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LESSON NO. 51

WAVEMETERS AND TEST OSCILLATORS

WE ARE STARTING THIS LESSON WITH AN EXPLANATION OF WAVEMETERS, WHICH ALTHOUGH BEING A VERY SIMPLE DEVICE AS REGARDS CONSTRUCTION IS NEVERTHELESS A VERY VALUABLE TESTING UNIT WITH WHICH TO MEASURE THE WAVELENGTH OF RADIO FREQUENCY ENERGY.

THE MOST EXTENSIVE APPLICATION FOR WAVEMETERS IS TO DETERMINE THE WAVELENGTH OF THE R.F. ENERGY BEING RADIATED BY AN OSCILLATOR OR TRANSMITTER AND IN FIG.2 YOU WILL SEE THE FUNDAMENTAL CIRCUIT FOR THIS APPARATUS.

AS YOU WILL OBSERVE IN FIG. 2, THE WAVEMETER IS NOTHING MORE THAN AN ORDINARY TUNING CIRCUIT, CONSISTING OF AN INDUCTANCE OR COIL CONNECTED IN SERIES WITH A VARIABLE CONDENSER.

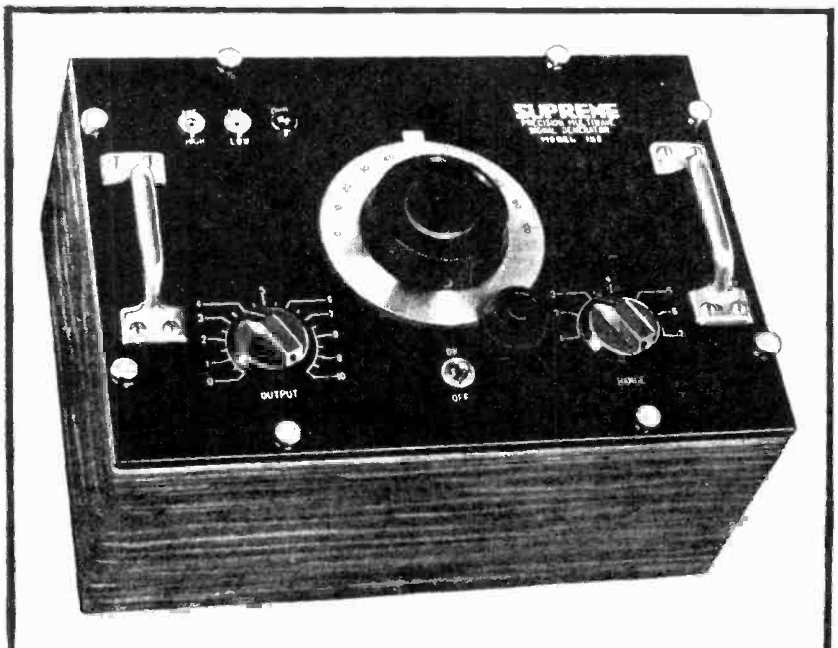

FIG. 1

A Multi-wave Signal Generator.

BY CHOOSING THE PROPER INDUCTANCE AND CONDENSER VALUES, THIS CIRCUIT CAN BE TUNED OVER A DEFINITE RANGE OF WAVELENGTHS. THE VARIABLE CONDENSER USED IN THIS CASE SHOULD PREFERABLY BE OF THE STRAIGHT-LINE WAVELENGTH TYPE, SO THAT THE WAVELENGTH TO WHICH THE CIRCUIT IS TUNED WILL VARY APPROXIMATELY IN DIRECT PROPORTION TO THE MOVEMENT OF THE

CONDENSER PLATES OR TUNING DIAL.

BESIDES WAVEMETERS, WE ALSO HAVE FREQUENCY-METERS. BOTH OF THESE UNITS ARE CONSTRUCTED ALIKE, WITH THE EXCEPTION THAT THE WAVEMETER IS CALIBRATED FOR WAVELENGTHS EXPRESSED IN METERS, WHEREAS THE FREQUENCY-METER IS CALIBRATED FOR FREQUENCIES EXPRESSED IN KILOCYCLES. FURTHERMORE, FOR FREQUENCY-METERS, IT IS PREFERABLE TO USE A STRAIGHT-LINE FREQUENCY CONDENSER SO THAT THE FREQUENCY TO WHICH THE CIRCUIT IS TUNED WILL VARY APPROXIMATELY IN DIRECT PROPORTION TO THE MOVEMENT OF THE CONDENSER PLATES OR TUNING DIAL. THE DIAL USED ON BOTH THESE INSTRUMENTS IS GENERALLY OF THE PRECISION VERNIER TYPE IN ORDER TO KEEP THE DEGREE OF ACCURACY AS HIGH AS POSSIBLE.

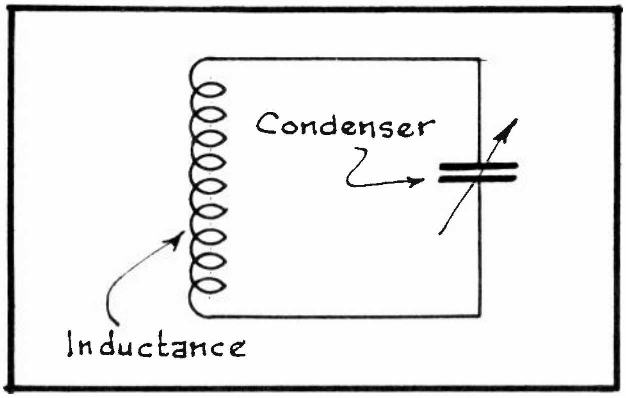

FIG. 2
Fundamental Wavemeter Circuit.

AS YOU WILL RECALL FROM YOUR STUDIES OF RESONANCE CIRCUITS, THE CURRENT FLOW THROUGH A SERIES RESONANCE CIRCUIT IS MAXIMUM AT THE RESONANT FREQUENCY AND DECREASES RAPIDLY TOWARDS EITHER SIDE OF THE RESONANT FREQUENCY. THIS IS THE BASIC PRINCIPLE GOVERNING THE OPERATION OF WAVEMETERS AND FREQUENCY METERS, SO BEAR IT IN MIND AS WE CONTINUE WITH THE EXPLANATION REGARDING THE APPLICATION OF THESE TWO INSTRUMENTS.

RESONANCE INDICATORS

THE NEXT STEP WITH RESPECT TO WAVEMETERS AND FREQUENCY-METERS IS TO PROVIDE SOME MEANS WHEREBY ONE CAN DETERMINE WHEN THE TESTER IS TUNED TO RESONANCE WITH THE WAVE IN QUESTION. THERE ARE SEVERAL METHODS OF ACCOMPLISHING THIS AND A SIMPLE WAY IS ILLUSTRATED IN FIG. 3.

BY STUDYING FIG. 3, YOU WILL OBSERVE THAT A SMALL FLASHLIGHT BULB IS CONNECTED IN SERIES WITH THE TUNING CIRCUIT OF THE WAVEMETER. THIS METHOD IS ONLY SUITABLE FOR MAKING A TEST WHEN THE R.F. ENERGY BEING PICKED UP IS QUITE STRONG SO THAT A CONSIDERABLE VOLTAGE IS INDUCED INTO THE COIL OF THE WAVEMETER. SUCH IS THE CASE, WHEN MAKING A TEST WITH TRANSMITTERS, TEST OSCILLATORS ETC.

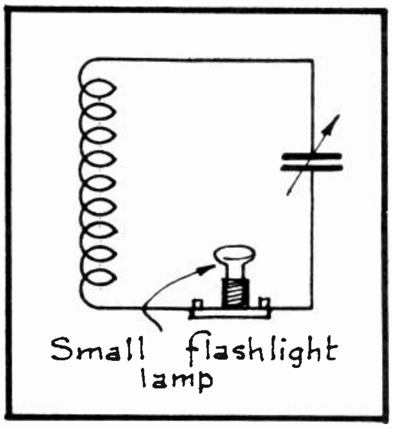

FIG. 3
Lamp Resonance Indicator.

WHEN USING THE SET-UP ILLUSTRATED IN FIG. 3, YOU WILL FIND THE LAMP TO BURN WITH INCREASED BRILLIANCE AS THE WAVEMETER IS BEING TUNED NEARER TO RESONANCE WITH THE WAVE UNDER TEST, SINCE THE CURRENT FLOW THROUGH THE WAVEMETER CIRCUIT INCREASES AS THE RESONANT FREQUENCY IS APPROACHED. THE CONDITION OF RESONANCE IS THEREFORE INDICATED WHEN THE LAMP BURNS AT MAXIMUM BRILLIANCE.

WHEN TAKING SUCH A WAVE MEASUREMENT, THE WAVEMETER SHOULD BE COUPLED

AS LOOSELY AS POSSIBLE WITH THE CIRCUIT UNDER TEST. THAT IS, KEEP THE WAVEMETER COIL AS FAR AWAY FROM THE CIRCUIT UNDER TEST AS CONSISTENT WITH AN INDICATION FROM THE LAMP. THE LOOSER THE COUPLING BETWEEN THE WAVE-METER AND THE CIRCUIT UNDER TEST, THE SHARPER WILL BE THE TUNING CHARACTERISTIC OF THE WAVEMETER AND THE GREATER THE DEGREE OF ACCURACY IN TAKING A MEASUREMENT.

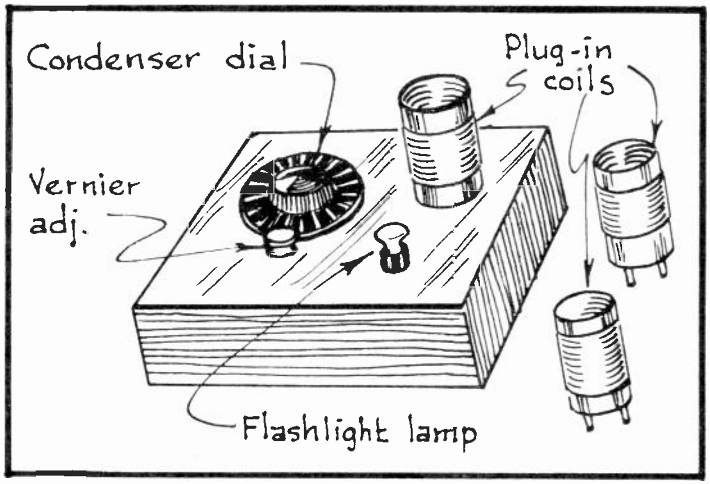

FIG. 4
The Complete Wavemeter.

THE ACTUAL APPEARANCE OF SUCH A WAVEMETER IS SHOWN YOU IN FIG. 4. NOTICE THAT IT IS A COMMON PRACTICE TO USE PLUG-IN COILS IN ORDER TO COVER A GREATER RANGE OF WAVE-LENGTHS AND FREQUENCIES.

THE MORE EXPENSIVE TYPE WAVEMETERS, GENERALLY EMPLOY A HOT-WIRE MILLIAMMETER AS A RESONANCE INDICATOR, CONNECTING THIS INSTRUMENT IN SERIES WITH TUNING CIRCUIT AS SHOWN IN FIG. 5. THE HOT-WIRE MILLIAMMETERS GENERALLY USED FOR THIS PURPOSE HAVE A RANGE OF ABOUT 0 TO 3 MA. AND A .01 MFD. CONDENSER SHOULD BE SHUNTED ACROSS IT AS ALSO SHOWN IN FIG. 5, IN ORDER TO REDUCE THE HIGH FREQUENCY RESISTANCE OF THE CIRCUIT WHICH WOULD ORDINARILY BE INCREASED APPRECIABLY BY INCLUDING THE METER IN THE CIRCUIT.

ALSO OBSERVE IN FIG. 5 THAT THE WAVEMETER HERE ILLUSTRATED REQUIRES NO PLUG-IN COILS. A SELECTOR SWITCH PROVIDES THREE WAVE RANGES. FOR INSTANCE, WITH THE SWITCH CLOSED TO POSITION #1, ONLY COIL #1 WILL BE INCLUDED IN THE CIRCUIT. WITH THE SWITCH IN POSITION #2, COILS #1 AND #2 WILL BE CONNECTED IN SERIES, THEREBY INCREASING THE INDUCTANCE AND FINALLY IN POSITION #3, ALL THREE COILS WILL BE CONNECTED IN SERIES AND THEREBY INCREASE THE INDUCTANCE STILL MORE.

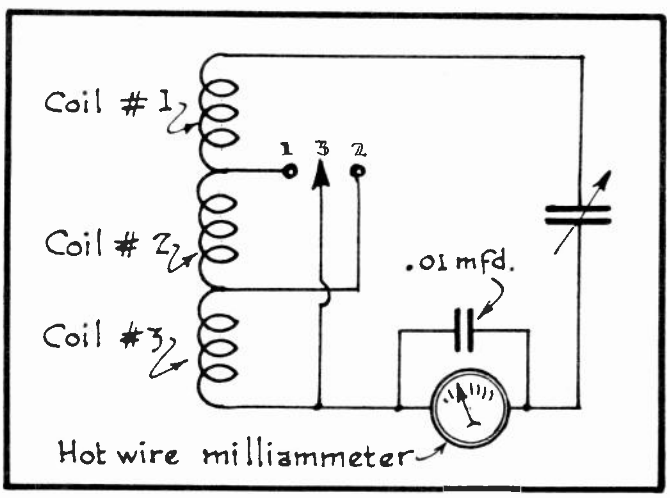

FIG. 5
Wavemeter With Milliammeter Resonance Indicator.

HEADPHONES AS A RESONANCE INDICATOR

THE MAIN OBJECTION TO CONNECTING ANY TYPE OF RESONANCE INDICATOR IN SERIES WITH THE TUNING CIRCUIT OF THE WAVEMETER IS THAT SUCH DEVICES ADD TO THE RESISTANCE OF THE CIRCUIT AND RESISTANCE IN SUCH A CIRCUIT YOU WILL RECALL CAUSES BROAD TUNING. TO MAINTAIN ACCURACY, A WAVEMETER SHOULD BE RATHER SHARP TUNING AND THIS MEANS THAT THE RESISTANCE OF ITS TUNING CIRCUIT MUST BE KEPT DOWN TO

A MINIMUM VALUE. IT IS FOR THIS REASON THAT YOU WILL FIND WAVEMETERS WHERE THE INDICATING DEVICE IS CONNECTED TO THE TUNING CIRCUIT THROUGH ELECTROMAGNETIC COUPLING.

AN EXAMPLE OF THIS PRACTICE IS ILLUSTRATED IN FIG. 6, WHERE THE RESONANCE INDICATOR CONSISTS OF A SET OF HEADPHONES USED IN CONJUNCTION WITH A CARBORUNDUM CRYSTAL. THIS INDICATOR CIRCUIT IS COUPLED TO THE WAVEMETER COIL THROUGH ELECTROMAGNETIC INDUCTION WITH THE AID OF THE INDICATOR COUPLING COIL.

WITH THIS SET-UP, THE R.F. ENERGY PICKED UP BY THE TUNED WINDING WILL INDUCE CORRESPONDING VOLTAGES IN THE INDICATOR COUPLING. THE ENERGY TRANSFER IS GREATEST AT RESONANCE AND IS INDICATED BY MAXIMUM SOUND IN THE HEADPHONES.

THE R.F. WAVE UNDER TEST MUST OF COURSE BE MODULATED AT AN AUDIO FREQUENCY IN ORDER TO BE HEARD IN THE HEADPHONES—THE CRYSTAL ACTING AS THE DETECTOR, AS IT WERE, SO AS TO MAKE THE SIGNAL AUDIBLE.

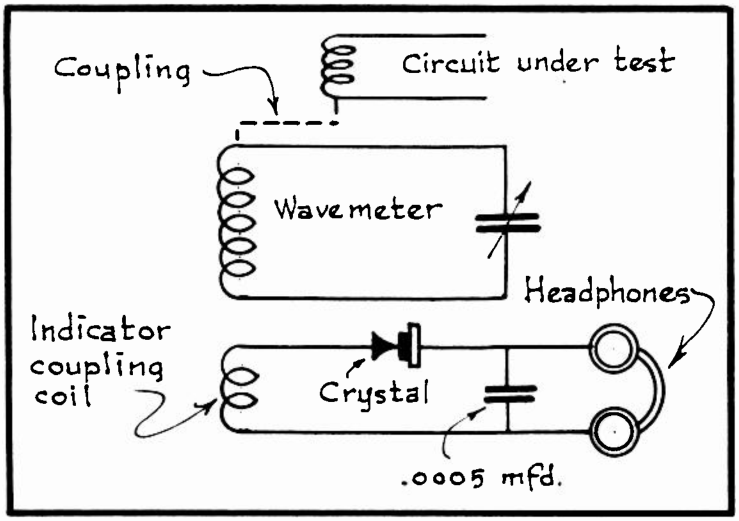

FIG. 6
The Coupled Indicator Circuit.

VERY LITTLE CURRENT IS REQUIRED TO PRODUCE AN AUDIBLE SOUND IN THE HEADPHONES AND THE SOUND INCREASES RAPIDLY AS THE WAVEMETER IS TUNED CLOSER TO RESONANCE WITH THE CIRCUIT BEING TESTED. BECAUSE OF THIS, THE METHOD HERE DESCRIBED IS VERY SENSITIVE AND CAPABLE OF TESTING COMPARATIVELY WEAK R.F. ENERGY.

THE INDICATOR COUPLING COIL WHICH IS USED IN FIG. 6 MAY CONSIST OF FROM 1 TO 20 TURNS OF #18 B&S MAGNET WIRE WOUND ON A TUBULAR BAKELITE FORM HAVING A DIAMETER OF ABOUT 2" AND PLACED SEVERAL INCHES FROM THE TUNED WINDING IN THE WAVEMETER AND ENCLOSED IN THE SAME BOX OR CONTAINER.

IF TOO MANY TURNS ARE USED ON THE COUPLING COIL AND IT IS COUPLED TOO CLOSE TO THE TUNED WINDING, THEN IT WILL ABSORB TOO MUCH ENERGY FROM THE TUNED CIRCUIT AND AT THE SAME TIME CAUSE POOR TUNING. TOO FEW TURNS ON THE COUPLING COIL AND TOO LOOSE COUPLING BETWEEN IT AND THE TUNED WINDING MAY RESULT IN SUCH A SMALL ENERGY TRANSFER THAT THE INDICATING DEVICE MAY NOT RESPOND DEFINITELY.

FOR THIS REASON, THE LOGICAL THING TO DO IS TO EXPERIMENT AND TO USE AS FEW TURNS AS POSSIBLE ON THE COUPLING COIL AND ONLY SUFFICIENT COUPLING BETWEEN THE TWO CIRCUITS AS CONSISTENT WITH A DEFINITE RESPONSE IN THE INDICATING DEVICE BEING USED.

IN THE EVENT THAT CONDITIONS HAPPEN TO BE SUCH AS TO MAKE INDUCTIVE COUPLING BETWEEN THE CIRCUIT UNDER TEST AND THE WAVEMETER IMPRACTICAL SO

THAT HARDLY ANY ENERGY CAN BE ACCEPTED BY THE WAVEMETER, THEN THE DESIRED COUPLING CAN GENERALLY BE ACCOMPLISHED BY SIMPLY CONNECTING A LENGTH OF WIRE BETWEEN ONE END OF THE WAVEMETER'S TUNED WINDING AND SOME CONVENIENT POINT OF THE CIRCUIT UNDER TEST, AS INDICATED BY THE DOTTED LINE IN FIG.6.

APPLYING THE ABSORPTION PRINCIPLE

WE CAN ALSO LOOK UPON THE WAVEMETER OR FREQUENCY-METER AS BEING AN ABSORPTION CIRCUIT IN THAT IT HAS THE ABILITY TO ABSORB RADIO FREQUENCY ENERGY WHEN INFLUENCED BY SUCH A FIELD — THIS ABSORBING EFFECT BEINGMOST PRONOUNCED AT THE RESONANT FREQUENCY.

FOR EXAMPLE, IF AN OSCILLATOR IS RADIATING ENERGY AT 700 KC.,THEN IF THE SIMPLE FREQUENCY-METER OF FIG. 2 IS LOOSELY COUPLED TO THE OSCILLATOR AND ALSO TUNED TO 700 KC., A MILLIAMMETER CONNECTED IN THE PLATE CIRCUIT OF THE OSCILLATOR WOULD SHOW A DECREASE IN THE FLOW OF PLATE CURRENT, AS COMPARED TO ITS READING WHEN THE FREQUENCY-METER IS TUNED TO SOME FREQUENCY OTHER THAN THE OSCILLATOR FREQUENCY OF 700 KC.

BY ALREADY HAVING THE DIAL NUMBERS ON THE FREQUENCY-METER ACCURATELY CALIBRATED TO READ FREQUENCIES IN KILOCYLES, IT IS OBVIOUS THAT WITH AN OSCILLATOR RADIATING ENERGY OF UNKNOWN FREQUENCY, THE WAVE-METER COULD BE LOOSELY COUPLED TO IT AND ITS DIAL SLOWLY TURNED UNTIL THE SETTING IS DETERMINED WHERE THE METER IN THE OSCILLATOR'S PLATE CIRCUIT SHOWS MAXIMUM CHANGE. THE FREQUENCY AS INDICATED BY THE DIAL POSITION OF THE WAVE-METER THUS TELLS ONE THE FREQUENCY AT WHICH THE OSCILLATOR IS RADIATING ENERGY.

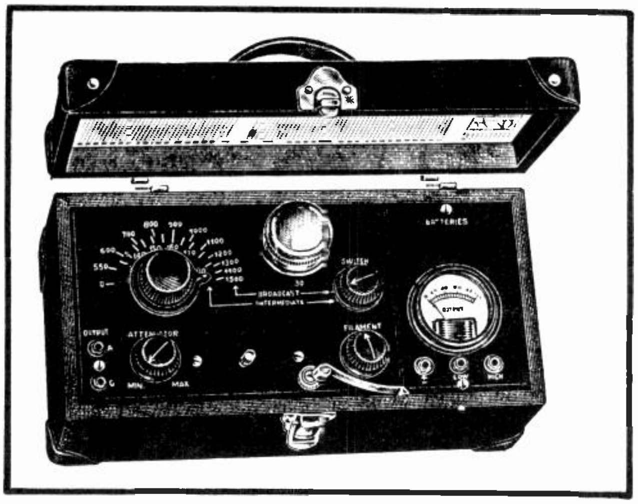

FIG. 7

A Typical Service Oscillator.

WHEN DETERMINING THE FREQUENCY OF A SIGNAL BEING RECEIVED BY A RADIO RECEIVER, THE CALIBRATED FREQUENCY-METER CAN BE LOOSELY COUPLED TO THE RECEIVER INPUT AND WHEN THE FREQUENCY-METER IS ALSO TUNED TO RESONANCE WITH THIS SAME FREQUENCY, A DECREASE IN SIGNAL STRENGTH WILL BE INDICATED BY THE RECEIVER AND THE SETTING OF THE FREQUENCY-METER DIAL WILL TELL ONE THE FREQUENCY OF THE SIGNAL BEING RECEIVED.

ALTHOUGH SIMPLE IN CONSTRUCTION, THIS TYPE OF FREQUENCY-METER IS QUITE DEPENDABLE, FOR BY NOTING THE CHANGE IN THE OSCILLATOR OR RECEIVER CIRCUIT INSTEAD OF CONNECTING A METER IN THE FREQUENCY-METER CIRCUIT TO DENOTE RESONANCE, IT IS OBVIOUS THAT RESISTANCE IS KEPT DOWN TO A MINIMUM IN THE FREQUENCY-METER AND THIS MEANS GREATER ACCURACY.

IN DESIGNING THE TUNING CIRCUITS OF THE WAVEMETERS DESCRIBED IN THIS LESSON, THE SAME METHOD IS EMPLOYED AS WAS ALREADY DESCRIBED TO YOU IN PREVIOUS LESSONS REGARDING THE TUNING CIRCUITS OF RECEIVERS.

CONSTRUCTION OF TEST OSCILLATORS

ALTHOUGH A GREAT MANY DIFFERENT MAKES OF GOOD TEST OR SERVICE OSCILLATORS CAN BE PURCHASED READY MADE, YET A NUMBER OF OUR STUDENTS WISH TO CONSTRUCT THEIR OWN. IT IS FOR THIS LATTER REASON THAT WE HAVE PREPARED THE FOLLOWING INSTRUCTION. FURTHERMORE, EVEN THOUGH YOU DO NOT CARE PARTICULARLY TO CONSTRUCT SUCH A UNIT, YET IT IS REALLY PART OF YOUR TRAINING TO LEARN HOW THESE OSCILLATORS ARE BUILT. WE SHALL START WITH THE SIMPLER DESIGNS FIRST AND THEN WORK ON THROUGH THE MORE COMPLEX UNITS SUCH AS ILLUSTRATED IN FIG. 7.

