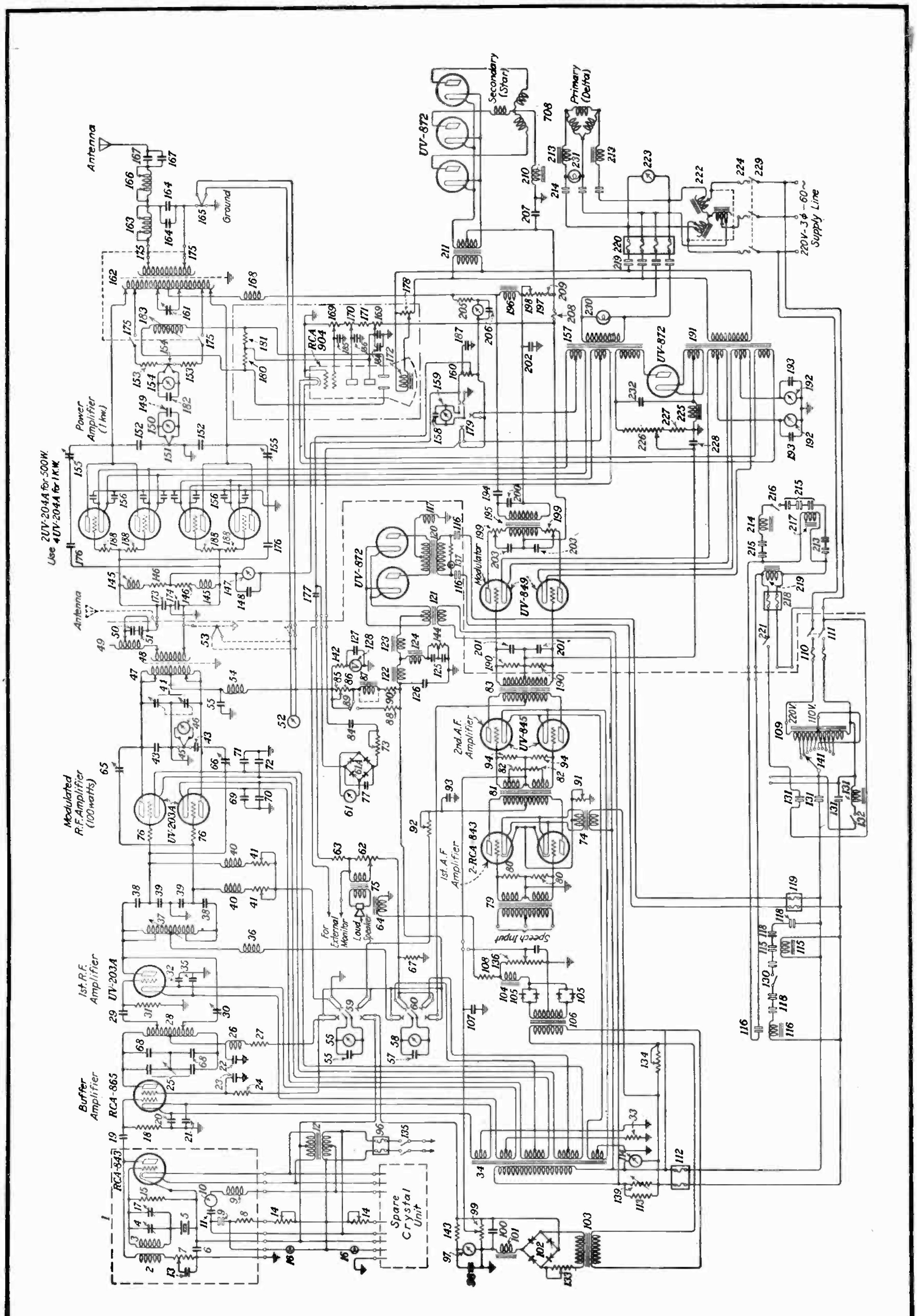

FIG. 8

R.C.A. Victor 1-Kw. Broadcast Transmitter.

1	Crystal oscillator unit.
2	Oscillator plate inductance.
3	Oscillator grid inductance.
4	Oscillator tank circuit capacity, 0.000365 mf.
5	Quartz plate.
6	By-pass condenser, 0.01 mf., 2,000-volt rating.
7	Plate feed-back resistance, 1,000 ohm, 3 watts.
8	Crystal heater resistances, 500 ohms.
9	Heater control relay.
10	Mercury thermo-regulator.
11	Relay condenser, 0.2 mf., 300-volt rating.
12	Filament transformer, 50 or 60 cycles.
13	By-pass condenser, 0.01 mf., 2,000-volt rating.
14	Heater control resistance, 500 ohms, 60 watts.
15	Oscillator grid leak resistance, 1 megohm, 1 watt.
16	Heater indicator lamp.
17	Frequency vernier capacity, 0.00007 mf.
18	Buffer amplifier grid resistance, 100,000 ohms, 1 watt.
19	Coupling capacity, 0.00004 mf., 5,000-volt rating.
20–23	By-pass condenser, 0.01 mf., 2,000-volt rating.
24	Screen grid resistance, buffer amplifier, 50,000 ohms, 44 watts.
25	Split stator tank circuit capacity, 0.00048 mf. each section.
26	Plate choke coil.
27	Plate resistance, 15,000 ohms, 100 watts.
28	Plate inductance.
29	Blocking condenser, 0.001 mf., 5,000-volt rating.
30	Neutralizing condenser, 0.000034 mf.
31	Grid resistance, 2,000 ohms, 5 watts.
32	By-pass condenser, 0.01 mf., 2,000-volt rating.
33	Biasing resistance, 100 ohms, 5 watts.
34	Filament transformer.
35	By-pass condenser, 0.01 mf., 2,000 volt rating.
36	R.F. choke coil.
37	Plate inductance.
38	Coupling condenser.
39	By-pass condenser.
40	R.F. choke coil.
41	Power amplifier grid leak resistance, 20,000 ohms, 75 watts.
42	Spare crystal unit. Same as 5.
43	Tank circuit by-pass condenser.
44	Tank circuit tuning condenser, 0.00022 mf.
45	Thermocouple, 0 to 5 amp.
46	R.F. ammeter, 0 to 5 amp.
47	R.F. transformer.
48	Antenna coupling coil.
49	Loading inductance.
50–51	Antenna series capacity, 0.001 mf.
52	Antenna radio-frequency ammeter.
53	Thermocouple for antenna r.f. ammeter (not shown).
54	R.F. choke coil.
55	Meter by-pass condenser, 0.01 mf.
56	D-c. milliammeter, 0 to 150 ma.
57	Meter by-pass condenser, 0.01 mf.
58	D-c. milliammeter, 0 to 500 ma.
59–60	Meter switch.
61	Modulation indication meter, 0 to 1.5 ma.
61A	Modulation indication meter Rectox rectifier units.
62	Loud-speaker volume-control potentiometer, 500 ohms, 50 watts.
63	Monitor resistances, 30 ohms, 20 watts.
64	Monitoring loud-speaker.
65–66	Neutralizing condenser, 0.000056 mf.
67	Bleeder resistance, 25 ohms, 25 watts.
68	Condenser for buffer amplifier tank.
69–72	By-pass condenser, 0.01 mf., 2,000-volt rating.
73	Modulation indicator adjustable resistance, 10,000 ohms, 75 watts.
74	Filament transformer.
75	Loud-speaker input transformer.
76	Grid resistance, 100 ohms, 5 watts.
77	By-pass condenser, 0.01 mf., 2,000-volt rating.
78	A.F. amplifier and modulator (not separately numbered on diagram).
79	Audio-input transformer.
80	Audio-input load resistance, 9,000 ohms, 1 watt.
81	Interstage coupling transformer.
82	Load resistance, 15,000 ohms, 3 watts.
83	Modulator interstage coupling transformer.
84	Blocking condenser, 2 mf., 2000 volt rating.
85, 86	Amplifier feed resistance.
87	Modulator reactor.
88	Shunt reactor resistance.
89	Power changing switch.
90	Power-amplifier plate resistance, 2,500 ohms with 10 taps, 200 watts.
91	Biasing resistance, 750 ohms, 100 watts. Variable.
92	Plate feed resistance.
93	By-pass condenser, 4 mf., 1,000-volt d-c. rating.
94	Grid resistance, 100,000 ohms, 3 watts.
95	Power equipment (not separately numbered on diagram).
96	Cartridge-type fuses, 6 amp., 250 volts.
97	D-c. voltmeter, 0 to 500 volts.
98	Meter by-pass condenser, 0.01 mf.
99	Potentiometer, 3,500 ohms, 50 watts.
100	Filter condenser, 18 mf., 1,000-volt rating.
101	Filter choke coil.
102	Rectox rectifier unit.
103	Rectifier transformer.
104	Filter choke coil.
105	Rectox rectifier units.
106	Rectifier transformer.
107	Filter condenser, electrolytic type. 200 mf., 50-volt rating.
108	Voltage divider resistance section, 40 ohms, 100 watts.
109	Autotransformer.
110	Cartridge-type fuses, 30 amp., 250 volts.
111	Line switch.
112	Cartridge-type fuses, 10 amp., 250 volts.
113	Section of regulating resistance, 10 ohms, 100 watts.
114	Filament voltmeter. 150 volts, A.c.