A BATTERY-OPERATED OSCILLATOR

A SIMPLE BATTERY-OPERATED OSCILLATOR IS SHOWN YOU IN FIG. 8 AND AS YOU WILL OBSERVE, IT EMPLOYS A SINGLE -99 TUBE. SO THAT THE BATTERY WEIGHT MAY BE KEPT DOWN AS MUCH AS POSSIBLE, THREE SERIES-CONNECTED FLASH LIGHT CELLS CAN BE USED FOR THE $4\frac{1}{2}$ VOLT "A" SUPPLY AND A SMALL-SIZE 45 VOLT "B" BATTERY FOR THE "B" SUPPLY.

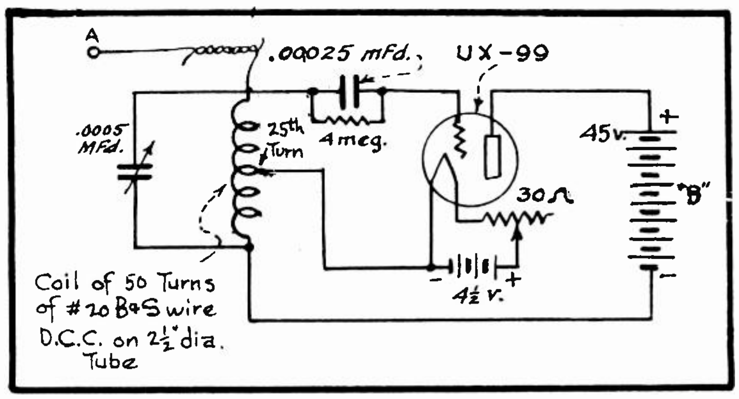

FIG. 8

The Battery Operated Oscillator.

THE TUNED WINDING TO USE WITH THIS OSCILLATOR IN CONJUNCTION WITH A .0005 MFD. VARIABLE CONDENSER CONSISTS OF 50 TURNS OF #20 B&S DOUBLE COTTON-COVERED MAGNET WIRE WOUND ON A PIECE OF INSULATIVE TUBING $2\frac{1}{2}$" IN DIAMETER. THIS WILL PERMIT THE OSCILLATOR TO BE TUNED OVER THE BROADCAST BAND. THE TAP IS MADE AT THE 25TH TURN OF THE WINDING.

BY STUDYING THIS DIAGRAM MORE CLOSELY, YOU WILL NOTICE THAT HALF OF THE WINDING IS INCLUDED IN THE GRID CIRCUIT AND HALF IN THE PLATE CIRCUIT OF THE TUBE SO THAT THERE IS VERY CLOSE COUPLING BETWEEN THEM. THIS CONDITION CAUSES REGENERATION TO SUCH AN EXTENT THAT THE CIRCUIT COMMENCES TO OSCILLATE AND GENERATE RADIO FREQUENCY ENERGY JUST LIKE THE OSCILLATOR TUBE IN A SUPERHETERODYNE RECEIVER. THE FREQUENCY OF THESE OSCILLATIONS WILL OF COURSE BE DETERMINED BY THE TUNING CONSTANTS OF THE CIRCUIT AS FIXED BY THE COIL AND CONDENSER COMBINATION.

IN ORDER FOR THE OSCILLATOR SIGNAL TO BE AUDIBLE IN THE RECEIVER WITH WHICH IT IS BEING USED, THE R.F. SIGNAL MUST BE MODULATED AT AN AUDIO FREQUENCY AT THE OSCILLATOR. THIS IS ACCOMPLISHED BY INSTALLING A FIXED CONDENSER AND LEAK RESISTOR IN THE GRID CIRCUIT OF THE OSCILLATOR TUBE. THE EFFECT OF THIS GRID CONDENSER AND LEAK IS TO BLOCK AND FREE THE TUBE AT AN AUDIBLE FREQUENCY RATE THEREBY MODULATING THE R.F. WAVE-FORM. THIS MODULATED SIGNAL IS THEN PICKED UP BY A RECEIVER AND REPRODUCED BY THE SPEAKER AS A SORT OF BUZZING SOUND. CHANGING THE VALUES OF THE GRID CONDENSER AND LEAK WILL CHANGE THE PITCH OF SOUND.

THE OSCILLATOR IS COUPLED TO THE RECEIVER UNDER TEST BY CONNECTING TERMINAL "A" OF THE OSCILLATOR IN FIG. 8 TO THE ANTENNA TERMINAL OF THE RECEIVER. INSIDE OF THE OSCILLATOR, ONE END OF A SHORT PIECE OF INSULATED

WIRE IS CONNECTED TO TERMINAL "A". THE END OF ANOTHER SHORT PIECE OF INSULATED WIRE IS CONNECTED TO ONE END OF THE OSCILLATOR'S TUNED WINDING. THE FREE ENDS OF THESE TWO PIECES OF WIRE ARE THEN TWISTED TOGETHER FOR A LENGTH OF FROM 1 TO 2 INCHES. THIS TWISTING PROCESS WILL INTRODUCE CAPACITIVE COUPLING OF A COMPARATIVELY LOW ORDER BETWEEN TERMINAL "A" AND THE OSCILLATOR CIRCUIT. THE OSCILLATOR IS THEREFORE REALLY COUPLED TO THE RECEIVER UNDER TEST THROUGH CAPACITIVE COUPLING.

A 10 MMFD. CONDENSER COULD ALSO BE USED IF PREFERRED SO AS TO PRODUCE THIS CAPACITIVE COUPLING INSTEAD OF THE TWISTED PAIR OF WIRES.

A 110 VOLT A.C.-D.C. OSCILLATOR

IN FIG.9 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF A SIMPLE MODULATED OSCILLATOR WHICH CAN BE OPERATED FROM EITHER A 110 VOLT A.C. OR D.C. SUPPLY. THE TUBE USED IS EITHER AN -01A OR A -12A AND A 25 WATT 110 VOLT INCANDESCENT LAMP IS CONNECTED IN SERIES WITH THE FILAMENT OF THE RADIO TUBE IN ORDER TO REDUCE THE LINE VOLTAGE BY THE PROPER AMOUNT FOR THIS PURPOSE.

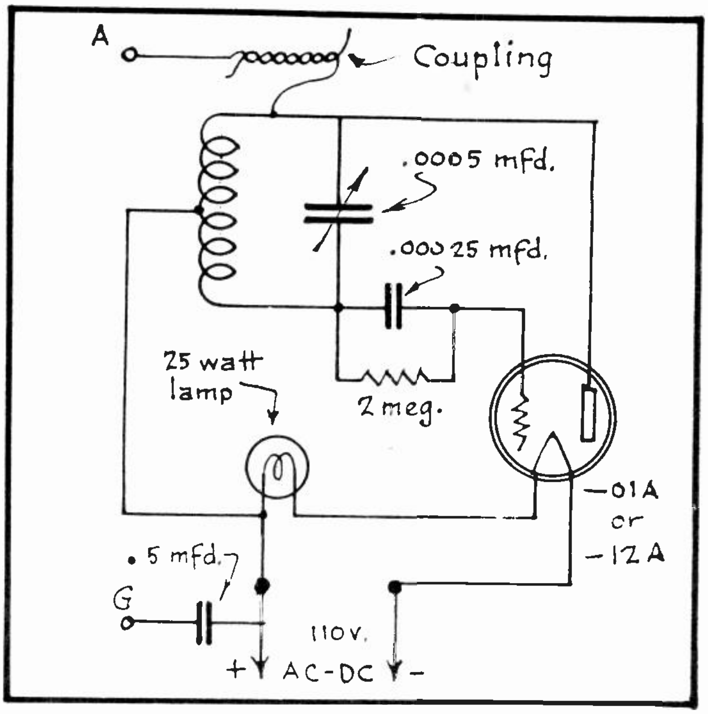

FIG. 9
The A.C.-D.C. Oscillator.

IF AN A.C. SUPPLY IS BEING USED, IT MAKES NO DIFFERENCE IF THE A.C. LEAD CONNECTIONS TO THE 110 VOLT LINE ARE REVERSED BUT IF A D.C. SUPPLY IS BEING USED, THEN THE LINE CONNECTIONS SHOULD BE MADE TO CORRESPOND WITH THE POLARITY AS INDICATED IN FIG. 9.

WHEN USING A .0005 MFD. TUNING CONDENSER, THE COIL TO COVER THE BROADCAST BAND MAY CONSIST OF 60 TURNS OF #20 B&S DOUBLE SILK COVERED WIRE WOUND ON AN INSULATIVE TUBULAR FORM HAVING A DIAMETER OF $2\frac{1}{2}$". THE TAP SHOULD BE MADE AT THE 30TH TURN.

IT WILL BE WELL TO REMIND YOU AT THIS TIME THAT THE CONSTANTS OF THESE OSCILLATOR TUNING CIRCUITS CAN BE WORKED OUT IN EXACTLY THE SAME MANNER AS ALREADY EXPLAINED TO YOU IN PRECEDING LESSONS WITH RESPECT TO THE TUNING CIRCUITS FOR RECEIVERS.

FOR THE OSCILLATOR OF FIG. 9, THE SAME METHOD OF COUPLING TO THE RECEIVER'S ANTENNA TERMINAL CAN BE USED AS SPECIFIED FOR THE OSCILLATOR OF FIG. 8. THE "G" TERMINAL OF THE OSCILLATOR IN FIG. 9 IS TO BE CONNECTED TO THE RECEIVER'S GROUND TERMINAL.

THE DYNATRON OSCILLATOR

IN FIG. 10 YOU ARE SHOWN A STILL DIFFERENT OSCILLATOR DESIGN. IN

THIS CASE, THE TUNING CIRCUIT IS PLACED IN THE PLATE CIRCUIT OF THE TUBE RATHER THAN IN THE GRID CIRCUIT; A SCREEN GRID TUBE IS USED AND THE SCREEN GRID VOLTAGE IS MADE HIGHER IN VALUE THAN THE PLATE VOLTAGE. THE GRID RETURN CONNECTION IS MADE DIRECTLY TO ONE SIDE OF THE TUBE FILAMENT.

WHEN OPERATED UNDER THESE CONDITIONS, THE TUBE WILL OSCILLATE AND ITS FREQUENCY OF OSCILLATION WILL BE GOVERNED BY THE TUNING CIRCUIT. OSCILLATORS WHICH ARE BASED ON THIS DESIGN ARE KNOWN AS DYNATRON OSCILLATORS AND THE CHIEF ADVANTAGES OF THIS TYPE OF OSCILLATOR ARE ITS STABILITY OF OSCILLATION AND ABILITY TO MAINTAIN ACCURATE CALIBRATION. IT IS ALSO SIMPLE IN CONSTRUCTION.

THE CIRCUIT DESIGN SHOWN IN FIG. 10 IS ALSO SUITABLE FOR BOTH A.C. AND D.C. 110 VOLT OPERATION AND IT CAN BE COUPLED TO THE ANTENNA TERMINAL OF THE RECEIVER UNDER TEST THROUGH THE 10 MMFD. COUPLING CONDENSER ALSO SHOWN IN FIG. 10.

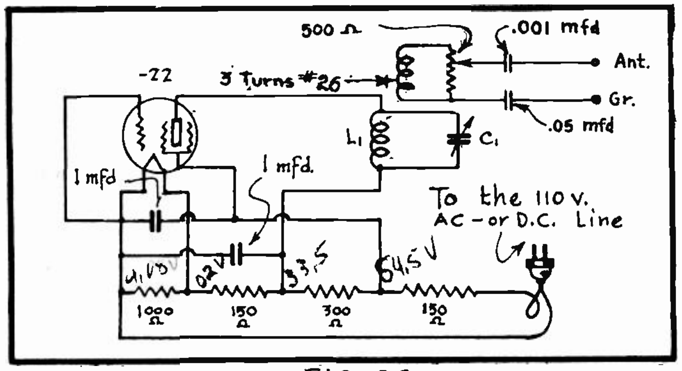

FIG. 10

The Dynatron Oscillator.

FOR THE BEST PERFORMANCE, ALL TEST OSCILLATORS SHOULD BE ENCLOSED IN A METAL SHIELD CAN. FURTHERMORE, THE INSTRUMENT CAN BE USED MORE EASILY IF THE TUNING CONDENSER IS OF THE STRAIGHT-LINE FREQUENCY TYPE.

CALIBRATING OSCILLATORS

NOW THAT YOU ARE FAMILIAR WITH THE BASIC OSCILLATOR CIRCUITS, THE NEXT STEP WILL BE TO LEARN HOW SUCH TESTING UNITS ARE CALIBRATED. FOR THE PRESENT, WE SHALL CONSIDER THE CALIBRATION OF SUCH OSCILLATORS WHICH ARE DESIGNED TO COVER THE BROADCAST BAND ONLY.

BEFORE ATTEMPTING TO CALIBRATE THE OSCILLATOR, BE SURE THAT ALL PARTS AND WIRING ARE IN TACT, THAT THE TUBE VOLTAGES ARE CORRECT AND THAT ALL SHIELDING IS IN PLACE. SHOULD THE UNIT BE CALIBRATED WITHOUT ALL SHIELDING IN PLACE, IT WOULD BE FOUND THAT THE TUNING WOULD BE AFFECTED AFTER THE SHIELDING IS IN USE AND THE CALIBRATION WOULD THEREFORE BE IN ERROR.

IF NO CALIBRATED WAVEMETER OR FREQUENCY METER IS AVAILABLE, THEN THE NEWLY CONSTRUCTED OSCILLATOR CAN BE CALIBRATED WITH ANY GOOD BROADCAST RECEIVER. IN ORDER TO USE A RECEIVER FOR THIS PURPOSE, IT IS NECESSARY TO FIRST CALIBRATE THE RECEIVER DIAL ITSELF AND FOR THIS, BROADCAST STATIONS OPERATING AT ACCURATELY CONTROLLED FREQUENCIES CAN BE USED TO GREAT ADVANTAGE.

TO CALIBRATE THE RECEIVER DIAL PROCEED AS FOLLOWS: START IN AT THE LOW FREQUENCY END OF THE DIAL AND TUNE IN AS MANY OF THE GOOD BROADCAST STATIONS AS YOU CAN UNTIL THE DIAL INDICATOR HAS TRAVELED ACROSS ITS ENTIRE SCALE. AS EACH STATION IS TUNED IN BY THE RECEIVER, CAREFULLY TAKE NOTE OF THE DIAL READING AT THAT PARTICULAR TIME. WRITE THIS DIAL READING ON A PIECE OF PAPER AND NEXT TO IT PLACE THE FREQUENCY AT WHICH THE PARTICULAR STATION OPERATES. DO THIS FOR ALL STATIONS HEARD.

UPON COMPLETION OF THIS PROCESS, YOU WILL HAVE PERHAPS TEN DIFFERENT

DIAL NUMBERS AT WHICH STATIONS ARE RECEIVED AND THE CORRESPONDING FREQUENCY IN KILOCYCLES. LET US SUPPOSE, FOR EXAMPLE, THAT THE DIAL OF THE RECEIVER BEING USED IS NUMBERED FROM 0 TO 100 AND THAT WHEN TUNING IN THE DIFFERENT STATIONS, YOU OBTAIN THE DATA AS GIVEN IN TABLE I.

TABLE I

DIAL READING	FREQUENCY OF STATION BEING RECEIVED
95	600 Kc.
85	625 Kc.
75	700 Kc.
58	875 Kc.
50	975 Kc.
38	1125 Kc.
30	1250 Kc.
20	1400 Kc.
13	1500 Kc.

USING THIS DATA, YOU CAN PLOT A CALIBRATION CURVE AS THAT SHOWN YOU IN FIG. 11. TO DO THIS, WE USE CROSS-RULED PAPER OR "GRAPH PAPER", LAYING OFF THE DIAL NUMBERS ALONG THE BOTTOM FROM THE LEFT TOWARDS THE RIGHT AND FREQUENCIES ALONG THE LEFT EDGE FROM THE BOTTOM TOWARDS THE TOP.

WE THEN MARK ONE POINT ON THE GRAPH WHERE THE 95 DIAL NUMBER LINE CROSSES THE 600 Kc. LINE TO CONFORM WITH THE FIRST READING OF TABLE I. SIMILAR POINTS ARE MARKED IN THE SAME MANNER ON THIS GRAPH PAPER TO CORRESPOND WITH THE REST OF THE DATA IN TABLE I AND THESE POINTS ARE THEN ALL CONNECTED TOGETHER WITH A CONTINUOUS LINE, RESULTING IN THE "CALIBRATION CURVE."

BY REFERRING TO SUCH A GRAPH, YOU CAN TELL AT A GLANCE TO WHICH FREQUENCY THE RECEIVER'S TUNING CIRCUITS ARE TUNED AT ANY PARTICULAR DIAL SETTING. EVEN IF THE RECEIVER IN USE IS EQUIPPED WITH A DIAL ALREADY CALIBRATED IN KILOCYCLES, ITS READINGS SHOULD BE CAREFULLY CHECKED AGAINST THE DIFFERENT STATION FREQUENCIES, SINCE THE DIAL READINGS ARE NOT ALWAYS ACCURATE.

HAVING THE RECEIVER DIAL CALIBRATED, YOU CAN DISCONNECT THE RECEIVER FROM ITS ANTENNA SYSTEM AND CONNECT THE NEW OSCILLATOR TO IT. BY TUNING THE RECEIVER TO ANY KNOWN FREQUENCY, ADJUST THE OSCILLATOR TUNING DIAL UNTIL THE OSCILLATOR SIGNAL IS PICKED UP BY THE RECEIVER. THE OSCILLATOR WILL AT THIS TIME BE TUNED TO RESONANCE WITH THE RECEIVER AND ITS DIAL SETTING SHOULD THEREFORE BE NOTED.

BY REPEATING THIS TEST AT SEVERAL DIFFERENT FREQUENCIES, YOU WILL HAVE AVAILABLE A NUMBER OF DIFFERENT OSCILLATOR DIAL SETTINGS WITH THE CORRESPONDING FREQUENCIES. FROM THIS DATA, A DIAL CALIBRATION CURVE CAN BE PLOTTED FOR

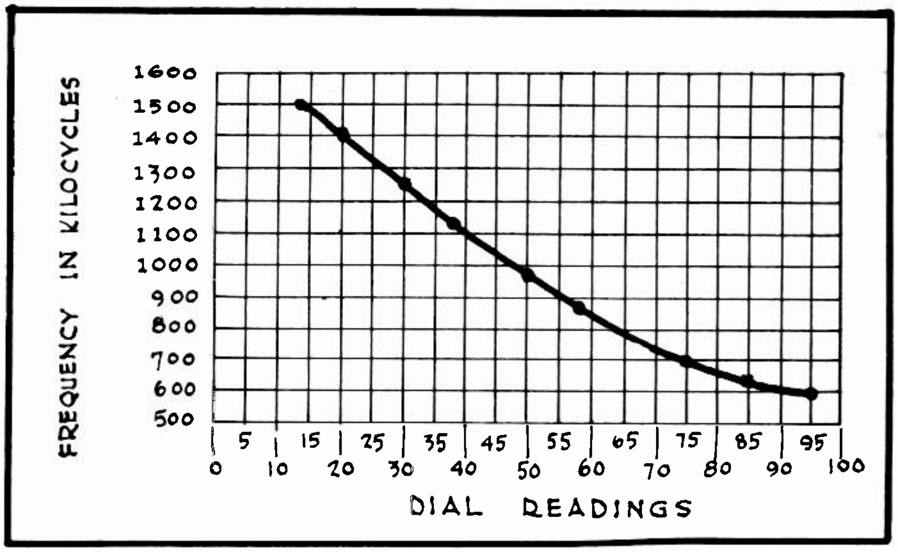

FIG. 11

A Dial Calibrating Curve.

THE OSCILLATOR SIMILAR TO THAT ALREADY PREPARED FOR THE RECEIVER IN FIG. 11. FROM THIS CALIBRATION CURVE, YOU CAN THEN QUICKLY INTERPRET ANY OSCILLATOR DIAL SETTING TO ITS EQUIVALENT FREQUENCY EXPRESSED IN KILOCYCLES. THE OSCILLATOR IS THEN SAID TO BE "CALIBRATED."

WHILE WE ARE ON THE SUBJECT OF CALIBRATION, IT WILL BE WELL TO MENTION A FEW THINGS REGARDING THE CALIBRATION OF WAVEMETERS AND FREQUENCY-METERS. THESE UNITS CAN BE CALIBRATED IN A SIMILAR MANNER AND A SUITABLE CALIBRATION CURVE PLOTTED. IN THIS CASE, IT IS ONLY NECESSARY TO SET UP A CALIBRATED OSCILLATOR AND THE WAVEMETER OR FREQUENCY-METER AND TUNE THE OSCILLATOR TO VARIOUS KNOWN FREQUENCIES. AS THE FREQUENCY METER IS TUNED TO RESONANCE WITH THESE DIFFERENT SIGNALS, ITS DIAL READINGS ARE NOTED. FROM THE DATA THUS OBTAINED, THE FREQUENCY METER DIAL READINGS CAN BE PLOTTED AGAINST THE CORRESPONDING FREQUENCIES AND A CALIBRATION CURVE DRAWN. IN THE CASE OF A WAVEMETER, THE FREQUENCIES CAN BE CONVERTED TO CORRESPONDING WAVELENGTHS AND THE CALIBRATION CURVE PLOTTED ON THE BASIS OF DIAL READINGS AGAINST WAVELENGTH IN METERS.

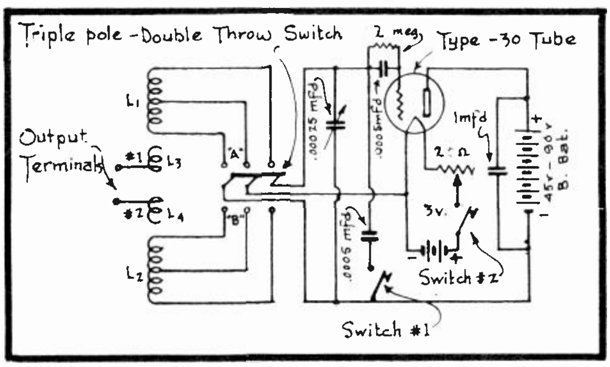

FIG. 12
Circuit of the R.F.-I.F. Oscillator.

THESE SAME OSCILLATORS, WHICH WERE JUST ILLUSTRATED, CAN ALSO BE USED TO TUNE OVER THE FREQUENCY RANGE AS USED IN THE I.F. AMPLIFIERS OF SUPERHETERODYNE RECEIVERS SIMPLY BY USING A COIL AND CONDENSER COMBINATION WHICH WILL TUNE THE OSCILLATOR CIRCUIT TO THE DESIRED I.F. FREQUENCY. THE OSCILLATOR CAN THEN BE USED AS AN AID TO ALIGN THE I.F. STAGES IN SUPERHETERODYNE RECEIVERS.

CONSTRUCTION OF A SELF-MODULATED R.F. OSCILLATOR FOR 545 -1500 Kc. AND 175-180 Kc.

THE MODULATED R.F. OSCILLATOR, WHOSE CONSTRUCTION IS ILLUSTRATED IN FIG. 12, CAN BE USED FOR THE ALIGNMENT OF THE I.F. TRANSFORMERS IN SUPERHETERODYNE RECEIVERS, AS WELL AS FOR A GENERAL PURPOSE TEST OSCILLATOR TO COVER THE BROADCAST BAND.

COIL L_1 OF THIS OSCILLATOR SHOULD CONSIST OF 80 TURNS OF #26 B&S DOUBLE SILK COVERED WIRE WOUND ON A TUBULAR FORM 3" IN DIAMETER. THIS COIL SHOULD BE CENTER-TAPPED AT THE 40TH TURN. COUPLING COIL L_3 SHOULD CONSIST OF 3 TURNS OF THE SAME WIRE WOUND AT A DISTANCE OF ABOUT $\frac{1}{2}$" FROM COIL L_1.

FOR COIL L_2 WIND 160 TURNS OF #26 B&S DOUBLE SILK COVERED WIRE ON ANOTHER TUBULAR FORM, HAVING A DIAMETER OF 3". CENTER-TAP THIS COIL AT THE 80TH TURN. COUPLING COIL L_4 SHOULD CONSIST OF 3 TURNS OF THE SAME WIRE WOUND AT A DISTANCE OF ABOUT $\frac{1}{2}$" FROM COIL L_2. THE WINDING FORM CONTAINING COILS L_1 AND L_3 SHOULD BE MOUNTED AT RIGHT ANGLES TO THE FORM CONTAINING COILS L_2 AND L_4 WHEN ASSEMBLING THE UNITS IN THE TEST KIT.

TO COVER THE BROADCAST BAND FROM 545-1500 Kc. WITH THIS OSCILLATOR, CLOSE THE TRIPLE POLE SWITCH TO POSITION "A", OPEN SWITCH #1 AND CLOSE SWITCH #2. USE OUTPUT TERMINAL #1 TO COUPLE THE UNIT TO THE RECEIVER UNDER

TEST AND TUNE TO THE DESIRED BROADCAST FREQUENCY BY MEANS OF THE .00025 MFD. TUNING CONDENSER. THE OSCILLATOR WILL OF COURSE REQUIRE "CALIBRATION" OVER THIS FREQUENCY BAND, AS YOU HAVE ALREADY LEARNED IN THIS LESSON.