115	Time-delay relay. Dash-pot type.
116	Plate contactor.
117	D-c. overload relay, dash-pot type.
118	Door switches.
119	Cartridge-type fuses, 20 amp., 250 volts.
120	Plate-supply power transformers.
121	Filament transformer.
122–124	Filter choke coil.
125	Filter condenser, 2 mf., 1,500-volt d-c. rating.
126	Filter condenser, 10 mf., 1,000-volt d-c. rating.
127	By-pass condenser, 0.01 mf.
128	Plate voltmeter, 0 to 1,500 volts.
129	Electrolytic condenser, 200 mf., 50-volt rating.
130	Plate-voltage switch.
131	Filament contactor.
132	Transmitter starting switch.
133	Rectox regulator resistance.
134	Regulator resistance for T103 and T106.
135	Crystal-heater switch.
136	Biasing potentiometer, 5,000 ohms, 50 watts.
137	Plate-voltage indicator light.
138	Spare-crystal indicator light.
139	Filament rheostat, 10 ohms, 75 watts. Adjustable.
140	Meter panel lights.
141	Line-voltage switch.
142	Voltmeter multiplier for 0 to 1,500-volt meter.
143	Voltmeter multiplier for 0 to 500-volt meter.
144	Filter resistance, 500,000 ohms, 3 watts.
145	R.F. choke coil.
146	Grid resistance, 2,000 ohms, 60 watts.
147	D.c. ammeter, 0 to 300 ma.
148	By-pass condenser, .01 mf.
149	By-pass condenser, 0.01 mf.
150	R.F. ammeter, 0 to 8 amp.
151	External thermocouple for 0- to 8-amp. meter.
152	Power-amplifier tank circuit condenser.
153	Phantom antenna resistance, twelve 220-ohm units in series.
154	Phantom antenna ammeter, 0 to 1 amp.
155	Variable condenser, 0.00011 mf.
156	By-pass condenser, 0.01 mf., 2,000-volt rating.
157	Filament and bias rectifier transformer.
158	By-pass condenser, 0.01 mf.
159	Power-amplifier plate ammeter, 0 to 1 amp.
160	Biasing resistance, 150 ohms, 200 watts.
161	Variable tank-circuit capacity, 0.00022 mf.
162	R.F. transformer.
163	Harmonic suppression inductance.
164	Antenna-coupling condenser.
165	Antenna ammeter thermocouple.
166	Antenna loading inductance.
167	Antenna condenser.
168	R.F. choke coil.
169	Potentiometer, 100,000 ohms.
170	Potentiometer, 350,000 ohms.
171	Separating resistance.
172	Cathode-ray sweep-circuit coils
173	Grid tuning condenser.
174	Grid tuning condenser.
175	Phantom antenna switch.
176	Neutralising condenser, 0.0001 mf.
177	Monitor blocking condenser, 28 mf., 1,000-volt d-c. rating.
178	Potentiometer, 2,300 ohms.
179	Meter switch.
180–181	Coupling-coil balancing resistance.
182	By-pass condenser, 0.01 mf.
183	Coupling coil for cathode-ray modulator indicator.
184	By-pass condenser, 0.001 mf., 5,000-volt rating.
185	By-pass condenser, 0.01 mf., 2,000-volt rating.
186	By-pass condenser, 0.01 mf., 2,000-volt rating.
187	Power-supply filter condenser, 10 mf., 1,000-volt rating.
188	Power-amplifier grid resistance, 100 ohms, 5 watts.
189	Modulator (not separately numbered on diagram).
190	Secondary stabilising resistances.
191	Filament transformer.
192	Plate ammeter, 0 to 300 ma.
193	By-pass condenser, 0.01 mf.
194	Blocking condenser, 6 mf., 2,000-volt rating.
195	Modulation output transformer.
196	Modulation reactor.
197, 198	Plate-feed resistances.
199	Modulation plate resistance, 100 ohms, 30 watts.
200	Secondary shunt condenser.
201, 202	Secondary by-pass condenser.
203	Primary by-pass condenser.
204	Power equipment (not separately numbered on diagram).
205	Voltmeter and multiplier, 0 to 5,000 volts, d.c.
206	By-pass condenser, 0.01 mf.
207	Filter condenser, two 3.5-mf. units, 3,000-volt rating.
208, 209	Fuse, 1 amp., 2,000 volts.
210	Filter choke coil.
211	Filament transformer.
212	Plate power transformers, 3.75-kva. rating.
213	Overload relays, oil dashpot, time-delay relay.
214	Plate contactor.
215	Door interlocking switches.
216	Plate ON switch.
217	Time-delay relay, oil-dashpot type.
218	Fuses, 6 amp., 250 volts.
219	Filament contactor.
220	Fuses, 6 amp., 250 volt.
221	Filament switch.
222	Autotransformer.
223	Line voltmeter, 0 to 250 volts a.c.
224	Fuses, 20 amp., 250 volts.
225	Bias filter choke coil.
226	Bias potentiometer, 125 ohms.
227	Bias resistance, 200 ohms, 200 watts.
228	Bias filter condenser, 200 mf., 200 volts, electrolytic type.
229	Line switch, three-pole single-throw variety.
230, 231	Indicator lamp.
232	Bias filter condenser.
233	Panel lights.

TABLE I

Parts of R.C.A. Victor Broadcast Transmitter.

R.C.A. VICTOR BROADCAST TRANSMITTERS

IN FIG 8 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF AN R.C.A. VICTOR BROADCAST TRANSMITTER WHICH IS RATED AT I KW. AND A REFERENCE INDEX FOR THE VARIOUS PARTS OF THIS TRANSMITTER APPEARS IN TABLE 1.

THIS TRANSMITTER CONSISTS OF TWO SELF-CONTAINED UNITS,NAMELY, A 100 WATT TRANSMITTER UNIT AND A 1000 WATT AMPLIFIER UNIT. IF SO DESIRED, THE ANTENNA SYSTEM CAN BE CONNECTED AS INDICATED BY THE DOTTED LINES AND THE UNIT THUS OPERATED AS A 100 WATT TRANSMITTER AND WITHOUT THE USE OF THE POWER AMPLIFIER UNIT.

FROM WHAT YOU HAVE ALREADY LEARNED ABOUT TRANSMITTERS, AND AIDED BY TABLE 1, YOU SHOULD BE ABLE TO ANALYZE FOR YOURSELF THE VARIOUS DETAILS OF THIS CIRCUIT. IT WILL BE WELL TO MENTION AT THIS POINT, HOWEVER, THAT THE R.C.A. 904 TUBE WHICH IS USED WITH THIS EQUIPMENT IS A CATHODE-RAY TUBE ACTING AS A MODULATION INDICATOR. FOR THE PRESENT,DON'T WORRY ABOUT THE OPERATION OF THIS TYPE OF MODULATION INDICATOR,AS YOU WILL RECEIVE COMPLETE INSTRUCTIONS REGARDING CATHODE-RAY TUBES AND ALL OF THEIR VARIOUS APPLICATIONS IN LATER LESSONS WHICH ARE INCLUDED INTHE "ELECTRONICS SERIES".

OPERATING POWER

THE DETERMINATION OF THE OPERATING POWER OR OUTPUT POWER IS A PROBLEM WHICH ARISES FREQUENTLY WITH RESPECT TO TRANSMITTER EQUIPMENT. TO ASCERTAIN THIS VALUE, THE FOLLOWING FORMULA CAN BE USED: OUTPUT POWER IN WATTS= PLATE VOLTS X PLATE CURRENT EXPRESSED IN AMPERES X F.