TO TUNE OVER THE 175-180 KC. BAND FOR I.F. TRANSFORMER ADJUSTMENTS, CLOSE THE TRIPLE POLE SWITCH TO POSITION "B" AND CLOSE SWITCHES #1 AND #2. USE OUTPUT TERMINAL #2 TO COUPLE THE TEST UNIT TO THE RECEIVER AND ADJUST TO THE DESIRED I.F. FREQUENCY WITH THE .00025 MFD. TUNING CONDENSER.

THE DIAL SETTING REQUIRED FOR THIS CONDENSER, IN ORDER TO TUNE TO 175 KC. AND THE VARIOUS OTHER COMMONLY USED INTERMEDIATE FREQUENCIES CAN BE DETERMINED BY CALIBRATING THE TESTER WITH ANY GOOD STANDARD MAKE COMM-ERCAIL I.F. OSCILLATOR. THAT IS, WITH THE I.F. TRANSFORMERS OF A GOOD SUPERHETERODYNE RECEIVER ADJUSTED TO EXACTLY 175 KC. WITH THE AID OF A RELIABLE OSCILLATOR, YOU CAN THEN COUPLE YOUR NEW OSCILLATOR TO THE I.F. STAGES OF THE SAME RECEIVER AND ADJUST ITS TUNING CONDENSER UNTIL THE MAX-IMUM SIGNAL IS HEARD IN THE RECEIVER'S SPEAKER. YOUR OSCILLATOR IS THEN TUNED TO THE 175 KC. FREQUENCY, SO NOTE ITS DIAL SETTING CAREFULLY. IT CAN BE CALIBRATED FOR ANY OTHER INTERMEDIATE FREQUENCY WITHIN ITS RANGE IN THE SAME MANNER.

HAVING CONCLUDED THIS LESSON, YOU SHOULD NOW HAVE A GOOD UNDERSTAND-ING OF THE CONSTRUCTIONAL FEATURES OF WAVEMETERS AND TEST OSCILLATORS. LA-TER ON, YOU WILL BE GIVEN SPECIFIC INFORMATION AS TO THE METHODS OF USING BOTH OF THESE TEST DEVICES TO THE GREATEST ADVANTAGE IN ACTUAL RADIO PRA-CTICE. FOR THE PRESENT, WE ARE CHIEFLY INTERESTED IN THE CONSTRUCTION OF THESE TESTERS IN THEMSELVES.

IN THE NEXT LESSON, YOU ARE GOING TO CONTINUE YOUR STUDY OF TEST EQUIPMENT BY LEARNING ABOUT TUBE CHECKERS AND WHICH YOU WILL FIND TO BE INTERESTING, HIGHLY INSTRUCTIVE AND PRACTICAL.

EXAMINATION QUESTIONS

LESSON NO. 51

1.- DESCRIBE THE BASIC PRINCIPLES OF THE WAVEMETER.

2. - WHAT IS THE DIFFERENCE BETWEEN A WAVEMETER AND A FREQUENCY METER?

3. - EXPLAIN THE ACTION OF THE WAVEMETER WHEN A LAMP IS USED AS THE RESONANCE INDICATOR.

4. - WHAT IS THE CHIEF ADVANTAGE OF USING ELECTROMAGNETIC COUPLING BETWEEN THE WAVEMETER AND RESONANCE INDICATOR CIRCUIT RATHER THAN CONNECTING THE RESONANCE INDICATOR DIRECTLY IN THE TUNING CIRCUIT OF THE WAVEMETER?

5. - DRAW A CIRCUIT DIAGRAM OF A BATTERY-OPERATED TEST OSCILLATOR.

6. - EXPLAIN HOW THIS SAME TEST OSCILLATOR OPERATES.

7. - WHAT ARE THE ESSENTIAL DIFFERENCES BETWEEN A DYNATRON OSCILLATOR AND THE CONVENTIONAL TYPE OF OSCILLATOR?

8. - EXPLAIN HOW YOU WOULD GO ABOUT THE TASK OF CALIBRATING A RECEIVER DIAL WHICH IS MARKED WITH THE NUMBERING SYSTEM FROM 0 TO 100 SO THAT ITS READINGS CAN BE EASILY CONVERTED TO EQUIVALENT FREQUENCIES EXPRESSED IN KILOCYCLES.

9. - HOW CAN YOU CALIBRATE A NEWLY CONSTRUCTED TEST OSCILLATOR TO COVER THE BROADCAST BAND, USING A STANDARD BROADCAST RECEIVER AS A GUIDE?

10.- DRAW A CIRCUIT DIAGRAM OF A SIMPLE TEST OSCILLATOR WHICH CAN BE OPERATED FROM EITHER A 100 VOLT A.C. OR D.C. POWER SUPPLY.

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LESSON NO. 52

• TUBE CHECKERS •

Of all the parts incorporated in radio receivers, amplifiers etc., the TUBES can be considered as being the most fragile part of the assembly. Not only are they subject to mechanical breakdown if abused through careless handling or thoughtless operation of the equipment but they will also become less efficient with continued use.

For this latter reason, it is considered good practice to renew all receiver tubes which have been in service for at least one year. Although the receiver may apparently still be working alright with the same old set of tubes, yet in the majority of cases, the receiver will be found to have better amplifying ability and improved tone quality when the new tubes are installed.

Although installing new tubes will demonstrate improved performance, yet before taking it for granted that the old tubes are no longer satisfactory, it is advisable to subject them to systematic tests which will definitely indicate their condition. Let us now proceed and see how these tests are made.

So that you will obtain a clear mental picture of this work, we shall start our explanation with the most simple form of tube tests or the fundamental tests, as it were, and then gradually carry our investigation through the more elaborate tube checkers such as illustrated in Fig. 1.

In this manner, you will more easily grasp the fundamental oper-

FIG. 1
A Modern Tube Checker.

ATING PRINCIPLE UPON WHICH ALL EQUIPMENT OF THIS TYPE IS BASED.

TESTING THE ELEMENTS

WHEN A RECEIVER DOES NOT OPERATE PROPERLY FOR SOME REASON OR OTHER, THE AVERAGE OWNER GLANCES AT THE TUBES FIRST OF ALL. IF HE OBSERVES THAT THE FILAMENTS OR HEATERS EMIT LIGHT, HE ASSUMES THAT THE TUBES ARE IN GOOD CONDITION AND SUSPECTS SOME OTHER PORTION OF THE CIRCUIT AS BEING AT FAULT.

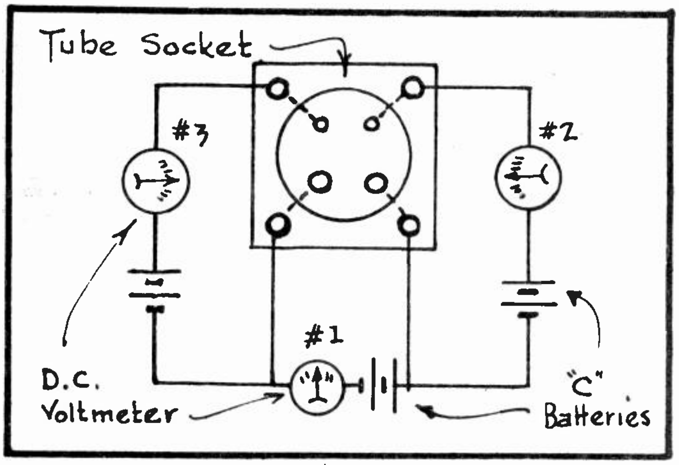

FIG. 2
The Short Tester.

NOW AN IMPORTANT THING FOR YOU TO REMEMBER IS THAT THE MERE FACT THAT A TUBE'S FILAMENT IS HEATED TO INCANDESCENCE, DOES NOT NECESSARILY MEAN THAT THE TUBE IS GOOD. FURTHERMORE, SOME TYPES OF TUBES NORMALLY DRAW SO LITTLE FILAMENT CURRENT THAT YOU CAN HARDLY TELL BY OBSERVATION WHETHER THE FILAMENT IS HOT OR NOT. EVEN THOUGH THESE FILAMENTS MAY BE INTACT, THE TUBE MAY BE INOPERATIVE DUE TO THERE BEING AN INTERNAL SHORT CIRCUIT BETWEEN ITS ELEMENTS, POOR ELECTRON EMISSION ETC.

IN FIG. 2 YOU ARE SHOWN A VERY SIMPLE FORM OF TESTER WHICH WILL INDICATE WHETHER OR NOT THE FILAMENT OF A FOUR-PRONG TUBE IS COMPLETE, AS WELL AS TO INDICATE WHETHER OR NOT ANY OF ITS ELEMENTS ARE SHORTED TOGETHER. AS YOU WILL OBSERVE, THIS DEVICE CONSISTS OF NOTHING MORE THAN A FOUR-PRONG (UX) SOCKET, THREE 4½ VOLT "C" BATTERIES AND THREE LOW-RANGE D.C. VOLTMETERS.

NOW THEN, IF METER #1 FAILS TO OFFER A READING WHEN THE TUBE IS INSERTED IN THE SOCKET, THE TEST INDICATES THAT THE FILAMENT IS OPEN CIRCUITED OR "BURNED OUT", AS WE GENERALLY SAY. IF METER #1 INDICATES "BATTERY VOLTAGE", THEN THE FILAMENT IS NOT BURNED OUT.

SHOULD METER #2 OFFER A READING, THEN THE TEST SHOWS THAT THE PLATE AND FILAMENT ARE SHORTED TOGETHER, WHEREAS A READING AT VOLTMETER #3 INDICATES THAT THE GRID AND FILAMENT ARE SHORTED TOGETHER. IF THE TUBE IS GOOD, NEITHER VOLTMETER #2 NOR METER #3 SHOULD OFFER ANY READING. THESE ARE NOTHING MORE THAN THE CONVENTIONAL CONTINUITY TESTS

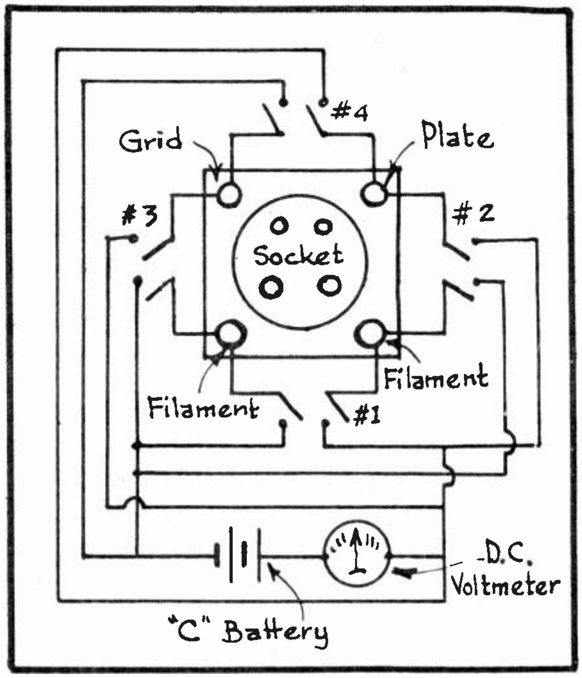

FIG. 3
A Short-Tester With Switches.

WITH WHICH YOU ARE ALREADY SO FAMILIAR.

THIS SAME SHORT CIRCUIT TEST COULD ALSO BE ACCOMPLISHED BY USING FLASHLIGHT CELLS TO REPLACE THE "C" BATTERIES AND SMALL FLASHLIGHT LAMPS TO TAKE THE PLACE OF THE VOLTMETERS. IN THIS CASE, A LAMP WOULD BURN WHENEVER A SHORT CIRCUIT EXISTS BETWEEN ANY OF THE ELEMENTS.

BY USING THE CRUDE ARRANGEMENT OF FIG. 2, THREE VOLTMETERS AND THREE "C" BATTERIES ARE REQUIRED, OR ELSE IF ONLY A SINGLE "C" BATTERY AND A SINGLE VOLTMETER IS USED, THEN THE CONNECTIONS WILL HAVE TO BE INTERCHANGED IN ORDER TO CONDUCT THE DIFFERENT TESTS. NEITHER OF THESE METHODS IS REALLY PRACTICAL FOR A TESTING INSTRUMENT OF THE COMMERCIAL TYPE, IN THAT THE FIRST METHOD INCREASES THE COST AND THE SECOND METHOD REQUIRES TOO MUCH MANIPULATION ON THE PART OF THE SERVICEMAN.

FROM A PRACTICAL STANDPOINT, NO EQUIPMENT SHOULD BE DUPLICATED AND THE ARRANGEMENT SHOULD BE SUCH THAT THE TESTS CAN BE MADE QUICKLY AND ACCURATELY. WITH THESE POINTS IN MIND, LET US NOW SEE HOW THE FEATURES AND BASIC PRINCIPLES AS FOUND IN FIG. 2 CAN BE APPLIED TO A SIMILAR TESTER OF COMMERCIAL APPEARANCE.

THE REVISED CIRCUIT APPEARS IN FIG. 3 AND AS YOU WILL NOTICE, ONLY A SINGLE BATTERY AND A SINGLE VOLTMETER IS USED AND ALL OF THE TESTS CAN BE CONDUCTED BY MERELY INSERTING THE TUBE UNDER TEST IN THE SOCKET AND CLOSING EACH OF THE FOUR SINGLE-THROW, DOUBLE-POLE SWITCHES ONE AT A TIME AS THE METER IS WATCHED.

NOTICE CAREFULLY HOW THIS ARRANGEMENT SIMPLIFIES MATTERS. FOR INSTANCE, TO TEST THE FILAMENT FOR CONTINUITY, IT IS ONLY NECESSARY TO CLOSE SWITCH #1; TO CHECK FOR A SHORT BETWEEN THE PLATE AND FILAMENT, CLOSE SWITCH #2; TO CHECK FOR A SHORT BETWEEN THE GRID AND FILAMENT, CLOSE SWITCH #3 AND TO TEST FOR A SHORT BETWEEN THE PLATE AND GRID, CLOSE SWITCH #4. ALL THAT WOULD BE VISIBLE ON THE CONTROL PANEL OF THIS TESTER IS THE VOLTMETER, THE SOCKET AND THE FOUR SWITCHES. THE REST OF THE EQUIPMENT AND WIRING WOULD ALL BE CONCEALED IN THE CABINET OF THE TESTER.

ONLY SLIGHT REVISIONS WOULD BE NECESSARY TO CONDUCT THESE SAME TESTS ON FIVE, SIX OR SEVEN PRONG TUBES, THE ONLY ADDITIONAL REQUIREMENTS BEING CORRESPONDING SOCKETS, AND THE ADDITIONAL SWITCHES AND WIRING SO THAT THE OTHER INTER-ELEMENT TESTS CAN BE MADE. REGARDLESS, OF THE TYPE TUBE SOCKET BEING EMPLOYED, THE FUNDAMENTAL PRINCIPLES AS DESCRIBED RELATIVE TO FIGS #2 AND #3 STILL APPLY -- THIS WILL BE MORE EVIDENT WHEN YOU STUDY THE CIRCUITS OF THE COMPLETE TUBE CHECKERS LATER IN THIS LESSON.

THE STATIC MUTUAL-CONDUCTANCE TEST

AFTER A TUBE HAS BEEN CHECKED FOR CONTINUITY OF ITS FILAMENT, AS WELL AS FOR INTER-ELEMENT SHORT CIRCUITS, IT SHOULD NEXT BE SUBJECTED TO A MUTUAL CONDUCTANCE TEST. THE MUTUAL CONDUCTANCE OF A TUBE, YOU WILL RECALL, IN A LARGE MEASURE DETERMINES ITS PERFORMANCE.

FIG. 4 SHOWS YOU THE FUNDAMENTAL CIRCUIT SET-UP WITH WHICH A SIMPLE MUTUAL-CONDUCTANCE TEST CAN BE MADE.

TO MAKE THIS TEST, RHEOSTAT R_1 AND POTENTIOMETERS R2, R3 AND R4 ARE

ALL ADJUSTED SO THAT THE FILAMENT, PLATE, SCREEN AND BIAS VOLTAGES WILL ALL CORRESPOND TO THE VOLTAGE VALUES AT WHICH THE TUBE IS NORMALLY TO BE OPERATED. THE SWITCH IN FIG. 4 IS AT THIS TIME CLOSED IN THE "DOWN POSITION".

WITH THESE VOLTAGE VALUES NOW FIXED, A DEFINITE PLATE CURRENT SHOULD FLOW WHICH CAN BE QUICKLY CHECKED WITH THE PLATE CURRENT VALUE WHICH THIS SAME TYPE OF TUBE SHOULD PASS UNDER THESE SAME CONDITIONS AS PER THE MANUFACTURER'S SPECIFICATIONS FOR THIS TYPE OF TUBE. THIS IN ITSELF IS A PARTIAL TEST OF THE TUBE'S OPERATING ABILITY.

THE NEXT STEP IS TO CHANGE THE GRID BIAS VOLTAGE AND OBSERVE THE CORRESPONDING CHANGE IN PLATE CURRENT AS INDICATED BY THE MILLIAMMETER. TO DO THIS IN THE CIRCUIT OF FIG. 4, IT IS ONLY NECESSARY TO CLOSE THE SWITCH IN THE "UPWARD POSITION", AT WHICH TIME, THE VOLT-DROP ACROSS POTENTIOMETER R5 WILL BE ADDED TO THE FORMER BIAS VOLTAGE AND THEREBY NOW INCREASE THE BIAS VOLTAGE. LET US ASSUME THAT R5 HAS BEEN ADJUSTED TO PRODUCE A DROP OF 1 VOLT.

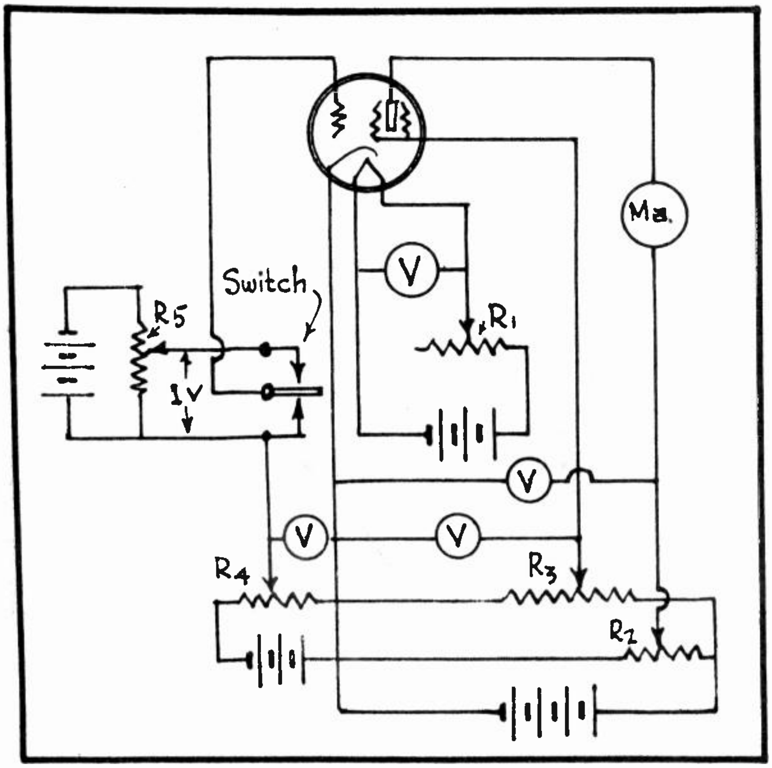

FIG. 4

A Static Mutual-Conductance Tester.

THIS INCREASED BIAS VOLTAGE WILL DECREASE THE PLATE CURRENT AND THE NEW PLATE CURRENT VALUE CAN THEN BE READ ON THE MILLIAMMETER. THE FORMULA FOR DETERMINING MUTUAL CONDUCTANCE IS AS FOLLOWS:

$$\text{MUTUAL CONDUCTANCE} = \frac{\text{CHANGE IN PLATE CURRENT PRODUCED}}{\text{CHANGE IN GRID POTENTIAL PRODUCING IT.}}$$

FOR INSTANCE, LET US SUPPOSE THAT WE ARE TESTING A TUBE IN THE CIRCUIT OF FIG. 4 AND FIND THAT WITH THE SWITCH CLOSED IN THE DOWNWARD POSITION, A BIAS VOLTAGE OF -3 VOLTS IS APPLIED TO THE GRID OF THE TUBE AND THE PLATE CURRENT AS INDICATED BY THE MILLIAMMETER IS 6 MA. THEN LET US SUPPOSE THAT WE CLOSE THE SWITCH TO THE UPPER POSITION SO THAT THE GRID BIAS NOW BECOMES -4 VOLTS AND THAT THE PLATE CURRENT DROPS TO 5 MA.

FROM THIS DATA, WE CAN READILY SEE THAT A CHANGE OF 4 MINUS 3 OR 1 VOLT IN THE BIAS VOLTAGE PRODUCED A CHANGE OF 6 MINUS 5 OR 1 MA. (.001 AMP.) IN THE PLATE CURRENT. SUBSTITUTING THESE VALUES IN OUR FORMULA, WE HAVE:

$$\text{MUTUAL CONDUCTANCE} = \frac{.001}{1} = .001$$ MHOS OR 1000 MICROMHOS. (IT IS THE

COMMON PRACTICE TO EXPRESS THE MUTUAL CONDUCTANCE OF TUBES IN MICROMHOS — ONE MICROMHO BEING EQUIVALENT TO 1,000,000 MHOS.) THE MUTUAL CONDUCTANCE OBTAINED IN THIS WAY CAN THEN BE COMPARED TO THAT SPECIFIED BY THE MANUFACTURER FOR A NEW TUBE OF THE SAME TYPE AND THE WORTH OF THE TUBE THUS JUDGED. THIS METHOD OF TESTING TUBES IS SOMETIMES CALLED THE "GRID- SHIFT" METHOD AND THIS SAME PRINCIPLE IS BEING EMPLOYED IN MOST OF THE COMMERCIAL TUBE TESTERS.

SO THAT THE SERVICEMAN NEED NOT STOP TO ACTUALLY WORK OUT THE MUTUAL CONDUCTANCE FORMULA FOR ANY TUBE UNDER TEST, MOST MANUFACTURERS OF TUBE CHECKERS SUPPLY A CHART WHICH INDICATES THE DESIRABLE CHANGE IN PLATE CURRENT FOR THE DIFFERENT TYPES OF TUBES FOR THEIR PARTICULAR TESTER. THE SERVICEMAN NEED THEREFORE ONLY NOTE THE TWO MILLIAMMETER READINGS HE OBTAINS FROM THE TEST AND COMPARE THEM WITH THOSE OF THE CHART IN ORDER TO JUDGE THE WORTH OF THE TUBE.

SOME OF THE COMMERCIAL TUBE CHECKERS, ESPECIALLY THOSE OF THE COUNTER TYPE, SUCH AS ILLUSTRATED IN FIG. 5, CARRY A SPECIALLY CALIBRATED METER SCALE WHICH IS DIVIDED INTO SECTIONS IN TERMS OF "SATISFACTORY", "DOUBTFUL" AND "UNSATISFACTORY" READINGS, FOR THE BENEFIT OF THE CUSTOMER SO THAT HE TOO CAN JUDGE THE CONDITION OF HIS OWN TUBES IN A SIMPLE MANNER AND WITHOUT BECOMING CONFUSED BY CONVENTIONAL METER READINGS WHICH MAY BE BEYOND HIS TECHNICAL UNDERSTANDING.

FIG. 5
A Counter Tube Checker.

EVEN THOUGH THE STATIC MUTUAL-CONDUCTANCE TEST MAY SHOW A TUBE AS BEING ENTIRELY SATISFACTORY, YET THIS DOES NOT NECESSARILY MEAN THAT THE TUBE WILL FUNCTION PROPERLY WHEN INSTALLED IN AN OPERATING RECEIVER CIRCUIT. IN OTHER WORDS, EVEN THOUGH THE MUTUAL CONDUCTANCE TEST PERMITS A SUFFICIENTLY ACCURATE CHECK IN THE MAJORITY OF CASES, STILL IT ISN'T ABSOLUTELY "FOOL PROOF" IN JUDGING A TUBE'S WORTH WHEN UNDER ACTUAL OPERATING CONDITIONS. SOMETIMES, SUCH A CHECK WILL SHOW A TUBE AS BEING "PERFECT" AND YET IT FAILS TO FUNCTION PROPERLY UNDER ACTUAL WORKING CONDITIONS IN THE CIRCUIT IN WHICH IT IS TO BE USED. WHEN SUCH A CONDITION ARISES, THE COMMON PRACTICE IS TO TRY A NEW TUBE IN THE CIRCUIT.

THE DYNAMIC MUTUAL-CONDUCTANCE TEST

THE FUNDAMENTAL CIRCUIT IN FIG. 6 SHOWS YOU HOW A DYNAMIC MUTUAL-CONDUCTANCE TEST CAN BE MADE. THIS METHOD IS SUPERIOR TO THE STATIC MUTUAL CONDUCTANCE TEST IN THAT AN A.C. VOLTAGE IS APPLIED TO THE CONTROL GRID. FOR THIS REASON, THE TUBE IS TESTED UNDER CONDITIONS WHICH APPROXIMATE ACTUAL OPERATING CONDITIONS.