THE FACTOR F IS A CONSTANT AND HAS THE FOLLOWING VALUE:

FOR TRANSMITTERS USING HIGH-LEVEL MODULATION

MAXIMUM RATED CARRIER POWER OF TRANSMITTER (WATTS)	FACTOR "F"
100	0.50
250-1,000	0.60
2,500-50,000	0.65

FOR TRANSMITTERS USING LOW-LEVEL MODULATION

MAXIMUM PERCENTAGE OF MODULATION	FACTOR "F"
75-85	0.40
86-100	0.33

FOR TRANSMITTERS USING GRID-BIAS MODULATION IN LAST RADIO STAGE

MAXIMUM PERCENTAGE OF MODULATION	FACTOR "F"
75-85	0.27
86-100	0.22

TO ILLUSTRATE THE USE OF THIS DATA, LET US CONSIDER A PRACTICAL PROBLEM: A CERTAIN TRANSMITTER EMPLOYS LOW-LEVEL MODULATION AND MODULATES THE CARRIER FREQUENCY AT 80%. THE PLATE VOLTAGE OF THE FINAL R.F AMPLIFYING TUBE IS 2500 VOLTS AND DRAWS A PLATE CURRENT OF 275 MA. THE FACTOR F IN THIS CASE WOULD BE APPROXIMATELY 0.40 AND BY SUBSTITUTING VALUES IN THE OUTPUT POWER FORMULA WE HAVE:

OUTPUT POWER IN WATTS = 2500 X .275 X 0.40 = 275 WATTS.

HAVING COMPLETED THIS LESSON, YOU SHOULD NOW BE THOROUGHLY FAMILIAR WITH BROADCAST TRANSMITTERS AND THEIR RELATED EQUIPMENT.

YOU MUST REMEMBER, OF COURSE, THAT NOT ALL BROADCAST STATIONS ARE DESIGNED EXACTLY ALIKE BUT THOSE INSTALLATIONS, WHICH WERE EXPLAINED TO YOU IN THESE LESSONS, ARE TYPICAL EXAMPLES. THEREFORE, BY HAVING A GOOD UNDERSTANDING OF THESE PARTICULAR ONES AND AIDED BY ALL OF THE ADDITIONAL KNOWLEDGE WHICH YOU NOW HAVE ABOUT TRANSMITTERS IN GENERAL, IT SHOULD BE A SIMPLE MATTER FOR YOU TO FULLY ACQUAINT YOURSELF WITH THE EQUIPMENT USED IN ANY CONVENTIONAL STATION.

AGAIN LET US REMIND YOU THAT EVEN IF YOU DO NOT INTEND TO SPECIALIZE IN ANY ONE OF THE MANY FIELDS WHICH INVOLVE TRANSMITTERS, YOU OWE IT TO YOURSELF TO GET AS MUCH OUT OF THIS SERIES OF LESSONS AS YOU POSSIBLY CAN.

NATIONAL HAS TRIED ESPECIALLY HARD TO MAKE THIS COURSE AS COMPLETE AS POSSIBLE SO THAT EACH AND EVERY STUDENT WILL HAVE AN EQUAL OPPORTUNITY TO SUCCEED IN THIS GREAT INDUSTRY. TO BE SUCCESSFUL IN THIS DAY AND AGE A MAN MUST HAVE A GOOD GENERAL KNOWLEDGE OF THE ENTIRE FIELD IN WHICH HE IS ACTIVE, AND IN ADDITION, HE MUST HAVE A MOST THOROUGH UNDERSTANDING OF THE SUBJECT WHICH HE SELECTS AS HIS PARTICULAR BRANCH OF SPECIALIZATION. FROM BEGINNING TO END, THIS COURSE HAS BEEN CAREFULLY PLANNED TO MEET THIS CONDITION AND WE URGE YOU TO MAKE THE MOST OF THE OPPORTUNITIES WHICH NATIONAL IS SO EAGER TO EXTEND TO YOU.

ans June 31, 1942

Examination Questions

LESSON NO. T-18

Education is the practical preparation of the individual in order to face and dominate the obstacles on the road to success.

1. - (A) MAKE A SIMPLE DIAGRAM WHICH ILLUSTRATES THE RELATION BETWEEN THE VARIOUS UNITS OR SECTIONS WHICH TOGETHER CONSTITUTE A TYPICAL BROADCAST STATION. (B) EXPLAIN THE PURPOSE OF EACH OF THESE UNITS.

2. - DRAW A CIRCUIT DIAGRAM OF A SERIES-RESONANCE EQUALIZER. DESCRIBE HOW IT IS USED, AND EXPLAIN HOW IT OPERATES.

3. - DRAW A CIRCUIT DIAGRAM OF A PARALLEL-RESONANCE EQUALIZER. DESCRIBE HOW IT IS USED, AND EXPLAIN HOW IT OPERATES.

4. - EXPLAIN HOW REMOTE-CONTROL BROADCASTS ARE GENERALLY HANDLED.

5. - MAKE A DRAWING OF THE TYPICAL SET-UP FOR MAKING A FREQUENCY RUN ON AN A.F. TRANSMISSION LINE.

6. - DESCRIBE THE PROCESSES WHICH ARE INVOLVED WHEN MAKING SUCH A FREQUENCY RUN.

7. - WHAT DOES A FREQUENCY RESPONSE CURVE INDICATE?

8. - WHAT ARE SOME OF THE MORE IMPORTANT PROTECTIVE DEVICES WHICH ARE USED IN THE LARGER BROADCAST TRANSMITTERS?

9. - IN WHAT WAYS DOES THE CONVENTIONAL BROADCAST TRANSMITTER DIFFER FROM THE ORDINARY PHONE-TYPE COMMERCIAL TRANSMITTER?

10 - EXPLAIN IN DETAIL HOW THE OPERATING POWER OF A BROADCAST TRANSMITTER CAN BE DETERMINED.

NATIONAL SCHOOLS
LOS ANGELES CALIFORNIA

ESTABLISHED 1905 J. A. ROSENKRANZ, *President*

RADIO DIVISION

SPECIAL EXAMINATION #9

Dear Student:

Having by this time completed eighteen lessons treating with Radio Transmitters, you should now have a good understanding of this subject.

Since answering your last special examination, you have learned a great deal concerning the power supply for transmitters, constructional features and operation of radio-telegraph transmitters, handling radio messages, transmitter tubes, communication receivers, and broadcast transmitters.

Due to the outstanding importance of these subjects, as well as those which were discussed with you during the first nine lessons of the Transmitter Series, it is advisable that you review this entire series of Transmitter Lessons with special care.

Upon the completion of this intensive review, answer fully the following questions which are based upon all of the transmitter lessons which you have studied thus far, and send them to us for correction.

You will find this set of examination questions to serve as a good guide for conducting your review and I am confident that you will do your utmost to receive a splendid grade on this examination.

Sincerely yours,

J. A. Rosenkranz

President

EXAMINATION QUESTIONS

1. - Draw a complete circuit diagram of a commercial type radio-telegraph transmitter.

2. - Explain the procedure for operating the transmitter whose diagram you have drawn in answer to question #1.

3. - What Greenwich Mean Time corresponds to an Eastern Standard Time of 11 p.m.?

(over)

4. - Draw a complete circuit diagram of a three-phase, half-wave rectifier that is suitable for a transmitter's "B" supply.

5. - Draw a diagram of a crystal filter circuit as used in a receiver and explain its operation in detail.

6. - Draw a circuit diagram showing how a beat oscillator may be coupled to the second detector of a superheterodyne receiver and explain in detail how the complete system operates.

7. - What is the object of providing a short-circuiting switch for the crystal filter of a receiver?

8. - What are the operating characteristics of a type 204A transmitter tube?

9. - What are the operating characteristics of a type 866 tube?

10. - Draw a complete circuit diagram of the equipment which you would expect to find in the studios and control room of a typical broadcast station.

11. - Describe the equipment and circuits which you would expect to find in the transmitter room of a typical broadcast station.

12. - What important facts should be considered in laying out the design of a phone transmitter?

13. - Draw a complete circuit diagram of a phone transmitter employing the Heising system of modulation.

14. - Explain in detail the operation of the circuit whose diagram you have drawn in answer to question #13.

15. - Draw a circuit diagram of a phone transmitter employing grid bias modulation.

16. - Explain in detail the operation of the circuit whose diagram you have drawn in answer to question #15.

17. - Explain what is meant by "modulation percentage" and also explain how this value can be determined.

18. - What is the general procedure for tuning a transmitter which does not employ any frequency-multiplier stages?

19. - What is the general procedure for tuning a transmitter which does employ one or more frequency-multiplier stages?

20. - What are some of the more important precautions which should be exercised when operating any radio transmitter?