THE ALTERNATING COMPONENT OF THE PLATE CURRENT IS READ BY MEANS OF A SPECIAL A.C. MILLIAMMETER. THE MUTUAL CONDUCTANCE OF THE TUBE IS THEN EQUAL TO THE A.C. PLATE CURRENT DIVIDED BY THE INPUT SIGNAL VOLTAGE. IN OTHER WORDS, IF A ONE-VOLT RMS SIGNAL IS APPLIED TO THE GRID, THE PLATE CURRENT READING IN MILLIAMPERES MULTIPLIED BY ONE-THOUSAND WILL BE THE VALUE OF THE MUTUAL-CONDUCTANCE IN MICROMHOS.

THE EMISSION TEST

THE FUNDAMENTAL CIRCUIT FOR MAKING AN "EMISSION TEST" IS ILLUSTRATED

FOR YOU IN FIG. 7. THIS IS PERHAPS THE SIMPLEST METHOD OF INDICATING A TUBE'S CONDITION. SINCE THE ELECTRON EMISSION DECREASES AS THE TUBE WEARS OUT, LOW EMISSION IS A SYMPTOM OF THE END OF TUBE SERVICE ABILITY.

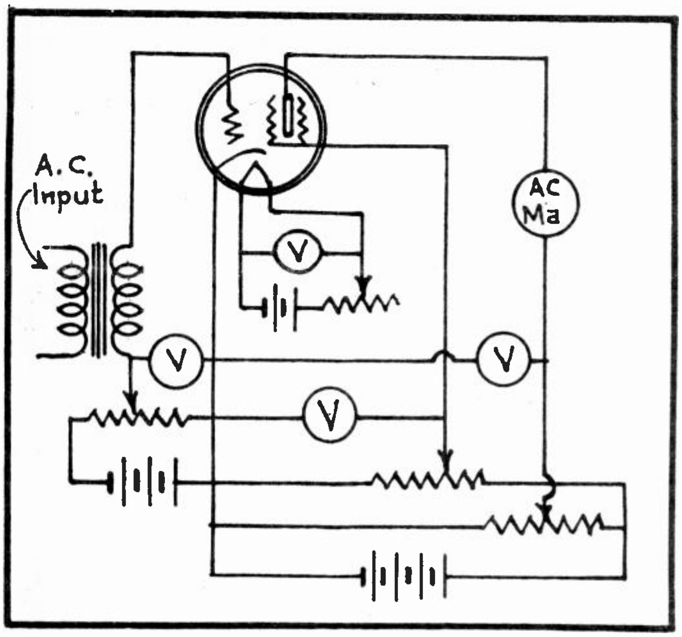

FIG. 6

The Dynamic Mutual-Conductance Tester.

TO MAKE THIS EMISSION TEST, ALL OF THE ELECTRODES, EXCEPT THE CATHODE ARE CONNECTED TO THE PLATE. THE FILAMENT, OR HEATER IS THEN OPERATED AT RATED VOLTAGE AND A LOW POSITIVE VOLTAGE IS APPLIED TO THE PLATE. AFTER THE TUBE HAS REACHED CONSTANT TEMPERATURE, THE ELECTRONIC EMISSION IS READ ON THE MILLIAMMETER. READINGS WHICH ARE WELL BELOW THE AVERAGE FOR A PARTICULAR TUBE TYPE INDICATE THAT THE TOTAL NUMBER OF AVAILABLE ELECTRONS HAS BEEN SO REDUCED THAT THE TUBE IS NO LONGER ABLE TO FUNCTION PROPERLY.

THE EMISSION TEST IS NOT ALTOGETHER RELIABLE IN THAT COATED FILAMENTS OR CATHODES OFTEN DEVELOPE ACTIVE SPOTS FROM WHICH THE EMISSION IS SO GREAT THAT THE RELATIVELY SMALL GRID AREA ADJACENT TO THESE SPOTS CANNOT CONTROL THE ELECTRON STREAM. UNDER THESE CONDITIONS, THE TOTAL EMISSION MAY INDICATE THE TUBE TO BE NORMAL ALTHOUGH THE TUBE IS UNSATISFACTORY. ON THE OTHER HAND, COATED TYPES OF FILAMENTS ARE CAPABLE OF SUCH LARGE EMISSION THAT THE TUBE WILL OFTEN OPERATE SATISFACTORILY AFTER THE EMISSION HAS FALLEN FAR BELOW THE ORIGINAL VALUE.

COMPLETE TUBE CHECKERS

NOW THAT YOU HAVE INVESTIGATED THE BASIC PRINCIPLES UPON WHICH ALL CONVENTIONAL TYPES OF TUBE CHECKERS OPERATE, LET US NEXT LOOK AT THE CIRCUIT ARRANGEMENT OF THE COMPLETE TUBE CHECKERS AS USED IN THE INDUSTRY SO THAT MANY DIFFERENT TYPES OF TUBES CAN BE TESTED IN THE SAME UNIT.

THE PANEL LAYOUT OF A SIMPLE BUT SERVICEABLE MODERN TUBE CHECKER IS SHOWN YOU IN FIG. 8. AS YOU WILL OBSERVE, IT HAS FOUR SOCKETS TO ACCOMODATE FOUR, FIVE, SIX AND SEVEN-PRONG TUBES; A SINGLE METER; A ROTARY -TYPE SELECTOR SWITCH FOR VARIOUS FILAMENT VOLTAGES; TWO PUSH-BUTTON SWITCHES; EIGHT TOGGLE SWITCHES; AND A RED GLASS "BULL'S-EYE" TO EXPOSE A PILOT LIGHT.

THE CIRCUIT DIAGRAM FOR THIS SAME TUBE

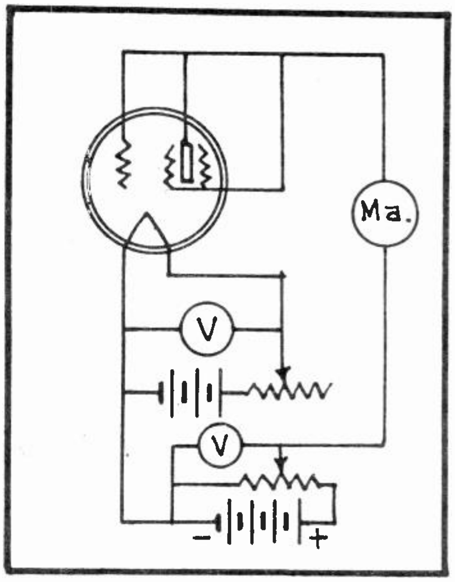

FIG. 7

The Emission Test

CHECKER IS SHOWN IN FIG. 9 AND YOU WILL READILY OBSERVE THAT IT IS A.C. OPERATED. THIS TUBE CHECKER IS DESIGNED TO TEST ALL TYPES OF TUBES FOR EVERY POSSIBLE TYPE OF SHORT CIRCUIT WITHIN THE TUBE, TO TEST EACH ELEMENT SEPARATELY, TO TEST HEATER-CATHODE LEAKAGE IN ADDITION TO OFFERING AN EMISSION TEST REQUIRING NO CALCULATIONS AND WHICH IS SUFFICIENTLY ACCURATE FOR THE GENERAL TYPE OF TESTS AS REQUIRED FROM TESTERS OF A PORTABLE NATURE.

BY STUDYING FIG. 9 YOU WILL SEE THAT A SPECIAL TYPE OF POWER TRANSFORMER IS USED. ITS PRIMARY WINDING IS DESIGNED FOR 105-125 VOLTS AND ITS SECONDARY WINDING HAS NUMBEROUS TAPS SO THAT A LARGE VARIETY OF FILAMENT VOLTAGES ARE AVAILABLE.

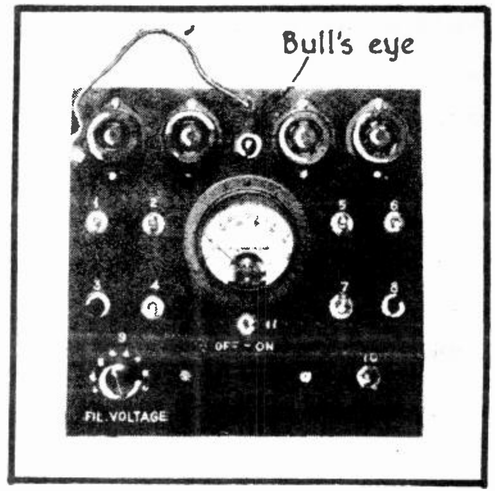

FIG. 8

Panel of a Tube Checker.

TRANSFORMERS OF THIS TYPE CAN BE PURCHASED READY-MADE FROM SEVERAL OF THE LARGER RADIO SUPPLY HOUSES AND ARE KNOWN AS "TUBE TESTER FILAMENT TRANSFORMERS".

SWITCHES SW. 1-2-4-5-6 AND 10 ARE OF THE SINGLE-POLE, DOUBLE-THROW TOGGLE TYPE; SW-3 IS A SINGLE POLE, SINGLE-THROW PUSH-BUTTON SWITCH; SW-8 IS A SINGLE-POLE, DOUBLE THROW PUSH-BUTTON SWITCH OF THE NON-LOCKING TYPE; SW-7 IS A DOUBLE-POLE, DOUBLE-THROW TOGGLE SWITCH; SW-9 IS A 10-POINT, SINGLE DECK NON-SHORTING ROTARY SWITCH AND SW-11 IS A SINGLE CIRCUIT "ON-OFF" TOGGLE SWITCH. THE METER IS A WESTON MODEL 301 D.C. MILLIAMMETER HAVING A RANGE OF 0-50 MA.

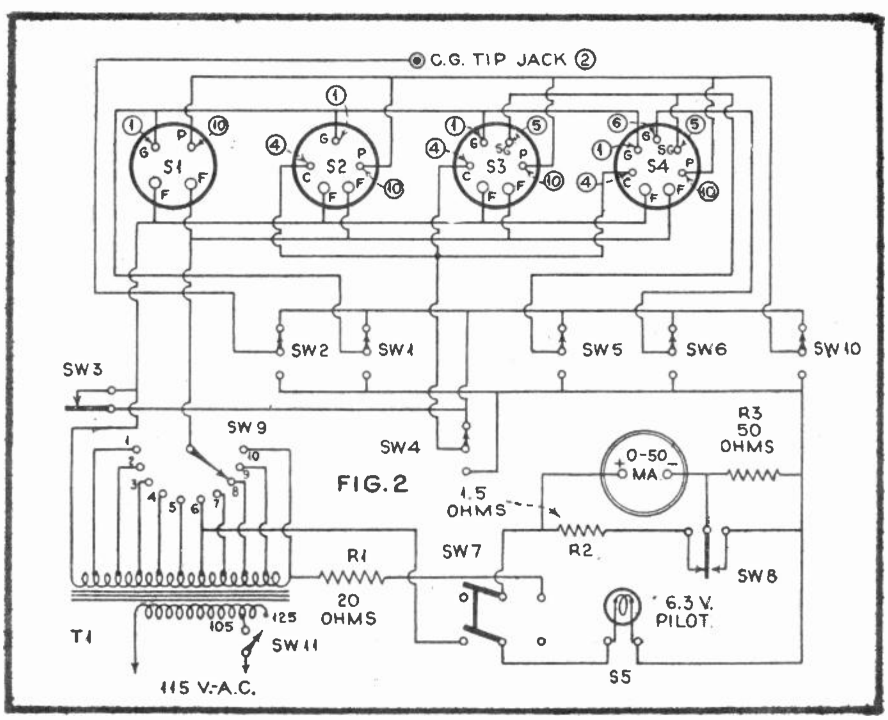

FIG. 9

Circuit Diagram of the Tube Checker.

TO USE THIS TUBE CHECKER PROCEED AS FOLLOWS:

(1) INSTALL THE TUBE IN THE PROPER SOCKET AND SET SWITCH 9 FOR THE RATED FILAMENT VOLTAGE OF THE TUBE BEING TESTED. (THE SECONDARY WINDING OF THIS TYPE OF TRANSFORMER ARE GENERALLY TAPPED TO OFFER VOLTAGES OF 1.5-2.0-2.5-

3.3-5.0-6.3-7.5-12.6-25 AND 30 VOLTS.)

(2) NOW CLOSE SWITCH SW-11 AND PLACE SWITCH 7 TO THE UP POSITION AND SWITCH 10 TO THE LEFT AND ALL OTHER TOGGLE SWITCHES TO THE DOWN POSITION (ALL OF THESE POSITIONS BEING FIGURED ACCORDING TO THE LAYOUT IN FIG. 8.)

(3) FOR ALL FILAMENT TYPE 4,5, AND 6 PRONG TUBES, SIMPLY READ THE METER. IF THE READING IS BELOW 20, DEPRESS THE SHUNT SWITCH 8 AND TAKE A READING.

(4) FOR ALL HEATER TYPE TUBES, PROCEED AS ABOVE BUT THROW SWITCH 4 TO THE UP POSITION AND READ THE METER. IF NO READING RESULTS, THEN THE TUBE IS OF A SPECIAL TYPE AND THE CATHODE IS NOT IN THE USUAL PLACE. IF THE LOCATION OF THE CATHODE IS UNKNOWN, MOVE EACH SWITCH UP AND DOWN, ONE AT A TIME, UNTIL THE MAXIMUM READING IS OBTAINED.

(5) FOR DUPLEX DIODE-TRIODES, THE DIODES SHOULD BE TESTED INDEPENDENTLY BY THROWING THE SWITCH CONNECTED TO ONE DIODE DOWN, SWITCH 10 TO THE RIGHT AND ALL OTHER SWITCHES UP. THEN TEST THE OTHER DIODE THE SAME WAY. THE TRIODE CAN BE TESTED INDEPENDENTLY AS PER THE NOTES GIVEN IN CONNECTION WITH TABLE I.

(6) FOR ALL FULL-WAVE RECTIFIER TUBES, PROCEED AS IN NOTE (5) AND FOR ALL HALF-WAVE RECTIFIERS, PROCEED AS IN NOTE (3). DO NOT DEPRESS THE SHUNT BUTTON SW-8 WHEN TESTING MERCURY-VAPOR RECTIFIERS, SUCH AS THE -82 AND -83. FOR ALL OTHERS, DEPRESS SW-8.

A LIST OF READINGS OBTAINED WITH THIS TESTER IS GIVEN IN TABLE I. THE LAST COLUMN OF THIS TABLE, WHICH IS TITLED "TOTAL", GIVES THE READINGS AS OBTAINED WITH ALL THE ELEMENTS EXCEPT THE FILAMENT AND CATHODE CONNECTED TO THE PLATE. WITH THE SWITCHES SET FOR THIS READING, THE OTHER READINGS ARE OBTAINED (EXCEPT AS OTHERWISE NOTED) BY MOVING EACH SWITCH IN TURN TO THE UP POSITION. AFTER THE READING HAS BEEN NOTED BY DOING THIS WITH SWITCH 1, FOR INSTANCE, RETURN THIS SWITCH TO THE DOWN POSITION AND REPEAT THIS OPERATION WITH SWITCH 2 IN THE UP POSITION ETC., UNTIL ALL READINGS HAVE BEEN OBTAINED. THE BLANK COLUMNS IN TABLE I INDICATE THAT THE OPERATION DOES NOT AFFECT THE READING, DUE TO THE SWITCH BEING OUT OF THE CIRCUIT FOR THE PARTICULAR TUBE BEING TESTED.

TABLE I

Tube Test Chart

TYPE	SW1	SW2	SW4	SW5	SW6	SW10	Total
24A	23	2				32	35
26	2					16	25
27	2					17	29
34	17	2				22	23
35	21	2				29	32
36	22	2				29	32
37	2					19	28
38	23	2				28	32
40	27	2				33	36
41	3			21		30	30
42	3			22		28	28
45	7					18	42
46	5		23			30	37
47	3		26			32	40
53(d)	33		43(a)	33	(c)	43(b)	20(s)
55(d)	6	14		6			35
56	2					24	35
57	37	2		32		37	43
58	38	2		32		38	42
59	36			24	3	34	40
71A	7					14	34
75(d)	4	27		4		1	37
77	33	2		27		34	37
78	24	2		18		25	28
79	(c)	36	56	38		17(S)	20(S)
80	18					18	36
82	32(S)					32(S)	R
83	33(S)					33(S)	R
84	40					40	R
2A3	12					42	22(S)
2A5	2			22		26	28
2A6(d)	10	28		12			42
2A7	2	40		32	42	42	44
2B7(d)	6	14		2	6		30
6F7	18	8		20	22	24	24

THE NOTES WHICH YOU WILL FIND IN TABLE I HAVE THE FOLLOWING MEANING: (A)= SW1 DOWN ALSO; (B)=SW5 DOWN ALSO; (C) = UP FOR ALL READINGS; (D)=START READINGS WITH ALL SWITCHES UP. MOVE ALTERNATELY DOWNWARD, READ, AND RETURN TO UP POSITION. (R)=RECTIFIER -- READINGS OF BOTH PLATES UNNECESSARY. (S)=SHUNTED.

VARIATIONS OF 15 TO 20% OF THE READINGS AS GIVEN IN TABLE I ARE NORMAL. TUBES READING 40% LESS THAN THE VALUES GIVEN IN TABLE I ARE DOUBTFUL, WHILE TUBES READING LESS THAN 50% OF THE VALUES GIVEN IN THE TABLE SHOULD

BE REPLACED WITH NEW ONES.

TYPE -30,-31,-32,-33 AND -34 TUBES SHOULD BE TESTED AT 1.5 FILAMENT VOLTS IN THIS TUBE CHECKER AND NOT AT THEIR NORMAL FILAMENT VOLTAGE. THIS IS DESIRABLE BECAUSE THESE TUBES ARE SUBJECT TO DETERIORATION IF ALL ELEMENTS ARE MADE HIGHLY POSITIVE AT FULL FILAMENT EMISSION.

SHORT-CIRCUIT TESTS

TO APPLY THIS TUBE CHECKER IN ORDER TO LOCATE INTER-ELEMENT SHORT CIRCUITS THROW SWITCH 7 TO THE DOWN POSITION. THEN PLACE ALL OTHER SWITCHES IN THE SAME POSITION AS SPECIFIED UNDER NOTE (2) OF THE PREVIOUS EXPLANATION. SHOULD THE PILOT LAMP CAST A BEAM OF LIGHT THROUGH THE RED BULL'S-EYE, THEN SOME ELEMENT IS SHORTED TO THE FILAMENT. IF NOT, THROW SWITCHES 1,2,5 AND 6 SUCCESSIVELY TO THE UP POSITION. IF THE BULL'S-EYE GLOWS, SOME OTHER INTER-ELEMENT SHORT CIRCUIT IS PRESENT.

CATHODE-HEATER LEAKAGE TEST

DEPRESS SWITCH 3 WHILE READING THE METER FOR THE TUBE CONDITION TEST. IF THE POINTER DOES NOT DROP TO ZERO, THEN CATHODE-HEATER LEAKAGE IS PRESENT. THAT IS TO SAY, THE CATHODE IS NOT FULLY INSULATED FROM THE HEATER AND THIS CONDITION IS LIKELY TO CAUSE HUM OR NOISY TUBE ACTION.

A TUBE CHECKER WITH MUTUAL-CONDUCTANCE TEST

IN FIG. 10 YOU ARE SHOWN THE PANEL LAYOUT OF A TUBE CHECKER WHICH IS DESIGNED STILL DIFFERENT FROM THE ONE YOU JUST STUDIED. THE CHECKER OF FIG. 10, IN ADDITION TO INDICATING A TUBE'S EMISSION AND TESTING FOR SHORTED ELEMENTS, ALSO OFFERS A TEST FOR MUTUAL-CONDUCTANCE. THE CIRCUIT DIAGRAM OF THIS SAME TUBE CHECKER APPEARS IN FIG. 11.

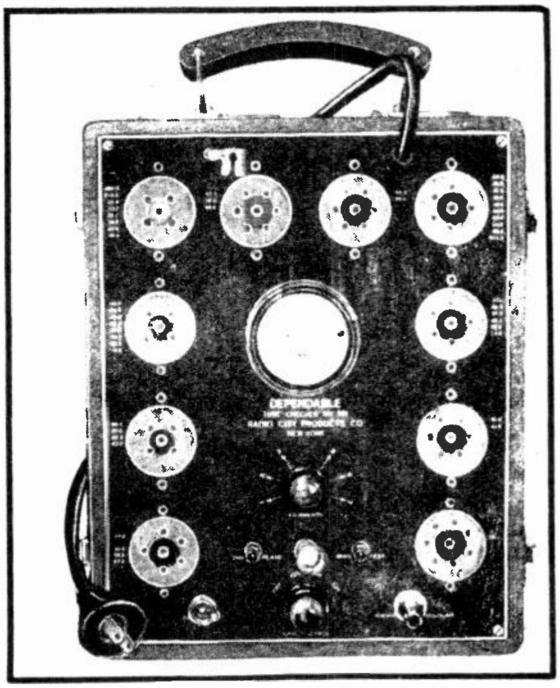

FIG. 10
Panel Layout.

TEN INDIVIDUAL SOCKETS ARE MOUNTED ON THE PANEL TO ACCOMMODATE THE DIFFERENT TYPES OF TUBES AND THE D.C. MILLIAMMETER HAS A RANGE OF 0 TO 15 MA. BUT ITS SCALE IS ESPECIALLY CALIBRATED IN ARBITRARY UNITS FROM 0 TO 30.

THE POWER TRANSFORMER WHICH IS USED IN CONJUNCTION WITH THIS TESTER HAS ITS PRIMARY WINDING TAPPED FOR LINE VOLTAGES OF 105-115 AND 125 VOLTS. THE SECONDARY WINDING IS TAPPED SO THAT FILAMENT VOLTAGES OF 1.5-2-2.5-3.3-5-6.3 AND 7.5 VOLTS ARE AVAILABLE SIMPLY BY SETTING THE 7 POSITION SELECTOR SWITCH SW-3 TO THE PROPER POSITION.

SWITCH SW-1 IS A SIX-LEAF JACK SWITCH; SWITCH SW-2 IS A FOUR-POINT ROTARY LINE VOLTAGE SWITCH; SWITCH SW-4 IS A SINGLE-POLE, DOUBLE-THROW TOGGLE SWITCH; SWITCHES SW-5 AND SW-6 ARE THREE-LEAF MOMENTARY CONTACT SWITCHES (PUSH-BUTTON).

Socket V-1 of the diagram in Fig. 11 is intended to accommodate type 24-35-36-38-39-44-64-65-68 and 51 tubes. Socket V-2 is to be used for type -33-46-47-49-52 and LA tubes. Socket V-3 is for type -41 and-42 tubes. Socket V-4 is for the -59. Socket V-5 is for type -27 -37 -56 and 67 tubes. Socket V-6 is for the -80-81-82 and -83. Socket V-7 is for the -10-12A-20 -26-31-45-50 and -71A. Socket V-8 is for the -00A-01A-22-30-32-34-40 and 99. Socket V-9 is for the -57-58 and 89. Socket V-10 is for the 55-85 and 2A6.

This tube checker is used in the following manner:

Connect the plug to the A.C. lighting circuit, insert the tube to be tested in the proper socket and connect the control grid cap if such is necessary. Keep switch SW-4 thrown to the left except when testing type -22-32 and -34 tubes and at which time, it should be thrown to the right.

Set selector switch SW-3 for the proper filament voltage for the tube

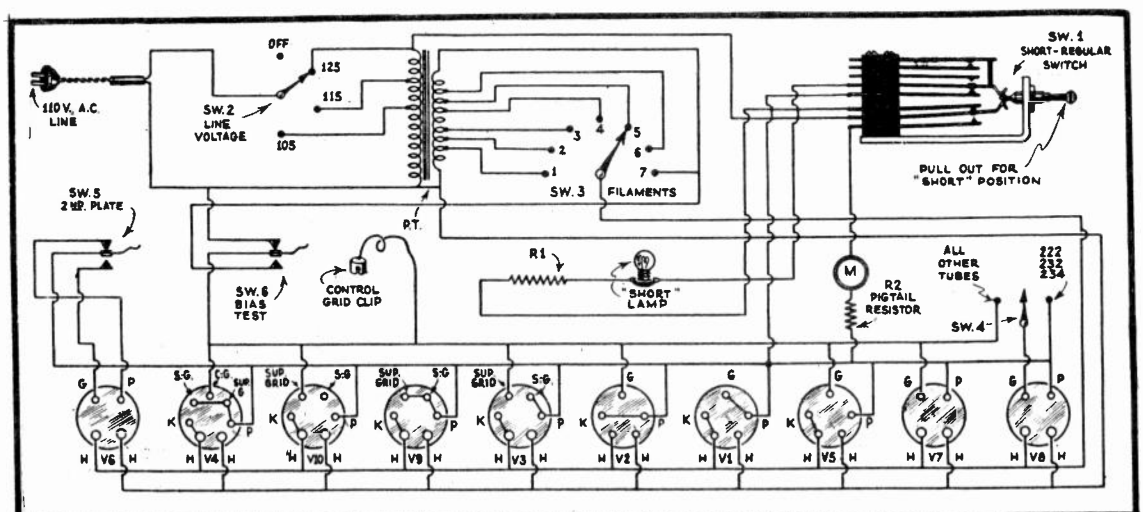

FIG. 11

Circuit Diagram of the Tube Checker.

under test and turn the line voltage switch SW-2 to the position corresponding to the actual line voltage present.

Make the "short" test first by pulling out on switch SW-1. The pilot light will glow if the tube is shorted.

Now push in on switch SW-1 and note the meter reading—this is known as the "regular reading". Now press the "bias test" button SW-6 and note the meter reading. The arithmetical difference or "change" between the "regular reading" and the "bias test reading" is an indication of the tube's mutual conductance.

Table II will give you an idea of what "change" for the different types of tubes indicates that the tube is in good condition when tested in this particular tube checker.

Tubes are considered poor if the actual difference between the readings or "change" is less than 25% from "change" as listed in Table II.

THE PROPER "CHANGE" OF ANY OTHER TUBES NOT LISTED IN THIS TABLE CAN BE DETERMINED VERY EASILY, SIMPLY BY TESTING A TUBE WHICH IS KNOWN TO BE GOOD AND USING ITS "CHANGE" IN READING AS A BASIS TO WHICH TUBES OF THIS TYPE CAN BE COMPARED.

TABLE II

TUBE	CHANGE	TUBE	CHANGE
00A	14	44	12
01A	6	45	9
10	6	46	12
12	10	47	13
20	4.5	49	11
22	2.5	50	7
24	15	51	16
26	11	52	12
27	12	55	14
30	5.5	56	19
31	7.5	57	21
32	10	58	17
33	9	59	13
34	5	71A	7.5
35	13	85	12
36	13	89	10
37	12	99	3.5
38	11	LA	13
39	12	80	25
40	6	81	25
41	12	82	25
42	12	83	25

SECOND PLATES OF RECTIFIERS ARE TESTED BY PRESSING THE BUTTON OF SWITCH SW-5.

FROM THE INFORMATION GIVEN YOU IN THIS LESSON, YOU SHOULD NOW HAVE A GOOD UNDERSTANDING OF THE CONSTRUCTIONAL FEATURES INCORPORATED IN TUBE CHECKERS, AS WELL AS WITH THE PROPER METHODS OF USING THEM. AT THE SAME TIME, YOU WILL ALSO FIND MANY SUGGESTIONS OFFERED IN THIS LESSON WHICH SHOULD PROVE TO BE OF VALUE IN THE EVENT THAT YOU WISH TO CONSTRUCT EQUIPMENT OF THIS TYPE FOR YOUR OWN USE.

IN THE NEXT LESSON, YOU ARE GOING TO STUDY ABOUT THE CONSTRUCTIONAL FEATURES AND USE OF MODERN ANALYZERS, WHICH YOU WILL ALSO NO DOUBT FIND TO BE OF GREAT INTEREST.

THE RADIO TECHNICIAN IS CONSTANTLY USING TESTING EQUIPMENT ABOUT WHICH YOU ARE STUDYING IN THIS SERIES OF LESSONS AND FREQUENTLY COMES INTO CONTACT WITH PROBLEMS WHERE HE MUST THROUGH HIS OWN INITIATIVE DEVISE TESTING SET-UPS FOR TAKING THE DESIRED MEASUREMENTS. THE IMPORTANCE OF THIS WORK CANNOT BE OVER EMPHASIZED AND SO IT WILL BE WELL WORTH YOUR WHILE TO THOROUGHLY MASTER THIS GROUP OF LESSONS.

ANOTHER IMPORTANT FACT TO BEAR IN MIND IS THAT BY HAVING THIS KNOWLEDGE OF TESTING CIRCUITS, YOU ARE ALWAYS IN A POSITION TO FIGURE OUT FOR YOURSELF ANY NEW TESTING DEVICES WHICH MAY BE BUILT IN THE FUTURE TO KEEP UP WITH THE LATEST RADIO DEVELOPMENTS. CONTINUALLY, NEW TUBES AND NEW CIRCUITS ARE APPEARING IN COMMERCIAL RECEIVERS AND IT IS NECESSARY THAT TESTING EQUIPMENT BE MODERNIZED ACCORDINGLY.

Examination Questions

LESSON NO. 52

ans Feb 3, 41

Life's battles don't always go
To the stronger or faster man;
But, sooner or later, the man who wins
Is the man who thinks he can.

1.- IF THE FILAMENT OR HEATER OF A RADIO TUBE IS HEATED TO INCANDESCENCE, DOES THIS NECESSARILY MEAN THAT THE TUBE IS IN SATISFACTORY WORKING CONDITION?

2. - DESCRIBE HOW A STATIC MUTUAL-CONDUCTANCE TEST IS MADE.

3. - WHAT IS MEANT BY AN "EMISSION TEST"?

4. - DESCRIBE A METHOD WHEREBY A TUBE CAN BE CHECKED FOR POSSIBLE SHORT CIRCUITS BETWEEN ITS ELEMENTS.

5. - IF A TUBE TESTS PERFECT ACCORDING TO A COMPLETE SHORT CIRCUIT TEST, EMISSION TEST AND STATIC MUTUAL-CONDUCTANCE TEST, IS IT STILL POSSIBLE THAT THE TUBE MAY NOT OPERATE PROPERLY WHEN INSTALLED IN A RECEIVER?

6. - WHAT PROVISIONS ARE GENERALLY MADE ON COMMERCIAL TUBE CHECKERS SO THAT THE SERVICEMAN DOES NOT HAVE TO ACTUALLY CALCULATE THE MUTUAL CONDUCTANCE VALUE WHEN SUCH A TEST IS BEING MADE?

7. - HOW ARE THE VARIOUS NECESSARY FILAMENT VOLTAGES GENERALLY OBTAINED IN COMMERCIAL TUBE CHECKERS?

8. - DRAW A CIRCUIT DIAGRAM OF A COMPLETE TUBE CHECKER.

9. - EXPLAIN HOW TO OPERATE THE TUBE CHECKER WHOSE CIRCUIT YOU HAVE DRAWN IN ANSWERING QUESTION #8.

10.- WHY IS A PLAIN EMISSION TEST NOT ALTOGETHER RELIABLE?

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RADIO-TELEVISION

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

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Los Angeles, California

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LESSON NO. 53

• *ANALYZERS* •

NOW THAT YOU ARE FAMILIAR WITH TUBE CHECKERS, LET US NEXT GO INTO THE DETAILS REGARDING ANOTHER POPULAR FORM OF TESTING UNIT, NAMELY, THE ANALYZER.

AS YOU ALREADY KNOW FROM YOUR INTRODUCTION TO ANALYZERS SOMETIME AGO, THESE INSTRUMENTS ENABLE THE RADIO TECHNICIAN TO MAKE A PRACTICALLY COMPLETE ANALYSIS OF A DEFECTIVE RECEIVER IN A MOST CONVENIENT AND SYSTEMATIC MANNER. FOR THIS REASON, ANALYZERS ARE EXTENSIVELY USED IN THE RADIO INDUSTRY.

MANY DIFFERENT COMMERCIAL MODELS OF ANALYZERS ARE AVAILABLE, RANGING FROM COMPARATIVELY SIMPLE TO COMPLEX FORMS AND AT A GREAT VARIETY OF PRICES. FURTHERMORE, CONSTANT IMPROVEMENTS ARE BEING MADE IN THE DESIGN OF THIS TYPE OF EQUIPMENT TO KEEP UP WITH THE CHANGES MADE IN THE CONSTRUCTION OF RECEIVERS THRU THE USE OF NEW TUBES, CIRCUIT REFINEMENTS ETC.

IN THIS LESSON, OUR AIM IS TO FAMILIARIZE YOU WITH THE BASIC PRINCIPLES AROUND WHICH ALL ANALYZERS ARE BUILT. TO GIVE A DETAILED EXPLANATION OF THE CIRCUITS AND USE OF EACH MODEL AND MAKE OF COMMERCIAL ANALYZER EVER BUILT WOULD BE PRACTICALLY IMPOSSIBLE TO INCORPORATE IN INSTRUCTION OF THIS KIND AND WOULD REALLY BE UNNECESSARY IN THAT COMPLETE INSTRUCTIONS OF THESE INSTRUMENTS ARE ALWAYS FURNISHED BY THE MANUFACTURER AT THE TIME THE UNIT IS PURCHASED.

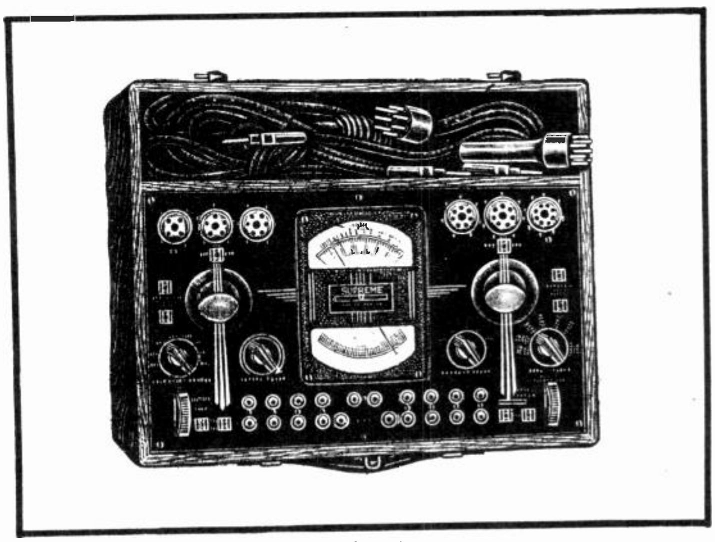

FIG. 1

A Modern Diagnometer.

Not only will this lesson offer you a good idea of the circuits used in the conventional types of analyzers but you will also find it to contain considerable valuable information which you can use to build equipment as this yourself.

A MODERN UNIVERSAL ANALYZER

In Fig. 2 you are shown the panel lay-out of a modern analyzer which will enable one to check all of the new style receivers and tubes. The circuit diagram of this same analyzer appears in Fig. 3.

By studying these two illustrations, you will notice that a single meter is used for all tests. The meter used is a Weston Model 301, 0-1ma. (50 volt full scale deflection) and fitted with a Van type 4 dial. This meter is used in conjunction with a 1000 ohm type rectifier so that both A.C. and D.C. voltage measurements can be taken. A two-pole, two-throw switch (30) in Fig. 3 is used to change the meter from an A.C. to a D.C. instrument or vice versa by including or excluding the rectifier. A three-circuit, six-position switch used in conjunction with multipliers 35 to 40 inclusive offers D.C. voltage ranges of 5-10-100-250-500 and 1000 volts. This same switch in conjunction with multiplier resistors 41-46 inclusive offers A.C. voltage ranges of 5-10-100-250-500 and 1000 volts. The third section of this switch in conjunction with shunt resistors 47-50 inclusive offer D.C. current ranges of 1-5-10-25-100 and 500 ma. An ohmmeter range of 0-100,000 ohms is also provided.

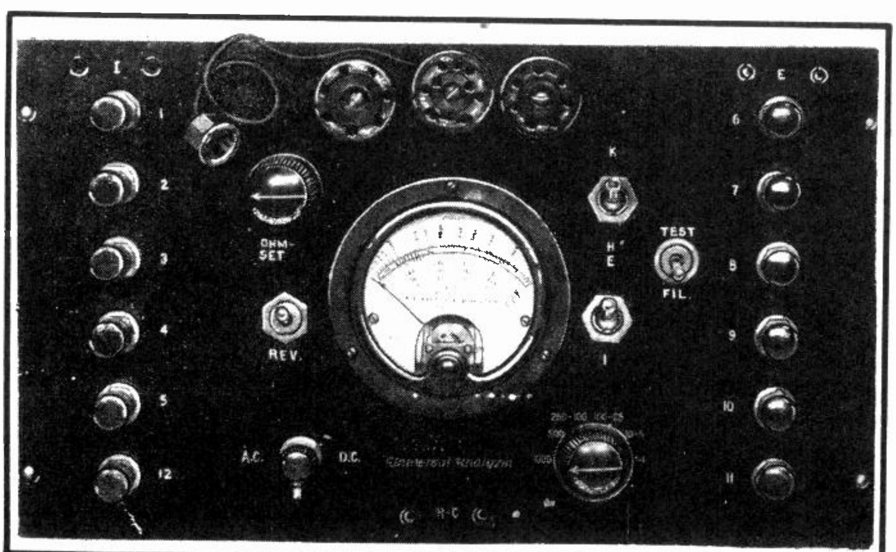

FIG. 2

Panel Lay-out of the Analyzer.

Three sockets are furnished to accommodate all types of tubes. Socket #4 in Fig. 3 is the large seven-prong type. Socket #5 is a universal socket which is so arranged as to take care of four, five, and six prong tubes, while socket #6 will take care of those tubes having a small type seven-prong base.

Switches SW-1-2-3-4-5 and 12 of Fig. 3 are all type 2006 non-locking Yaxley push-button switches. Switches SW-6-7-8-9-10 and 11 are all type 2004 Yaxley non-locking push-button switches.

Switch #30 is a three-pole, two-throw switch; #31 is a single-pole two-throw toggle switch; #13 and #23 are double-pole, two-throw switches.

THE VALUES FOR THE DIFFERENT RESISTORS OF THIS CIRCUIT ARE AS FOLLOWS:

A. C. MULTIPLIERS
(PRECISION TYPE)

#35 = 5,000 OHMS	#38=250,000 OHMS	#41=3,200 OHMS	#44=212,000 OHMS
#36 = 10,000 OHMS	#39=500,000 OHMS	#42=7,500 OHMS	#45=425,000 OHMS
#37 = 100,000 OHMS	#40=1 MEGOHM	#43=84,000 OHMS	#46=850,000 OHMS

SHUNTS FOR D.C. MILLIAMMETER RANGES

#47 = 12.5 OHMS; #48 = 2.083 OHMS; #49 = .5 OHM; #50 = .102 OHM.

THE MULTIPLIER #51 FOR RESISTANCE CONTINUITY TEST HAS A VALUE OF 4,000 OHMS. THE POTENTIOMETER #17 HAS A VALUE OF 1000 OHMS.

THE PLUG FOR CONNECTING THE ANALYZER TO THE RECEIVER UNDER TEST IS AN ALDEN, 7-PRONG ANALYZER PLUG WITH A 3-FOOT, 8-WIRE CABLE, TYPE 907 WLC. TO INSERT THIS PLUG INTO A RECEIVER SOCKET OTHER THAN OF THE SEVEN-PRONG TYPE, AN ADAPTER PLUG MUST FIRST BE INSERTED IN THE RECEIVER SOCKET AND THE ANALYZER PLUG IS THEN INSERTED IN THE TOP OF THE ADAPTER PLUG. THE FOLLOWING ADAPTER PLUGS ARE USED WITH THIS ANALYZER:

ONE ALDEN ADAPTER, TYPE 974 DS
ONE ALDEN ADAPTER, TYPE 975 DS
ONE ALDEN ADAPTER, TYPE 976 DS
ONE ALDEN ADAPTER, TYPE 977 DS

RECEIVER TESTS WITH THE ANALYZER

TO CHECK CIRCUITS WITH THIS ANALYZER, REMOVE THE TUBE FROM THE RE-

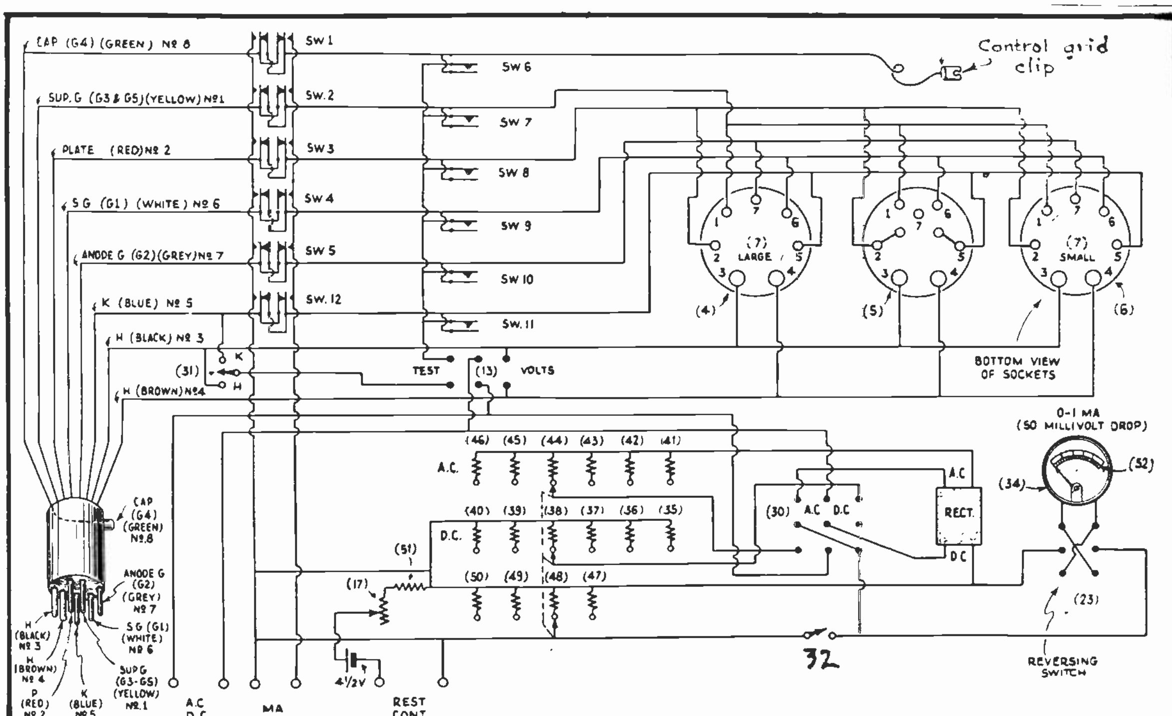

FIG. 3
Circuit Diagram of the Analyzer.

CEIVER SOCKET AT WHICH THE TEST IS TO BE MADE AND INSERT THE TUBE IN THE PROPER SOCKET OF THE ANALYZER, CONNECTING THE ANALYZER CONTROL GRID CLIP TO THE TUBE CAP IF THE TUBE IS OF THIS TYPE.

INSERT THE ANALYZER PLUG INTO THE VACATED TUBE SOCKET OF THE RECEIVER, USING THE PROPER ADAPTER IF SUCH IS REQUIRED AND IF THE TUBE HAS ITS CONTROL GRID CONNECTION AT THE TOP OF THE GLASS BULB, ATTACH THE CONTROL GRID CAP CLIP OF THE CIRCUIT WIRE TO THE CAP PROVIDED ON THE SIDE OF THE ANALYZER PLUG.

FOR A.C. VOLTAGE MEASUREMENTS, PLACE THE A.C–D.C. SWITCH TO THE "A.C. POSITION" AND FOR D.C. VOLTAGE MEASUREMENTS TO THE "D.C. POSITION." THEN TO CHECK THE DIFFERENT VOLTAGES AT THE RECEIVER'S TUBE SOCKET, IT IS ONLY NECESSARY TO OPERATE THE DIFFERENT SWITCHES WHOSE NUMBERS ARE TABULATED IN THE LEFT HALF OF TABLE I FOR THE DIFFERENT TYPES OF TUBES USED.

TABLE I

TUBE	VOLTAGE								CURRENT						
Type	Fil.	Plate	Grid No. 1	Grid No. 2	Grid No. 3	Grid No. 4	Cath. to H't'r	Full-Wave No. 2 Plate	Plate	Grid No. 1	Grid No. 2	Grid No. 3	Grid No. 4	Cath. to H't'r	Full Wave No. 2 Plate
WD-11	13	8	11	..	..	..	..	..	3	12	..	..	..	..	..
WX-12	13	8	11	..	..	..	..	..	3	12	..	..	..	..	..
41	13	8	9	7	..	..	11	..	3	4	2	..	..	12	..
42	13	8	9	7	..	..	11	..	3	4	2	..	..	12	..
44	13	8	6	7	..	..	11	..	3	1	2	..	..	12	..
49	13	8	7	11	..	..	..	..	3	2	12	..	..	..	..
55	13	8	6	..	..	..	11	..	3	1	..	..	..	12	..
56	13	8	7	..	..	..	11	..	3	2	..	..	..	12	..
57	13	8	6	7	9	..	11	..	3	1	2	4	..	12	..
58	13	8	6	7	9	..	11	..	3	1	2	4	..	12	..
12A	13	8	11	..	..	..	..	..	3	12	..	..	..	..	..
99	13	8	11	..	..	..	..	..	3	12	..	..	..	..	..
00A	13	8	11	..	..	..	..	..	3	12	..	..	..	..	..
01A	13	8	11	..	..	..	..	..	3	12	..	..	..	..	..
22	13	8	6	7	..	..	..	..	3	1	2	..	..	..	..
24	13	8	6	7	..	..	11	..	3	1	2	..	..	12	..
26	13	8	*11	..	..	..	..	..	3	12	..	..	..	..	..
27	13	8	7	..	..	..	11	..	3	2	..	..	..	12	..
30	13	8	11	..	..	..	..	..	3	12	..	..	..	..	..
32	13	8	6	7	..	..	..	..	3	1	2	..	..	..	..
34	13	8	6	7	..	..	..	..	3	1	2	..	..	..	..
35	13	8	6	7	..	..	11	..	3	1	2	..	..	12	..
36	13	8	6	7	..	..	11	..	3	1	2	..	..	12	..
37	13	8	7	..	..	..	11	..	3	2	..	..	..	12	..
39	13	8	6	7	..	..	11	..	3	1	2	..	..	12	..
40	13	8	11	..	..	..	..	..	3	12	..	..	..	..	..
Wunderlich	13	7	..	..	..	..	6	..	2	..	..	..	..	1	..
85	13	8	6	..	..	..	11	..	3	1	..	..	..	12	..
46	13	8	7	..	..	..	..	..	3	2	..	..	..	..	..
20	13	8	11	..	..	..	..	..	3	12	..	..	..	..	..
71A	13	8	11	..	..	..	..	..	3	12	..	..	..	..	..
10	13	8	11	..	..	..	..	..	3	12	..	..	..	..	..
31	13	8	11	..	..	..	..	..	3	12	..	..	..	..	..
33	13	8	7	11	..	..	..	..	3	2	12	..	..	..	..
38	13	8	6	7	..	..	11	..	3	1	2	..	..	12	..
45	13	8	11	..	..	..	..	..	3	12	..	..	..	..	..
47	13	8	7	11	..	..	..	..	3	2	12	..	..	..	..
50	13	8	11	..	..	..	..	..	3	12	..	..	..	..	..
LA	13	8	7	11	..	..	..	..	3	2	12	..	..	..	..
82	13	8	..	..	..	..	..	7	3	..	..	..	..	..	2
BA	..	8	..	..	..	..	..	..	3	..	..	..	..	..	..
BH	..	8	..	..	..	..	..	..	3	..	..	..	..	..	..
80	13	8	..	..	..	..	..	7	3	..	..	..	..	..	2
81	13	8	..	..	..	..	..	..	3	..	..	..	..	..	..
66	13	8	..	..	..	..	..	..	3	..	..	..	..	..	..
2A3	13	8	11	..	..	..	..	..	3	12	..	..	..	..	..
2A5	13	8	9	7	..	..	11	..	3	4	2	..	..	12	..
2A6	13	8	6	..	..	..	11	..	3	1	..	..	..	12	..
2A7	13	8	9	10	7	6	11	..	3	4	5	2	1	12	..
2B7	13	8	6	7	..	..	11	..	3	1	2	..	..	12	..
5Z3	13	8	..	..	..	..	..	7	3	..	..	..	..	..	2
6A4	13	8	7	11	..	..	..	..	3	2	12	..	..	..	..
6A7	13	8	9	10	7	6	11	..	3	4	5	2	1	12	..
6B7	13	8	6	7	..	..	11	..	3	1	2	..	..	12	..
25Z5	13	P_1 8	K_1 7	P_2 11	K_2 9	..	..	..	P_1 3	K_1 12	P_2 12	K_2 4	..	..	..
RCA-1	13	8	..	..	..	..	7	..	3	..	..	..	..	2	..
C-1V	13	8	..	..	..	..	7	..	3	..	..	..	..	2	..
C-19	13	P_2 8	G_2 7	G_1 9	P_1 11	..	..	..	P_2 3	G_2 2	G_1 4	P_1 12	..	..	..
44	13	8	6	7	..	..	11	..	3	1	2	..	..	12	..
43	13	8	9	7	..	..	11	..	3	4	2	..	..	12	..
PZ	13	8	7	11	..	..	..	..	3	2	12	..	..	..	..
59	13	8	10	7	9	..	..	..	3	5	2	4	..	..	..
75	13	8	6	..	..	..	11	..	3	1	..	..	..	12	..
77	13	8	6	7	9	..	11	..	3	1	2	4	..	12	..
78	13	8	6	7	9	..	11	..	3	1	2	4	..	12	..
79	13	P_2 8	G_2 7	G_1 9	P_1 11	..	..	..	P_2 3	G_2 2	G_1 4	P_1 12	..	..	..
83	13	8	..	..	..	..	..	7	3	..	..	..	..	..	2
89	13	8	6	7	9	..	11	..	3	1	2	4	..	12	..
UV99	13	8	11	..	..	..	..	..	3	12	..	..	..	..	..
UX99	13	8	11	..	..	..	..	..	3	12	..	..	..	..	..
GA	13	8	7	11	..	..	..	..	3	2	12	..	..	..	..
PZH	13	8	9	7	..	..	11	..	3	4	2	..	..	12	..
12A5	13	8	10	7	9	..	F11	..	3	5	2	4	..	F12	..
6C7	13	8	6	..	..	..	11	..	3	1	..	..	..	12	..
6D7	13	8	6	7	9	..	11	..	3	1	2	4	..	12	..
76	13	8	7	..	..	..	11	..	3	2	..	..	..	12	..
864	13	8	11	..	..	..	..	..	3	12	..	..	..	..	..
845	13	8	11	..	..	..	..	..	3	12	..	..	..	..	..
51	13	8	6	7	..	..	11	..	3	1	2	..	..	12	..
12Z3	13	8	..	..	..	..	7	..	3	..	..	..	..	2	..
6F7	13	PP8/PT10	6	7	11	GT9	11	..	PP3/PT5	1	2	12	GT 4	12	..
6E7	13	8	6	7	9	..	11	..	3	1	2	4	..	12	..