NATIONAL SCHOOLS

LOS ANGELES CALIFORNIA

ESTABLISHED 1905 J. A. ROSENKRANZ, *President*

RADIO DIVISION

SPECIAL EXAMINATION #8

Dear Student:

You are at the present time engaged in an intensive study of Radio Transmitters wherein many new and important principles are being explained. The knowledge of transmitters which you are now acquiring is going to be especially valuable to you if you intend to ultimately specialize in radio broadcasting, in any of the many applications of commercial operating, or in television.

Even if you do not plan to specialize in any field of radio which involves transmitters, you should not deny yourself this additional training. A thorough study of this subject will broaden your knowledge of radio in general and will also familiarize you with many facts which may be of tremendous value to you at some later time even though you may not realize it now.

The questions in this examination are based on the first nine lessons of the Transmitter Series. I therefore suggest that you review these nine lessons carefully, and then answer the following questions to the best of your ability.

Sincerely yours,

J. A. Rosenkranz.

President

EXAMINATION QUESTIONS

1. - Draw a circuit diagram of a spark transmitter and explain how it operates.

2. - What is the difference between a Y-cut crystal and an X-cut crystal?

3. - How would you designate the completion of a transmitted message by means of code?

4. - What is the difference between a series-feed oscillator and a shunt feed oscillator?

5. - Draw a complete circuit diagram of a radio-telegraph transmitter consisting of a push-pull oscillator stage only, using two type 10 tubes. The circuit of the power pack for A-C operation is also to be included in this diagram.

(over)

6. - DRAW A CIRCUIT DIAGRAM OF A HARTLEY OSCILLATOR AND EXPLAIN HOW IT OPERATES.

7. - DRAW A CIRCUIT DIAGRAM OF A MONITOR WHICH IS SUITABLE FOR AMATEUR USE. EXPLAIN HOW YOU WOULD CALIBRATE IT AND HOW YOU WOULD USE IT FOR ADJUSTING AN AMATEUR TRANSMITTER.

8. - WHAT IS THE MEANING OF THE SIGNAL ABBREVIATION "QSO"?

9. - DRAW A CIRCUIT DIAGRAM OF A CRYSTAL-CONTROLLED OSCILLATOR AND EXPLAIN HOW IT OPERATES.

10. - DRAW A CIRCUIT DIAGRAM OF A COMPLETE CODE-TRANSMITTER COMPRISING A TRI-TET OSCILLATOR, FOLLOWED BY ONE DOUBLER STAGE AND A FINAL POWER STAGE.

11. - DESCRIBE IN DETAIL HOW YOU WOULD ADJUST FOR OPERATION THE TRANSMITTER WHOSE DIAGRAM YOU HAVE DRAWN IN ANSWER TO QUESTION #10.

12. - DESCRIBE THE DIFFERENT TYPES OF COUPLING WHICH ARE PRACTICAL IN THE R-F STAGES OF A TRANSMITTER.

13. - UPON WHAT FACTORS DOES THE RESONANT FREQUENCY OF A QUARTZ CRYSTAL DEPEND?

14. - DESCRIBE THE CONSTRUCTIONAL FEATURES OF A SPLIT-STATOR TUNING CONDENSER AND MENTION THE ADVANTAGES OF USING SUCH A UNIT IN A TRANSMITTER.

15. - EXPLAIN IN DETAIL HOW YOU WOULD WORK OUT THE DESIGN FOR A HERTZ ANTENNA.

16. - EXPLAIN HOW A FREQUENCY MULTIPLIER OF A TRANSMITTER OPERATES.

17. - MAKE A SKETCH OF A ZEPPELIN ANTENNA AND EXPLAIN FULLY HOW YOU WOULD ADJUST SUCH AN ANTENNA SYSTEM TO RESONANCE WITH THE FREQUENCY AT WHICH THE TRANSMITTER IS OPERATING?

18. - WHAT IS THE ADVANTAGE OF USING FREQUENCY MULTIPLIER STAGES IN A TRANSMITTER?

19. - EXPLAIN HOW YOU WOULD PROCEED TO DESIGN AN UNTUNED TRANSMISSION LINE FOR A TRANSMITTER ANTENNA SYSTEM.

20. - DRAW A CIRCUIT DIAGRAM OF AN ELECTRON-COUPLED OSCILLATOR AND EXPLAIN HOW IT OPERATES.