WHEN CONDUCTING THESE TESTS, SWITCH #13 SHOULD BE CLOSED TOWARD THE RIGHT FOR READING FILAMENT POTENTIALS AND TO THE LEFT FOR READING ALL HIGHER VOLTAGES AS USED FOR PLATE, SCREEN-GRID POTENTIALS ETC.

WHEN SWITCH #31 IS CLOSED TO THE "K" POSITION", THE VOLTAGES READ WILL BE BETWEEN THE CATHODE AND THE OTHER ELEMENTS OF THE TUBE WHILE THE "H POSITION", OFFERS READINGS BETWEEN THE HEATER AND OTHER ELEMENTS OF THE TUBE. ALSO FOR VOLTAGE MEASUREMENTS, BE SURE THAT SWITCH #32 IS IN THE "OPEN OR E POSITION" AND FOR CURRENT MEASUREMENTS IN THE "CLOSED OR I POSITION." IT IS ALSO OF GREAT IMPORTANCE THAT THE SELECTOR SWITCH BE SET IN THE PROPER POSITION SO THAT THE RANGE OF THE METER WILL BE CONSISTENT WITH THE READING BEING TAKEN.

THE CURRENT MEASUREMENTS AT THE RECEIVER'S SOCKET ARE MADE BY OPERATING THE SWITCHES SPECIFIED IN THE RIGHT HALF OF TABLE I. THE TUBE GRIDS, YOU WILL NOTICE IN TABLE I ARE LISTED AS GRIDS #1-2-3- AND #4. GRID #1 IS THE CONTROL GRID, #2 IS THE SCREEN GRID, #3 IS THE SUPPRESSOR, AND #4 IS THE ANODE GRID IN PENTAGRID-CONVERTER TUBES ABOUT WHICH YOU WILL HEAR MORE IN A LATER LESSON.

THE REVERSING SWITCH IS PROVIDED SO THAT IN CASE THE METER SHOULD READ BACKWARDS, IT IS ONLY NECESSARY TO CLOSE THIS SWITCH TO THE OTHER POSITION, AT WHICH TIME THE METER WILL READ IN THE PROPER DIRECTION.

IN THE EVENT THAT IT IS DESIRED TO TAKE INDIVIDUAL VOLTAGE OR CURRENT MEASUREMENTS WITHOUT PLUGGING THE ANALYZER INTO THE RECEIVER, TWO PAIRS OF JACKS ARE PROVIDED INTO WHICH THE TEST LEADS CAN BE PLUGGED FOR TAKING GENERAL VOLTAGE AND CURRENT MEASUREMENTS. THE VOLTAGE JACKS ARE MARKED A.C.-D.C. AT THE LOWER LEFT OF FIG. 3 AND THE TWO MILLIAMMETER JACKS (MA) ARE LOCATED DIRECTLY TO THE RIGHT OF THE VOLTAGE JACKS.

WHEN USING THESE JACKS, IT IS ALSO IMPORTANT THAT THE SELECTOR SWITCH BE SET FOR THE PROPER RANGE AND THE A.C.-D.C. SWITCH TO THE PROPER POSITION.

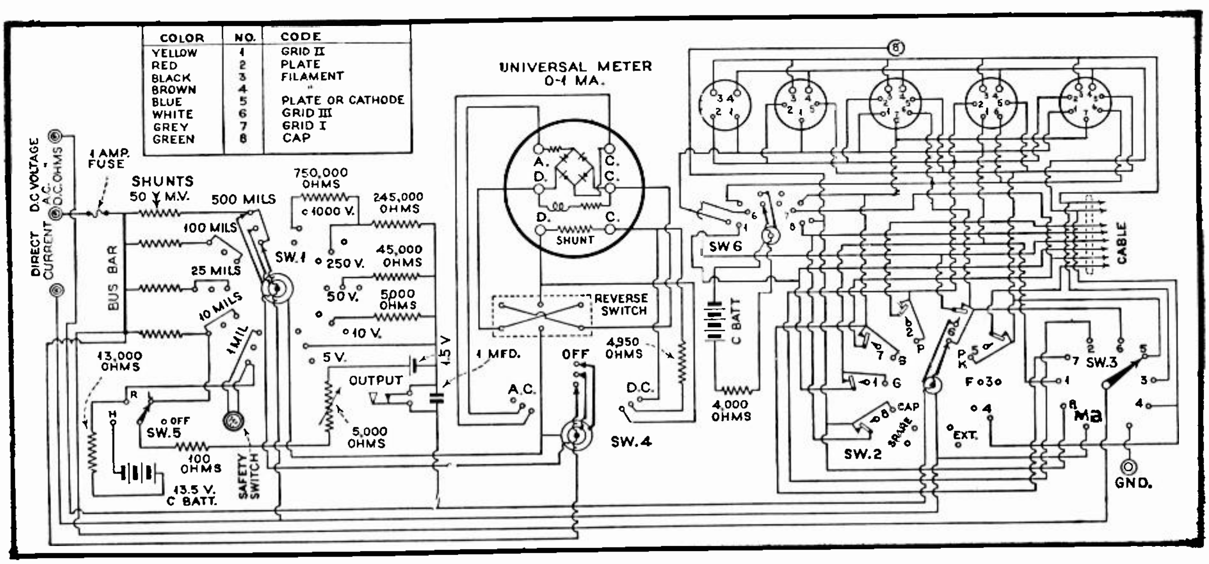

FIG. 4

Circuit Diagram of the Analyzer.

THIS SAME ANALYZER CAN ALSO BE USED FOR TESTING CONTINUITY AND MEASURING RESISTANCE. FOR THIS, THE OHMMETER SCALE IS READ AND THE VOLTAGE - CURRENT SELECTOR SWITCH SET FOR 1 MA. WITH THE TEST LEADS INSERTED IN THE "REST-CONT". JACKS, THEY ARE TOUCHED TOGETHER AS THE POTENTIOMETER (17) IS OPERATED SO AS TO ADJUST THE READING OF THE METER TO FULL SCALE. THE METER SCALE IS CALIBRATED TO READ OHMS RESISTANCE DIRECT.

THE METER CAN ALSO BE USED INDIVIDUALLY AS AN OUTPUT METER TO ALIGN TUNING STAGES ETC., AS WILL BE EXPLAINED TO YOU LATER.

ANOTHER ANALYZER CIRCUIT

IN FIG. 4 YOU ARE SHOWN THE DIAGRAM OF A MORE COMPLEX ANALYZER CIRCUIT AND THE PANEL LAYOUT OF THIS SAME UNIT APPEARS IN FIG. 5.

WHILE THIS ANALYZER IS DESIGNED PRIMARILY FOR MAKING TESTS DIRECTLY FROM THE SOCKETS OF A RADIO RECEIVER, THREE EXTERNAL CONNECTIONS ARE PROVIDED (AT THE LEFT OF FIG. 4) SO THAT DIRECT CURRENT, D.C. VOLTAGE, A.C. VOLTAGE, RESISTANCE ETC. CAN BE MEASURED. FIVE SOCKETS ARE MOUNTED ON THE PANEL OF THE TESTER TO ACCOMMODATE TUBES WITH FROM FOUR TO SEVEN-PRONG BASES.

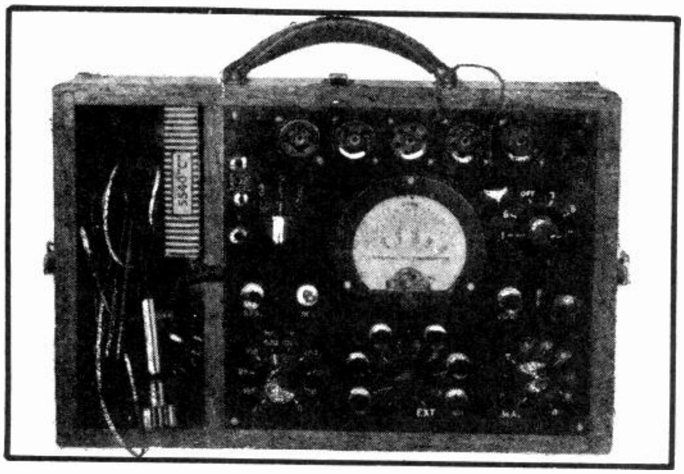

FIG. 5

The Weston 600 Analyzer.

LOOKING AT THE PANEL, THE THREE MAIN SWITCHES WILL BE FOUND AT THE BOTTOM. THE SWITCH AT THE LOWER LEFT OF FIG. 5 (SW-1 IN FIG. 4) IS THE METER CONTROL SWITCH WITH MILLIAMPERE RANGES ON ONE SIDE AND VOLTAGE RANGES ON THE OTHER. THE SWITCH SW-2 AT THE CENTER HAS NUMBER DESIGNATIONS FROM 1 TO 8, AN "EXTERNAL TEST" POSITION AND ONE SPARE. SIX OF THESE POSITIONS ARE ACCOMPANIED BY CURRENT PUSH-BUTTONS. THE "EXTERNAL TEST" POSITION OF THIS SWITCH SHOULD BE USED WHILE MAKING MEASUREMENTS EXTERNALLY THROUGH THE JACKS PROVIDED AT THE LEFT OF THE PANEL.

THE SWITCH (SW-3) AT THE EXTREME RIGHT IS NUMBERED FROM 1 TO 8 AND IS A REFERENCE POINT SWITCH, BEING CONNECTED WITH THE SAME CONTACTS AS SWITCH SW-2. THE PUSH-BUTTON SWITCH ABOVE SW-1 AT THE EXTREME LEFT IS THE SAFETY SWITCH FOR THE 1 MA. POSITION OF SW-1 AND DIRECTLY TO THE RIGHT OF THIS SWITCH ON THE PANEL, YOU WILL FIND THE REGULAR TOGGLE REVERSING SWITCH WHICH IS USED IN CASE THE METER READS BACKWARDS.

ABOVE THE REFERENCE SWITCH AT THE EXTREME RIGHT OF THE PANEL, YOU WILL FIND TWO MORE SWITCHES. ONE OF THESE IS MARKED "OUTPUT" IN FIG.4 WHICH CUTS IN A SERIES CONDENSER WHEN MAKING OUTPUT TESTS, OR ANY A.C. COMPONENT TEST SUCH AS HUM ETC. ABOUT WHICH YOU WILL HEAR IN A LATER LESSON. THIS SWITCH MUST BE IN THE SHORT CIRCUITING POSITION WHEN CONDUCTING ALL OTHER TESTS EXCEPT THE ONE JUST MENTIONED.

THE OHMMETER SWITCH IS MOUNTED ON THE PANEL DIRECTLY TO THE RIGHT OF

THE OUTPUT SWITCH AND IS INDICATED AS SW-5 IN FIG. 4. THIS OHMMETER SWITCH HAS AN "OFF" POSITION IN ADDITION TO THREE OTHER POSITIONS WHICH ARE MARKED L-R-H. WHEN USING THE INSTRUMENT AS AN ANALYZER, THIS SWITCH MUST BE IN THE "OFF" POSITION. WHEN MEASURING RESISTANCE, THE OHMMETER SWITCH IS TURNED TO THE "L" POSITION AT WHICH TIME IT WILL MEASURE RESISTANCE VALUES UP TO 10,000 OHMS. FOR MEASURING RESISTANCE VALUES UP TO 100,000 OHMS, THIS SWITCH IS PLACED IN THE "R" POSITION AND FOR MEASURING RESISTANCE VALUES UP TO 1 MEGOHM, THE "H" POSITION IS USED. THE 1 MA. POSITION OF SW-1 IS USED FOR THE R AND H POSITIONS OF SW-5 AND THE 10 MA. POSITION FOR POSITION "L" OF SW-5. A RHEOSTAT IS MOUNTED TO THE PANEL DIRECTLY ABOVE THE OHMMETER SWITCH AND WHICH IS USED TO ADJUST THE METER TO ZERO FOR ALL RANGES.

SWITCH SW-4 WHICH IS MOUNTED ON THE PANEL DIRECTLY TO THE RIGHT OF THE THREE "EXTERNAL JACKS" IS MARKED AS A.C.-OFF.- AND D.C. AND IS USED TO ARRANGE THE CIRCUIT SO AS TO USE THE METER AS AN A.C. OR D.C. INSTRUMENT. AN EXTERNAL JACK IS MOUNTED ON THE PANEL ABOVE THE OHMMETER RHEOSTAT AND IS MARKED "GND". THIS IS TO BE CONNECTED TO ANY DESIRED POINT ON THE CHASSIS OF THE RADIO SET, OR GROUND, FOR POINT TO POINT TESTING. SWITCH SW-6 BELOW THE TWO RIGHT HAND SOCKETS IS USED FOR INSERTING ANY DESIRED VOLTAGE IN ANY OF THE GRIDS USED FOR MUTUAL-CONDUCTANCE TESTING OF TUBES.

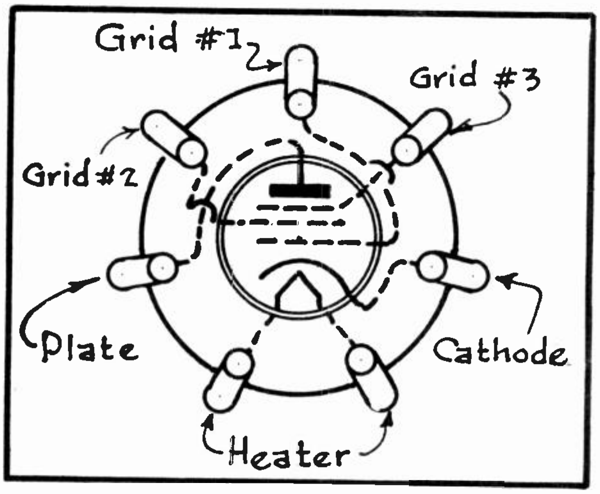

FIG. 6
The number System.

TO SIMPLIFY MATTERS WHEN TESTING CIRCUITS IN WHICH VACUUM TUBES ARE EMPLOYED, IT IS BECOMING THE COMMON PRACTICE TO REFER TO THE TUBE ELEMENTS BY NUMBER RATHER THAN BY NAME. IN THE SMALL TABLE ACCOMPANYING FIG. 4, YOU ARE SHOWN THE NUMBERS CORRESPONDING TO THE DIFFERENT TUBE ELEMENTS, AS WELL AS THE COLORS OF THE CORRESPONDING WIRES MAKING UP THE CABLE OF THE ANALYZER PLUG. TO STILL MORE CLEARLY ILLUSTRATE THIS NUMBERING SYSTEM, FIG. 6 HAS BEEN PREPARED, AND THE SOCKET TERMINALS NUMBERED TO CORRESPOND WITH THE DIFFERENT TUBE ELEMENTS.

USING THE ANALYZER

THIS ANALYZER IS CONNECTED TO THE RECEIVER UNDER TEST IN THE CONVENTIONAL MANNER, THAT IS, BY INSERTING THE ANALYZER PLUG INTO A RECEIVER TUBE SOCKET, PLACING THE TUBE IN AN ANALYZER SOCKET ETC. AND SEE THAT THE A.C.-D.C. SWITCH IS PROPERLY SET.

FROM NOW ON, ALL ORDINARY TESTS WILL BE PERFORMED BY USING SWITCH SW-1 TO CONTROL METER RANGES, SW-2 TO SELECT THE CIRCUIT AND SW-3 TO SELECT THE REFERENCE POINT. FOR INSTANCE, IF A PLATE READING IS NECESSARY, SET SW-1 AT 1000 VOLTS, SW-2 TO POSITION 2 AND SW-3 TO POSITION 5(CATHODE ACCORDING TO THE TABLE IN FIG. 4, SO THAT THE PLATE VOLTAGE WILL BE INDICATED WITH RESPECT TO THE CATHODE AS THE REFERENCE POINT).CURRENT READINGS WOULD BE MADE BY SETTING SW-3 ON THE "MA" POSITION AND PRESSING THE BUTTON INDICATED ON SW-2. BRING THE RANGES TO SUIT ON SW-1.

ANOTHER METHOD OF MEASURING CURRENT IS TO SET SW-2 AND SW-3 ON THE SAME POINTS AND THEN PRESS THE CORRESPONDING PUSH BUTTON AT SW-2. THE SAME OPERATION CAN BE COMPLETED FOR ALL ELEMENTS OF ANY TUBE.

SWITCH SW-6 IS EMPLOYED FOR MAKING MUTUAL CONDUCTANCE TESTS. POINTS #1-6-7 AND 8 OF THIS SWITCH ARE USED FOR THIS PURPOSE. THEY MERELY CONNECT A VARIABLE BIASING VOLTAGE (A #5540 BURGESS "C" BATTERY AND 4000 OHMS RESISTANCE) IN SERIES WITH ANY GRID LEAD.

THIS TEST IS A VERY IMPORTANT ONE AND REPRESENTS A VERY GOOD METHOD IN TUBE CHECKING DUE TO THE FACT THAT ANY VOLTAGE CAN BE INSERTED IN ANY GRID CIRCUIT. THE PLATE AND OTHER CURRENT READINGS FOR THIS TEST ARE MADE IN THE USUAL WAY.

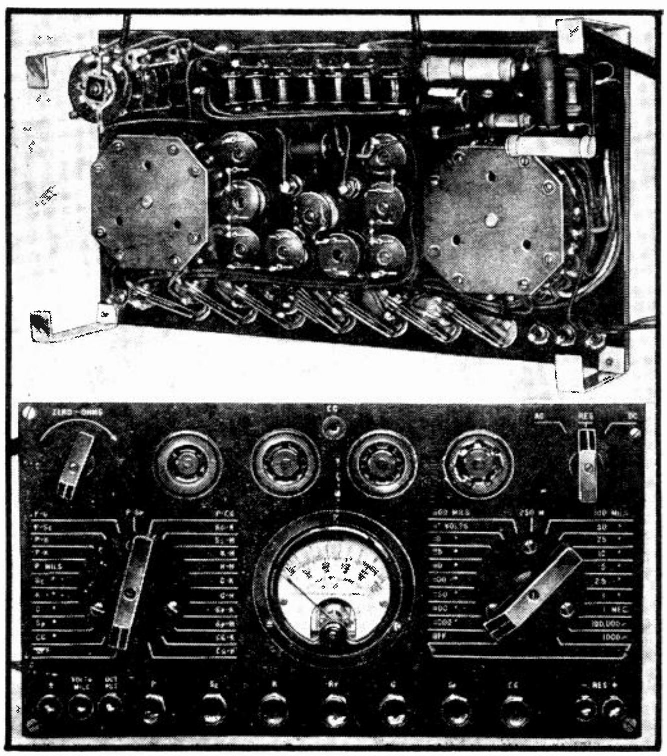

FIG. 7
Wiring and Panel Lay-out of the Analyzer.

BY USING CIRCUIT SELECTOR SWITCH SW-2 AND REFERENCE POINT SWITCH SW-3, SETTING SW-2 TO POINT 4 AND SW-3 TO POINT 4, 5 OR "GROUND" CONNECTION FROM THE EXTERNAL JACK (GND), IT IS POSSIBLE TO MAKE HUM TESTS, USING A LOW VOLTAGE RANGE AND PRESSING THE CONDENSER OR "OUTPUT BUTTON" AND SETTING FOR "A.C." ON THE A.C.-D.C. SWITCH. OUTPUT MEASUREMENTS CAN BE MADE FROM ANY POINT TO ANY OTHER POINT JUST BY CUTTING IN THIS CONDENSER AND SETTING THE SWITCHES. BE SURE TO CLOSE THIS SWITCH WHEN RETURNING TO OTHER MEASUREMENT. A LIST OF PARTS AS USED IN THE CONSTRUCTION OF THIS ANALYZER IS GIVEN IN TABLE II.

WHEN WIRING ANALYZER CIRCUITS, SPECIAL PRECAUTIONS SHOULD BE TAKEN TO KEEP THE RESISTANCE OF THE WIRING DOWN TO AS LOW A VALUE AS POSSIBLE SO AS TO PERMIT ACCURATE MEASUREMENTS TO BE MADE. FOR THIS REASON, THE WIRE SIZE USED SHOULD BE COMPARATIVELY LARGE, THE LEADS KEPT SHORT AND THE CONNECTIONS SOLDERED WITH UTMOST CARE. IT IS A COMMON PRACTICE TO USE #12 B&S WIRE COVERED WITH SPAGHETTI TUBING FOR THIS PURPOSE.

ANOTHER ANALYZER

A STILL DIFFERENT ANALYZER DESIGN IS SHOWN YOU IN FIG. 7. THE LOWER PORTION OF THIS ILLUSTRATION SHOWS YOU THE PANEL ARRANGEMENT OF THIS TESTER, WHILE THE UPPER PORTION OF THIS SAME ILLUSTRATION SHOWS YOU HOW THE WIRING JOB IS DONE ON THE BACK SIDE OF THE PANEL. THE CIRCUIT DIAGRAM OF THIS ANALYZER APPEARS IN FIG. 8.

TABLE II

LIST OF PARTS

SW1-1 YAXLEY 3-POLE, 10-POSITION SWITCH, TYPE 1630, NON-SHORTING
SW2, SW6-2 YAXLEY DOUBLE-POLE, 10-POSITION SWITCHES, TYPE 1620
SW3- YAXLEY SINGLE-POLE, 10-POSITION SWITCH, TYPE 1610 NON-SHORTING
SW4-1 YAXLEY 3-POLE, 3-POSITION SWITCH, TYPE 1633
SW5-1 YAXLEY SINGLE-POLE, 6-POSITION SWITCH, TYPE 55
1 YAXLEY SINGLE-POLE, DOUBLE-THROW PUSH BUTTON SWITCH, TYPE 2003, NON LOCKING
1 YAXLEY SINGLE-POLE, DOUBLE-THROW PUSH-BUTTON SWITCH, BREAK CONTACT LOCKING TYPE (CONDENSER SWITCH)
1 YAXLEY SINGLE-POLE, SINGLE-THROW PUSH-BUTTON SWITCH, BREACK CONTACT NON LOCKING TYPE (SAFETY SWITCH)
1 DOUBLE-POLE, DOUBLE-THROW TOGGLE SWITCH, NICKEL PLATE (REVERSING SWITCH)
1 ALDEN 4 PRONG SOCKET, TYPE No. 424
1 ALDEN 5 PRONG SOCKET, TYPE No. 425
1 ALDEN 6 PRONG SOCKET, TYPE No. 436
1 ALDEN 7 PRONG, MEDIUM BASE, SOCKET, TYPE No. 437
1 ALDEN 7 PRONG, LARGE BASE, SOCKET, TYPE No. 437A
4 ALDEN INSULATED TIP JACKS (ONE RED, ONE GREEN, TWO BLACK)
1 ALDEN INSULATED SCREEN GRID CAP AND LEAD
1 FROST 5000 OHM POTENTIOMETER, TYPE No. 6141
1 KIT OF MULTIPLIERS, (1-5000 OHM, 1-4950 OHM, 1-4500 OHM, 1-245000 OHM AND 1-750000 OHM)
1 KIT OF 50 MV. SHUNTS (1-10 MA., 1-25 MA., 1-100 MA., 1-500 MA.)
1 SMALL BAKELITE MOUNTING STRIP FOR SHUNTS AND MULTIPLIERS
1 ALDEN EIGHT WIRE CABLE, 6 FT. LONG WITH ALDEN ANALYZER PLUG, TYPE No. 907, WLC.
1 ALDEN SET OF 4 ADAPTERS, TYPE No's. 977 DS, 976 DS, 975 DS AND 974 DS
1-13000 OHM, 1 WATT RESISTOR, FOR CONTINUITY TESTS
1 YAXLEY 100 OHM, WIRE WOUND RESISTOR, TYPE 8100
1 HICKOK A.C.-D.C. METER, FLUSH TYPE MODEL 49X, 50 MILLIVOLT
1-4000 OHM, $\frac{1}{2}$ WATT RESISTOR, IN C BATTERY CIRCUIT
1 LITTLEFUSE 1 AMPERE INSTRUMENT FUSE, TYPE No. 1008 WITH MOUNTING CLIP TYPE No. 1010
5 INSTRUMENT KNOBS
3 BURGESS $7\frac{1}{2}$ VOLT C BATTERIES, No. 5540
1 EVEREADY FLASHLIGHT CELL, $1\frac{1}{2}$ VOLTS, TYPE No. 935
1 HARDWOOD CABINET, $15\frac{1}{4}$ INCHES BY 10 INCHES BY 5 INCHES HIGH
1 DRILLED AND ENGRAVED BAKELITE PANEL, 9 INCHES BY 10 INCHES BY INCHES
BUS-BAR, HOOKUP WIRE AND HARDWARE

Some of the more important features of this analyzer are: Only one meter to read; voltage and current tests on all tube elements; point to point resistance tests using the analyzer cable, with a resistance range of 1 ohm to 1 megohm; all tube elements can be measured with a variable range of 5 to 1000 volts on A.C. or D.C.; all tube elements (except the heater) can be measured for current with a variable range of 1 ma. up to 500 ma.; all ranges are available externally through five pin jacks on the analyzer -- two jacks are used for resistance measurements; the output range is from 5 to 100 volts; the voltmeter range is 5 to 1000 volts A.C. or D.C; and the current range is 1 to 500 ma. A.C. or D.C.

One position - selector switch and one meter - range selector switch are the main controls. There are four sockets mounted on the panel which take care of all tubes.

A very important feature of this analyzer is that a complete voltage and current test can be made at every prong and every circuit can be measured for resistance from point to point within the range of 1 ohm up to 1 megohm. This operation would instantly show the nature of the trouble, that is, whether it is an open circuit or shorted circuit. To make this point clear, let us consider a practical example:

TEST PROCEDURE

We shall assume that the analyzer cable is plugged into one of the R.F. stages of a receiver in which a type -24 tube is being used. We want to see if this tube is getting plate voltage, so we set the position selector (SW-1) on the P-H (plate or heater) position and the meter range selector switch (SW-2) can be set at any value desired (that is, from 5 to 1000 volts) but since we know beforehand that the -24 tube works with 180 to 250 volts

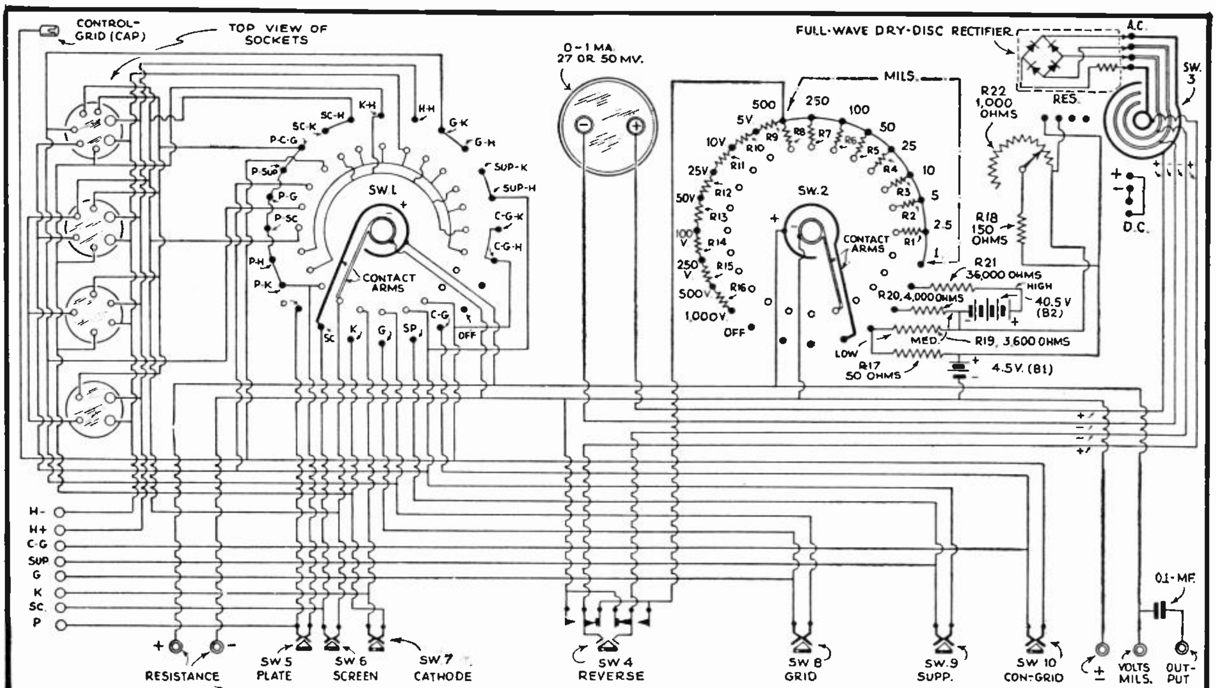

FIG. 8

Circuit Diagram of the Analyzer.

ON THE PLATE, IT IS LOGICAL TO CHOOSE THE 250 VOLT POSITION ON SW-2.

NOW THEN, IF THERE IS NO PLATE VOLTAGE INDICATION, IT IS DUE TO ONE OF THREE REASONS: (1) AN OPEN CIRCUIT (2) A SHORT CIRCUIT (3) A LARGE OVERLOAD IN SOME OTHER PART OF THE SET.

THE NEXT STEP IS TO SHUT OFF THE SWITCH ON THE RECEIVER, LEAVE THE ANALYZER PLUG WHERE IT WAS AND THE POSITION SWITCH SW-1 SET AT P-H. THEN SET THE A.C.-RES-D.C. SWITCH TO RES., AFTER WHICH THE METER RANGE SELECTOR SWITCH SW-2 IS SET TO THE DESIRED RESISTANCE RANGE -- THAT IS TO "HIGH" FOR 1 MEG., "MEDIUM" FOR 0.1 MEG. AND "LOW" FOR 1,000 OHMS.

IF THERE IS NO READING WHATSOEVER ON THE OHMMETER, IT WOULD INDICATE AN OPEN VOLTAGE DIVIDER SECTION, AN OPEN FIELD OR FILTER CHOKE OR A BROKEN WIRE SOMEWHERE IN THE CIRCUIT, THEREBY PROVING THAT THE TROUBLE IS ELSEWHERE AND NOT IN THE CIRCUIT UNDER TEST. THE THIRD INDICATION IS WHERE THE OHMMETER READS DEAD SHORT OR NEARLY SO AND IN WHICH CASE THE THINGS TO LOOK FOR ARE SHORTED BYPASS CONDENSERS, SHORTED SOCKET PRONGS AND GROUNDED WIRES.

SEVEN PUSH-BUTTON SWITCHES ARE MOUNTED IN A ROW ALONG THE BOTTOM EDGE OF THE PANEL AND ARE LETTERED AS P (PLATE), SG (SCREEN-GRID), K (CATHODE), G(GRID), SP (SUPPRESSOR GRID), CG (CONTROL GRID) ETC.

CURRENT MEASUREMENTS FROM 1 TO 500 MA. CAN BE OBTAINED ON ANY ONE OF THE TUBE ELEMENTS. FOR INSTANCE, IF PLATE CURRENT OF A -47 TUBE IS TO BE MEASURED, SWITCH SW-1 IS PLACED ON THE "P" POSITION AND SW-2 SET FOR THE 50 MA. RANGE. THE PLATE BUTTON SW-5 IS THEN PRESSED, AT WHICH TIME THE METER WILL READ THE PLATE CURRENT.

TO READ THE SUPPRESSOR GRID CURRENT OF A SIX-PRONG TUBE, SW-1 IS PLACED ON POSITION SP AND SUPP. BUTTON SW-9 IS PRESSED. A METAL CAP ON THE SIDE OF THE CABLE PLUG SERVES AS THE CONTROL GRID CONNECTION FOR THE RECEIVER. THE LIST OF PARTS AS USED IN THE CONSTRUCTION OF THIS ANALYZER FOLLOWS:

LIST OF PARTS

ONE WESTON MILLIAMETER, MODEL 301, 27 OR 50 MILLIVOLTS, 0-1 MA. RANGE;
TWO JEWELL 2-DECK, 24-POINT SWITCHES, SW. 1 AND SW. 2;
TWO JEWELL SMALL BAR HANDLES;
ONE 4-DECK, 3-POINT SWITCH, SW.3;
SIX PUSH-BUTTON SWITCHES, SW. 5, SW. 6, SW. 7, SW.8, SW.9, SW.10;
EIGHT METER SHUNTS 2.5-5-10-25-50-100-250-500 MA. R1 TO R8;
EIGHT VOLTAGE MULTIPLIERS, 4,950-5,000-15,000-25,000-50,000 OHMS AND .15-MEG. .25-MEG. .5-MEG., R9 TO R16;
ONE D.P.D.T. SWITCH, SW,4; FOUR SOCKETS 4-5-6-7 COMB.; SIX TIP-JACKS;
ONE ENGRAVED PANEL 7 X 13 X 3/16 INS.; ONE BAKELITE PANEL, 7 x 13 x 1/8 IN.; ONE TAUREX RECTIFIER WITH SCALE-ADJUSTING RESISTOR, ONE 1000 OHM RHEOSTAT, R22;
ONE NA-ALD ANALYZER CABLE WITH 4 ADAPTORS, TYPE 907 WLCA;
FIVE RESISTORS FOR OHMMETER, 50, 150, 3,600, 4,000 AND 36,000 OHMS, R17 TO R21;
THREE ROLLS OF HOOKUP WIRE, COLORED RED, GREEN AND BLACK;
ONE CARRYING CASE TO FIT COMPLETED ANALYZER CHASSIS; ONE 4½ V.BATT. B1; ONE 40½ V. SPECIAL BATTERY, 7x5½x5/8 IN., B2.

IN THE PAST SERIES OF LESSONS, YOU HAVE HAD THE OPPORTUNITY OF LEARNING CONSIDERABLE ABOUT THE TESTING EQUIPMENT AS USED IN RADIO. ALTHOUGH YOU MAY PERHAPS NOT BE PARTICULARLY INTERESTED IN BUILDING EQUIPMENT OF THIS KIND, YET THE OCCASSION WILL NO DOUBT ARISE WHEN YOU WILL FIND THIS INFORMATION TO BE MOST WELCOME. FURTHERMORE, EVERY RADIO TECHNICIAN SHOULD HAVE THIS KNOWLEDGE IN ORDER TO BE WELL-TRAINED.

IN THE NEXT LESSON, YOU ARE GOING TO STUDY AN ENTIRELY DIFFERENT SUBJECT, NAMELY, THE VARIOUS METHODS OF FREQUENCY CONVERSION AS USED IN SUPERHETERODYNE RECEIVERS OF RECENT DESIGN. HERE YOU WILL LEARN ABOUT ELECTRON COUPLED OSCILLATORS, THE AUTODYNE SYSTEM, SPECIAL TUBES FOR SUPERHETERODYNES ETC.

EXAMINATION QUESTIONS

Ans Feb 3, 41

LESSON NO. 53

4

1. - WHAT ARE SOME OF THE MORE IMPORTANT FEATURES WHICH AN ANALYZER SHOULD OFFER IN ORDER TO BE A REALLY PRACTICAL TESTING UNIT?

2. - WHY IS A REVERSING SWITCH PROVIDED ON MOST ANALYZERS?

3. - HOW IS IT POSSIBLE TO USE A SINGLE METER ON AN ANALYZER AND BE ABLE TO MEASURE VOLTAGES OF VARIOUS RANGES, D.C. CURRENT OF VARIOUS RANGES, IN ADDITION TO HAVING SEVERAL OHMMETER RANGES?

4. - EXPLAIN HOW AN ANALYZER IS USED IN ORDER TO CHECK A RECEIVER, USING ONE OF THE ANALYZERS DESCRIBED IN THIS LESSON AS AN EXAMPLE.

5. - WHAT PROVISIONS SHOULD BE MADE ON AN ANALYZER FOR TAKING EXTERNAL MEASUREMENTS WITHOUT HAVING TO PLUG THE TESTER INTO THE RECEIVER?

6. - WHAT ARE SOME OF THE MORE IMPORTANT THINGS TO CONSIDER RELATIVE TO THE WIRING OF AN ANALYZER?

7. - HOW ARE THE INTERNAL CIRCUITS OF ANALYZERS GENERALLY ARRANGED SO THAT A.C. OR D.C. VOLTAGE MEASUREMENTS CAN BE TAKEN WITH THE SAME METER?

8. - WHAT PROVISIONS ARE GENERALLY MADE SO THAT THE PLUG WHICH IS ATTACHED TO THE ANALYZER CABLE CAN BE INSERTED IN THE VARIOUS TYPES OF SOCKETS USED IN RECEIVERS?

9. - WHAT IS A "UNIVERSAL SOCKET"?

10. - WHY IS IT SO IMPORTANT TO CONSIDER BEFOREHAND THE MAXIMUM VOLTAGE OR CURRENT WHICH IS LIKELY TO BE PRESENT IN A GIVEN RECEIVER CIRCUIT UNDER TEST BEFORE CONNECTING THE METER OF THE ANALYZER TO THE CIRCUIT BY MEANS OF THE ANALYZER'S SWITCHING ARRANGEMENT?

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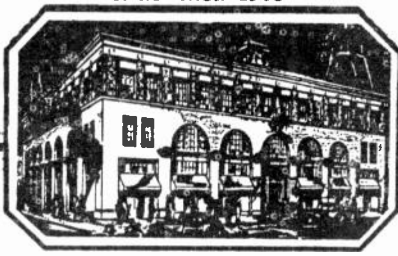

J. A. ROSENKRANZ, Pres.

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LESSON NO. 54

FREQUENCY CONVERSION IN SUPERHETERODYNE RECEIVERS

?

ALTHOUGH YOU ARE ALREADY SOMEWHAT FAMILIAR WITH SUPERHETERODYNE RECEIVERS, YET THERE ARE STILL A NUMBER OF IMPORTANT FEATURES REGARDING THIS TYPE OF CIRCUIT WHICH HAVE UP TO THIS TIME NOT BEEN BROUGHT TO YOUR ATTENTION. CONTINUALLY, THESE CIRCUITS ARE UNDERGOING A CHANGE IN DESIGN BY LEADING MANUFACTURERS SO THAT THE VERY LATEST IMPROVEMENTS MAY BE APPLIED.

IN THIS LESSON, YOU ARE GOING TO BE INFORMED OF THESE NEWER CIRCUITS.

ELECTRON-COUPLING

IN ALL OF THE SUPERHETERODYNE RECEIVERS ABOUT WHICH YOU STUDIED SO FAR, THE OSCILLATOR CIRCUIT WAS COUPLED TO THE CIRCUIT OF THE FIRST DETECTOR ELECTROMAGNETICALLY, OR "INDUCTIVELY" AS WE GENERALLY SAY — SOMEWHAT AS ILLUSTRATED IN FIG. 2 AND IN WHICH CASE THE OSCILLATOR AND FIRST DETECTOR ARE BOTH INDIVIDUAL TUBES. SUPERHETERODYNES OF MORE RECENT DESIGN, HOWEVER, EMPLOY A SINGLE TUBE WHICH SIMULTANEOUSLY SERVES THE PURPOSE OF THE OSCILLATOR AND FIRST DETECTOR. THIS IS MOST GENERALLY ACCOMPLISHED BY WHAT IS KNOWN AS ELECTRON COUPLING AND IN WHICH CASE, THE ELECTRON STREAM WITHIN THE TUBE SERVES AS THE COUPLING MEDIUM BETWEEN THE OSCILLATOR AND FIRST DETECTOR. THE TUBES, WHICH ARE MOST FREQUENTLY USED FOR THIS PURPOSE, ARE KNOWN AS THE 2A7, 6A7 AND THE 1A6.

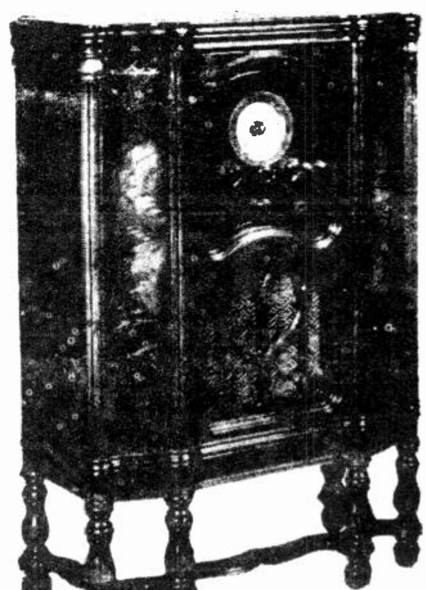

FIG. 1
A Modern Superheterodyne Receiver.

FIRST, WE SHALL CONSIDER THE CONSTRUCTIONAL FEATURES OF THESE TUBES AND THEN THEIR APPLICATION TO PRESENT-DAY CIRCUITS AND THE ADVANTAGES GAINED THRU THEIR

USE.

THE 2A7 TUBE

The 2A7 is classified as a PENTAGRID CONVERTER and its symbol appears in Fig. 3. This tube can be more simply analyzed by considering it as being two individual tube sections enclosed in a single glass envelope. For instance, grid #2 instead of being constructed in the conventional grid form is built in the shape of two connected vertical metal rods and acts as a plate of the tube's triode section. For this reason, grid #2 is called the ANODE GRID.

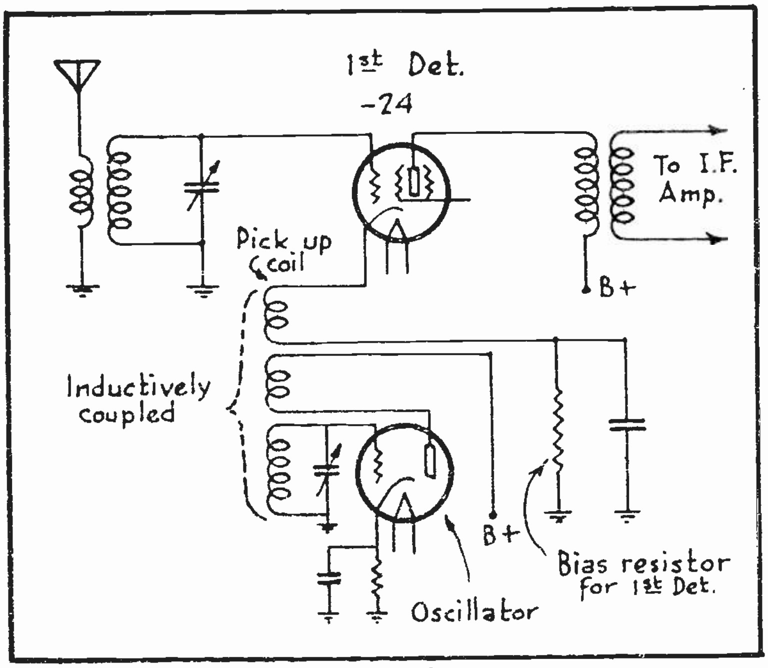

FIG. 2

Electromagnetic Coupled Oscillator.

This particular portion of the tube consisting of the heater, cathode, grid #1 and grid #2 acts as a conventional oscillator tube and is connected to the circuit as shown in Fig. 4.

By studying Fig. 4, you will notice that the oscillator tuning circuit is connected to grid #1 of the 2A7 tube through the grid condenser and that the plate winding of a conventional superheterodyne oscillator coil is connected between B+ and grid #2 of the tube. This anode grid is therefore being used as a regular plate of a triode oscillator tube and this portion of the tube produces oscillations at controlled frequencies the same as a conventional triode oscillator.

Having considered the oscillator section of the 2A7, let us now add the rest of the tube elements and see how the system will function. The circuit will now appear as illustrated in Fig. 5.

Upon studying Fig. 5, you will observe that the oscillator circuit remains exactly the same as illustrated in Fig. 4 and although the connection to the anode grid (#2) is made at the left of the tube in Fig. 5 for the sake of convenience, this in no way affects the meaning

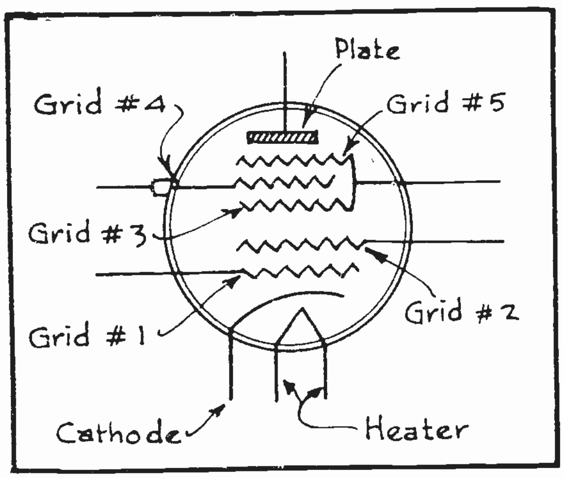

FIG. 3

Symbol of the 2A7.

OF THE SYMBOL.

STILL CLOSER INSPECTION OF FIG. 5 WILL REVEAL THAT GRID #4 SERVES AS THE CONTROL GRID TO WHICH THE TUNING CIRCUIT OF A CONVENTIONAL FIRST DETECTOR IS CONNECTED. A REGULAR PLATE, WHICH IS INSTALLED IN THIS TUBE, IS CONNECTED TO B+250V. THROUGH THE PRIMARY WINDING OF AN I.F.TRANSFORMER. GRIDS #3 AND #5 ARE CONNECTED TOGETHER WITHIN THE TUBE AND SERVE AS A SHIELD BETWEEN THE CONTROL GRID #4 AND THE PLATE, AS WELL AS BETWEEN GRID #4 AND THE ANODE GRID #2. IN OTHER WORDS, GRIDS #3 AND #5 TOGETHER ACT AS A SCREEN-GRID AND ARE THEREFORE CONNECTED TO A B+POTENTIAL AND BYPASSED WITH A FIXED CONDENSER.

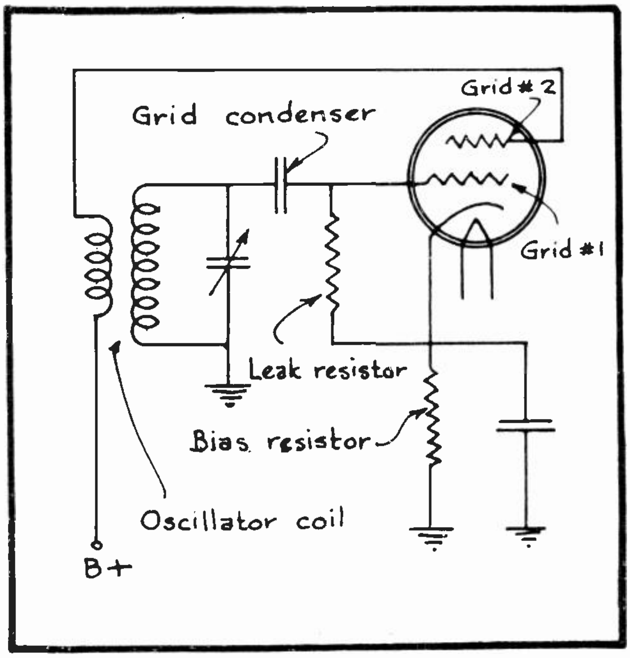

FIG. 4
The Oscillator Section.

THIS SECOND PORTION OF THE TUBE, WHICH WE HAVE NOW ADDED, MAY BE CONSIDERED TOGETHER WITH THE CATHODE AND HEATER (WHICH IS COMMON TO BOTH SECTIONS OF THE TUBE) AS A SCREEN-GRID TUBE.

NOW THEN, ALTHOUGH THE R.F. TRANSFORMER WHICH IS BEING USED IN THE 1ST DETECTOR CIRCUIT OF FIG. 5 IS DESIGNED EXACTLY THE SAME AS IN THE OTHER SUPERHETERODYNE CIRCUITS WHICH YOU ALREADY STUDIED, AS IS ALSO THE OSCILLATOR COIL, YET IN THE CIRCUIT DESIGN OF FIG. 5, THE R.F. TRANSFORMER OF THE 1ST DETECTOR CIRCUIT AND THE OSCILLATOR COIL ARE EACH WOUND ON SEPARATE FORMS AND SO PLACED ON THE RECEIVER CHASSIS THAT THERE IS NO INDUCTIVE COUPLING BETWEEN THEM.

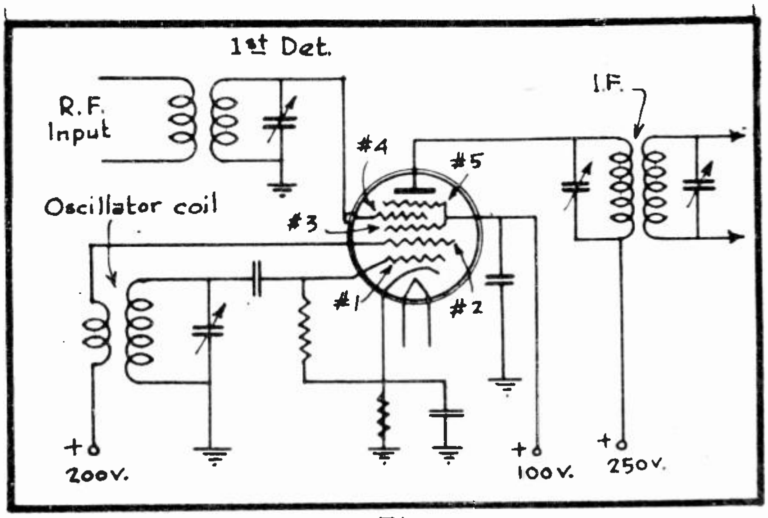

FIG. 5
Complete Circuit for the 2A7.

THE FIRST DETECTOR AND OSCILLATOR CIRCUITS ARE HOWEVER COUPLED THROUGH THE TUBE IN THAT THE GRID TO WHICH EACH IS CONNECTED IS LOCATED WITHIN A COMMON ELECTRON STREAM WHICH IS FLOWING THRU THE TUBE AND IT IS FOR THIS REASON THAT THIS SYSTEM IS REFERRED TO AS BEING ELECTRON COUPLED.

CIRCUIT OPERATION WITH THE 2A7

WITH THIS CIRCUIT IN MIND, LET US NOW SEE

HOW THE COMPLETE SYSTEM OPERATES SO AS TO PRODUCE THE DESIRED INTERMEDIATE FREQUENCY.

TO BEGIN WITH, THE HEATED CATHODE EMITS ELECTRONS WHICH ARE ATTRACTED TOWARDS THE POSITIVELY CHARGED ANODE GRID #2 AND SINCE GRID #1 IS PLACED BETWEEN THE CATHODE AND GRID #2, IT IS OBVIOUS THAT THESE ELECTRONS WILL BE CONTROLLED IN THEIR FLOW BY GRID #1 WHOSE POTENTIAL VARIES AT A RATE DETERMINED BY THE FREQUENCY TO WHICH THE OSCILLATOR CIRCUIT IS TUNED. CONDITIONS BEING SUCH, THIS SAME ELECTRON STREAM WILL BE MODULATED AT THE OSCILLATOR FREQUENCY.

THE ANODE GRID IS NOT CAPABLE OF COMPLETELY OBSTRUCTING THE FLOW OF ELECTRONS TOWARDS THE PLATE BECAUSE IT OFFERS BUT LITTLE EXPOSED SURFACE. FOR THIS REASON, THE GREATER PORTION OF THE ELECTRON STREAM CONTINUES ONWARDS TOWARDS THE PLATE WHICH IS CHARGED TO A STILL HIGHER POSITIVE POTENTIAL BUT IT FIRST COMES UNDER THE INFLUENCE OF GRID #3 WHICH IS ALSO BEING OPERATED AT A POSITIVE POTENTIAL WITH RESPECT TO THE CATHODE. THIS GRID #3 ALSO OFFERS LITTLE OBSTRUCTION TOWARDS THE ELECTRON FLOW DUE TO ITS CONSTRUCTION BUT BEING OF A FAIRLY HIGH POSITIVE CHARGE, IT ACCELERATES THE FLOW OF ELECTRONS TOWARDS THE PLATE. REMEMBER THOUGH, THAT THE ELECTRON STREAM WHICH REACHES THIS REGION OF THE TUBE IS ALREADY IN A MODULATED FORM, CONFORMING TO THE OSCILLATOR FREQUENCY DUE TO THE ACTION OF GRID #1.

NOW THEN, THE INCOMING RADIO-FREQUENCY SIGNAL APPEARING IN THE TUNING CIRCUIT, CORRESPONDING TO THE FIRST DETECTOR, IS APPLIED TO GRID #4 AND THEREFORE FURTHER MODULATES THE ELECTRON STREAM WHICH HAS ALREADY BEEN MODULATED AT THE OSCILLATOR FREQUENCY. THIS EFFECT PRODUCES COMPONENTS OF PLATE CURRENT, THE FREQUENCIES OF WHICH ARE THE VARIOUS COMBINATIONS OF THE OSCILLATOR AND SIGNAL FREQUENCIES. THEN SINCE THE PRIMARY CIRCUIT OF THE FIRST I.F. STAGE IS DESIGNED TO RESONATE AT THE INTERMEDIATE FREQUENCY WHICH IS EQUAL TO THE DIFFERENCE BETWEEN THE OSCILLATOR AND INCOMING SIGNAL FREQUENCY, ONLY THE DESIRED INTERMEDIATE FREQUENCY WILL BE PRESENT IN THE SECONDARY CIRCUIT OF THE I.F. TRANSFORMER FOR FURTHER AMPLIFICATION.

AMONG THE CHIEF ADVANTAGES OBTAINED THROUGH THIS SYSTEM OF FREQUENCY CONVERSION ARE THAT IS SIMPLIFIES THE DESIGN OF THE OSCILLATOR CIRCUIT WHILE AT THE SAME ELIMINATING ONE TUBE FROM THE CIRCUIT. IT ELIMINATES UNDESIRED INTERCOUPLING EFFECTS BETWEEN SIGNAL, OSCILLATOR AND MIXER CIRCUIT WITH ITS RESULTING DETUNING CHARACTERISTIC. IT REDUCES LOCAL FREQUENCY RADIATION AND IS MORE STABLE IN OPERATION IN THAT FREEDOM FROM THE EFFECTS OF VARIATION IN OSCILLATOR VOLTAGE CAN BE OBTAINED.

THE 2A7 IS FITTED WITH A SEVEN-PRONG BASE OF THE SMALL TYPE AND THE CONNECTIONS ARE MADE TO ITS SOCKET AS ILLUSTRATED IN FIG. 6 WHERE YOU ARE LOOKING AT THE SOCKET FROM BELOW. THE HEATER PRONGS OF THE TUBE CAN BE IDENTIFIED BY THE FACT THAT THEY ARE LARGER IN DIAMETER THAN THE OTHERS. THE CIRCUIT CONNECTION TO GRID #4 IS MADE TO THE CAP ON TOP OF THE TUBE'S GLASS BULB.

OPERATING CHARACTERISTICS OF THE 2A7

THE OPERATING CHARACTERISTICS OF THE 2A7 WHEN USED AS A FREQUENCY CONVERTER ARE AS FOLLOWS:

Heater Voltage = 2.5 Volts
Heater Current = 0.8 Amp.
Plate Voltage = 250 Volts
Plate Current = 3.5 Ma.
Screen Voltage = 100 Volts
(Grids #3 and #5)
Screen Current = 2.2 Ma.
Conversion conductance = 520 micromhos

Anode grid voltage = 200 Volts
(Grid #2)
Anode Grid Current = 4.0 Ma.
Control Grid Voltage = -3 Volts
(Grid #4)
Oscillator leak resistor = 50,000 Ohms
Cathode resistor = 300 Ohms
Plate resistance = 0.36 Megohm

The new term "conversion-conductance" which is used in connection with this tube is defined as the ratio of the alternating current at the intermediate frequency of the mixer output-circuit to the radio-frequency signal voltage applied to grid #4. This same characteristic is also frequently called the "conversion-transconductance."

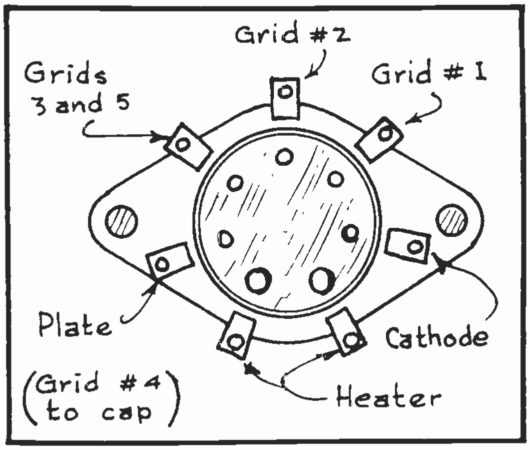

FIG. 6
Socket Arrangement for 2A7.

Another new term employed with this type of circuit is "translation gain". This is the ratio of the intermediate frequency output voltage to the signal voltage applied to grid #4. The translation gain obtainable with a circuit such as shown in Fig. 5 can be as much as 60 with ordinary transformers. If special low-loss equipment is employed, it is possible to obtain a translation gain of 100.

APPLICATION OF THE 2A7 TO COMPLETE RECEIVERS

In Fig. 7 you will see the complete circuit diagram of a superheterodyne receiver in which the 2A7 is being used as a combination first detector and oscillator. The circuit set-up around the 2A7, you will observe, is the same as was already outlined for you in the previous explanation and although a special type of high-gain transformer is being used in the pre-selector and 1st detector stage of the particular commercial re

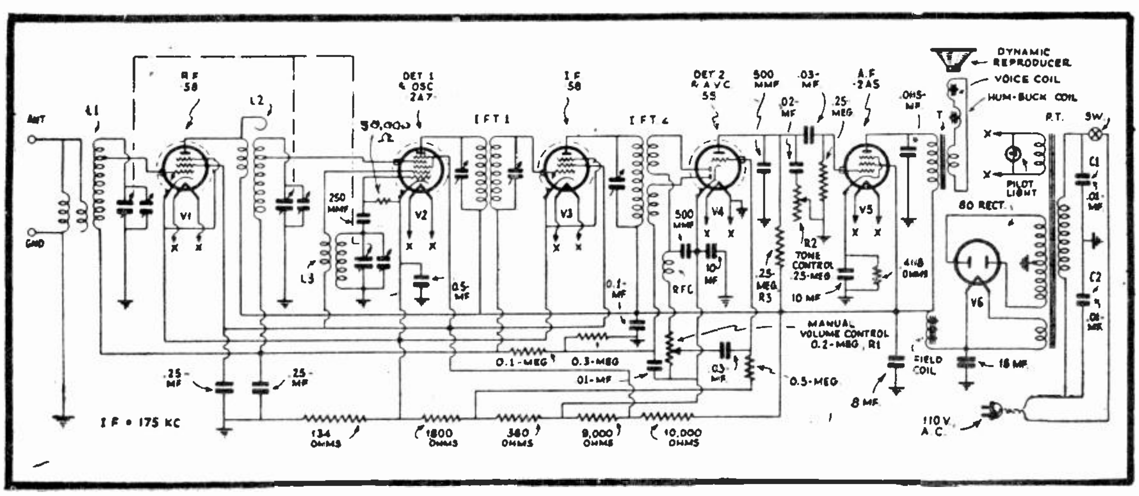

FIG. 7
Using the 2A7 In a Superheterodyne Receiver.

ceiver here illustrated, yet the conventional type of R.F. transformer would also work in this circuit. The rest of this receiver is no different than the other superheterodynes with which you are already acquainted. The 2A7 should be fully shielded for best results.

THE 6A7 TUBE

The 6A7 is an exact duplicate of the 2A7 with the exception that it is designed primarily for use in automobile receivers and for this reason, its heater is rated at 6.3 volts and 0.3 amp; The rest of its operating characteristics are the same as already given you for the 2A7. However, if the maximum "B" voltage available is somewhat low, the 6A7 may also be operated under the following conditions:

Plate voltage = 100 Volts
Plate Current = 1.3 Ma.
Screen voltage = 50 Volts
Screen current = 2.5 Ma.
Anode-grid voltage = 100 Volts

Anode-grid Current = 3.3 Ma.
Cathode resistor = 150 Ohms
Oscillator leak resistor = 10,000 ohms
Plate resistance = 0.6 megohm
Conversion conductance = 350 micromhos

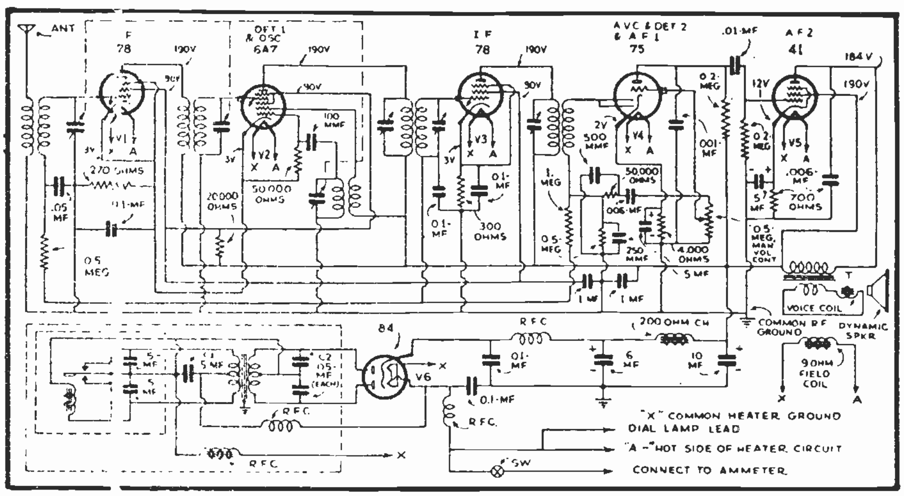

FIG. 8
Application of the 6A7.

Fig. 8 shows you the typical manner in which the 6A7 is used in automobile receivers. Observe, that its application is practically identical to that of the 2A7. The remaining portions of this circuit are also the same as used in most present day automobile receivers. The "B" supply, you will notice, is furnished by a tube-vibrator type "B" eliminator with the vibrator being used to interrupt the flow of battery current through the primary winding of the power transformer so as to obtain induction, while the 84 tube takes care of the high voltage rectification.

THE 1A6

The 1A6 is also a pentagrid converter, similar to the 2A7 and the 6A7, with the exception that it is designed for use in battery operated receivers where dry cells are used as the "A" supply. The symbol for the 1A6 is shown you in Fig. 9 and as you will observe, it is the same as that for the 2A7 and the 6A7 only that the cathode is eliminated.

The 1A6 is fitted with a 6-prong base and the circuit connections are made to its socket as illustrated in Fig. 10 where you are looking at the socket from below. The two larger socket holes are for the filament and the rest of the holes correspond to the different tube elements as illus-

TRATED IN FIG. 10. THE CONTROL GRID CONNECTION (GRID #4), YOU WILL NOTICE, IS MADE TO THE TOP OF THE CAP ON THE GLASS BULB.

THE OPERATING CHARACTERISTICS OF THE 1A6 ARE AS FOLLOWS:

FILAMENT VOLTAGE=2 VOLTS
FILAMENT CURRENT = 0.06 AMP.
PLATE VOLTAGE = 135-180 VOLTS
SCREEN VOLTAGE = 67.5 VOLTS (GRIDS #3 & #5)
SCREEN CURRENT = 2.5 MA.
ANODE GRID VOLTAGE (GRID #2) = 135 VOLTS
CONTROL GRID VOLTAGE (GRID #4) = -3 V.
ANODE-GRID CURRENT = 2.3 MA.
OSCILLATOR GRID CURRENT = 0.2 MA.
TOTAL CATHODE CURRENT = 6.2 MA.
OSCILLATOR LEAK RESISTOR = 50,000 Ω.
PLATE RESISTANCE 0.4 - 0.5 = MEGOHM
CONVERSION CONDUCTANCE = 4 MICROMHOS.

THE 1A6 IS APPLIED TO SUPERHETERODYNE CIRCUITS IN A SIMILAR MANNER AS THE 2A7 AND THE 6A7 AND IN FIG. 11 YOU ARE SHOWN A CIRCUIT DIAGRAM OF A BATTERY-OPERATED SUPERHETERODYNE IN WHICH THE 1A6 IS USED AS A FREQUENCY CONVERTER. IN THIS PARTICULAR CIRCUIT, AN R.F. OR PRESELECTOR STAGE EMPLOYING A TYPE-34 TUBE WORKS INTO THE FIRST DETECTOR WHERE A 1A6 SERVES AS A COMBINATION FIRST DETECTOR AND OSCILLATOR. THIS IS FOLLOWED BY AN I.F. STAGE IN WHICH ANOTHER -34 TUBE IS USED AND THEN IN TURN COME THE SECOND DETECTOR WITH A -32 TUBE, A FIRST AUDIO STAGE WITH A -30 TUBE AND FINALLY A POWER STAGE WITH TWO TYPE -30 TUBES IN PUSH PULL. A PERMANENT-MAGNET DYNAMIC SPEAKER IS USED WITH THIS RECEIVER AND AN "AIR-CELL" IS INTENDED FOR THE "A" SUPPLY. REGULAR "B" AND "C" DRY BATTERIES FURNISH THE "B" AND "C" SUPPLIES FOR THE RECEIVER.

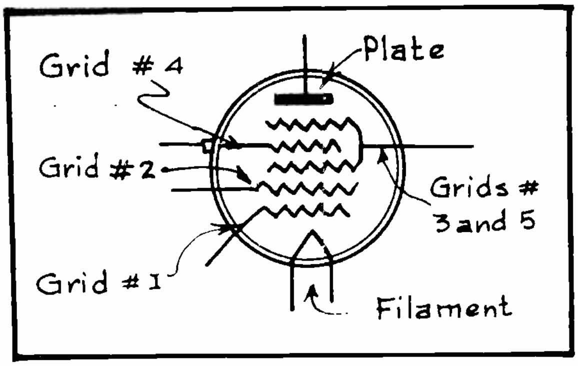

FIG. 9
Symbol of the 1A6.

THE AUTODYNE SYSTEM

IN FIG. 12 YOU ARE SHOWN A CIRCUIT DIAGRAM OF AN AUTOMOBILE TYPE SUPERHETERODYNE RECEIVER IN WHICH THE "AUTODYNE" PRINCIPLE IS EMPLOYED. HERE AN ORDINARY R.F. PENTODE (THE -39 IN THIS CASE) IS BEING USED AS A COMBINATION FIRST DETECTOR AND OSCILLATOR. THIS SYSTEM IS QUITE POPULAR IN SUPERHETERODYNE RECEIVERS OF COMPACT DESIGN IN THAT IT ELIMINATES THE ADDITIONAL OSCILLATOR TUBE AND IN THIS WAY SAVES SPACE. HOWEVER, IN SUPERHETERODYNES OF LATER DESIGN, THE USE OF THE PENTAGRID CONVERTER TUBES IS RAPIDLY TAKING THE PLACE OF THE AUTODYNE METHOD OF FREQUENCY CONVERSION BECAUSE IT IS MORE EFFICIENT IN OPERATION. NEVERTHELESS, SUPERHETERODYNES EMPLOYING THE AUDODYNE PRINCIPLE ARE STILL IN USE AND SO IT IS WELL FOR

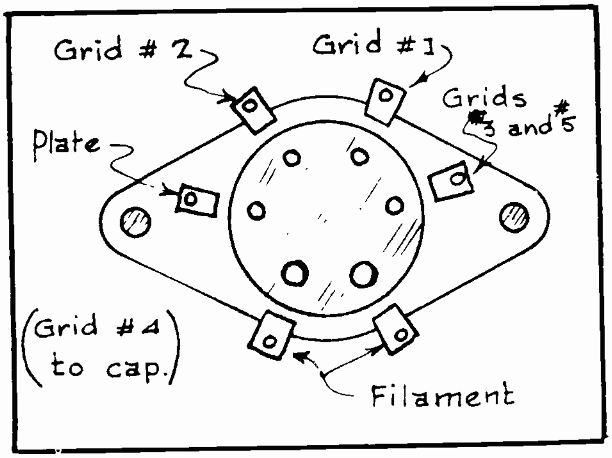

FIG. 10
Socket Arrangement of the 1A6.

YOU TO BE ACQUAINTED WITH THEM.

A COMMON METHOD OF ARRANGING THE OSCILLATOR COIL IN RECEIVERS OF THIS TYPE IS TO ENCLOSE THE OSCILLATOR COIL ASSEMBLY IN THE SAME SHIELD CAN WITH THE FIRST I.F. TRANSFORMER AS INDICATED BY THE ENCLOSURE DRAWN WITH DOTTED LINES IN FIG. 12. COMPLETE COIL ASSEMBLIES AS THIS ARE KNOWN AS "COMPOSITE" OSCILLATOR-I.F. UNITS AND IN FIG. 13 YOU ARE SHOWN THE CONSTRUCTION DETAILS OF SUCH A UNIT.

THE COILS OF THE I.F. TRANSFORMER, YOU WILL NOTICE ARE MOUNTED ON A WOODEN DOWEL WHILE THE OSCILLATOR TUNED WINDING AND THE PLATE CIRCUIT WINDING ARE WOUND ON A PIECE OF INSULATIVE TUBING SURROUNDING THE I.F. COILS. THE PLATE CIRCUIT WINDING IS WOUND DIRECTLY OVER THE TUNED OSCILLATOR WIND-

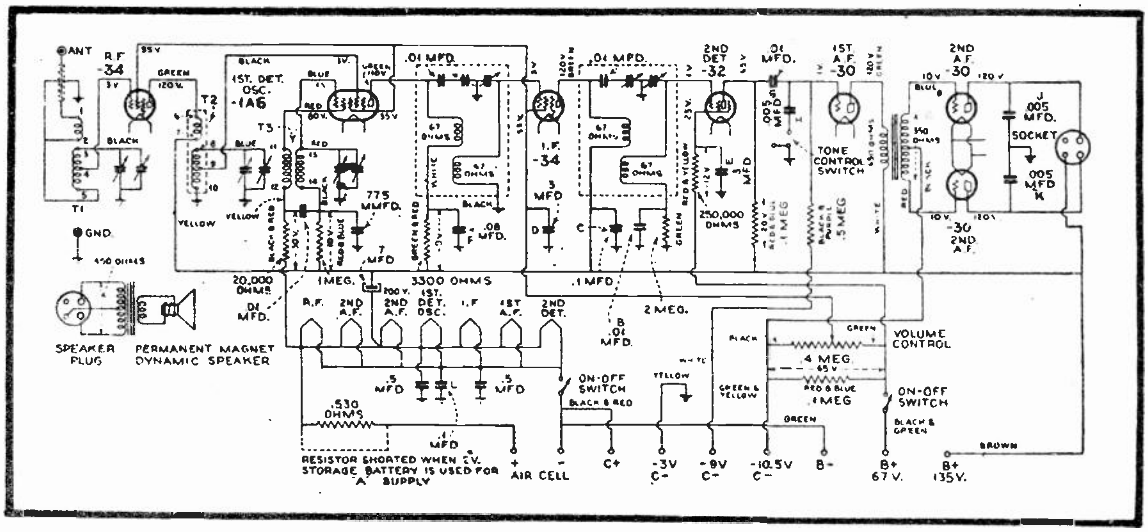

FIG. 11

Application of the 1A6.

ING WITH PAPER INSULATION BETWEEN THESE TWO WINDINGS SO AS TO AFFORD CLOSE COUPLING BETWEEN THEM.

THE I.F. TRIMMER CONDENSERS ARE MOUNTED IN THE UPPER PART OF THE SHIELD CAN AND HOLES ARE PROVIDED IN TOP OF THE CAN THROUGH WHICH THEY CAN BE ADJUSTED. ALL WINDING LEADS ARE BROUGHT OUT THROUGH THE BOTTOM OF THE CAN AS SHOWN AT THE RIGHT OF FIG. 13.

SINCE PART OF THE OSCILLATOR TUNED WINDING IS IN SERIES WITH THE CATHODE CIRCUIT OF THE DET-OSC. TUBE, THE OSCILLATOR COIL WILL ALSO BE COUPLED WITH THE CONTROL GRID CIRCUIT, AS WELL AS TO THE WINDINGS OF THE 1ST I.F. TRANSFORMER. THE OSCILLATOR FREQUENCY CAN THEREFORE REACT WITH THE INCOMING SIGNAL FREQUENCY SO AS TO PRODUCE THE DESIRED BEAT FREQUENCY WHICH IS TO BE AMPLIFIED BY THE I.F. AMPLIFIER.

A UNIVERSAL RECEIVER WITH THE 6A7

IN FIG. 14, YOU ARE SHOWN THE CIRCUIT DIAGRAM OF THE MODEL 54 PHILCO RECEIVER SO THAT YOU MAY SEE A TYPICAL EXAMPLE OF HOW THE 6A7 PENTAGRID CONVERTER TUBE IS BEING EMPLOYED IN A SUPERHETERODYNE TYPE "UNIVERSAL" RECEIVER (COMBINATION A.C.-D.C.). THE TUBES USED IN THIS RECEIVER ARE THE 6A7 AS

THE 1ST DETECTOR-OSCILLATOR, A 78 I.F. AMPLIFIER, A 75 SECOND DETECTOR, A

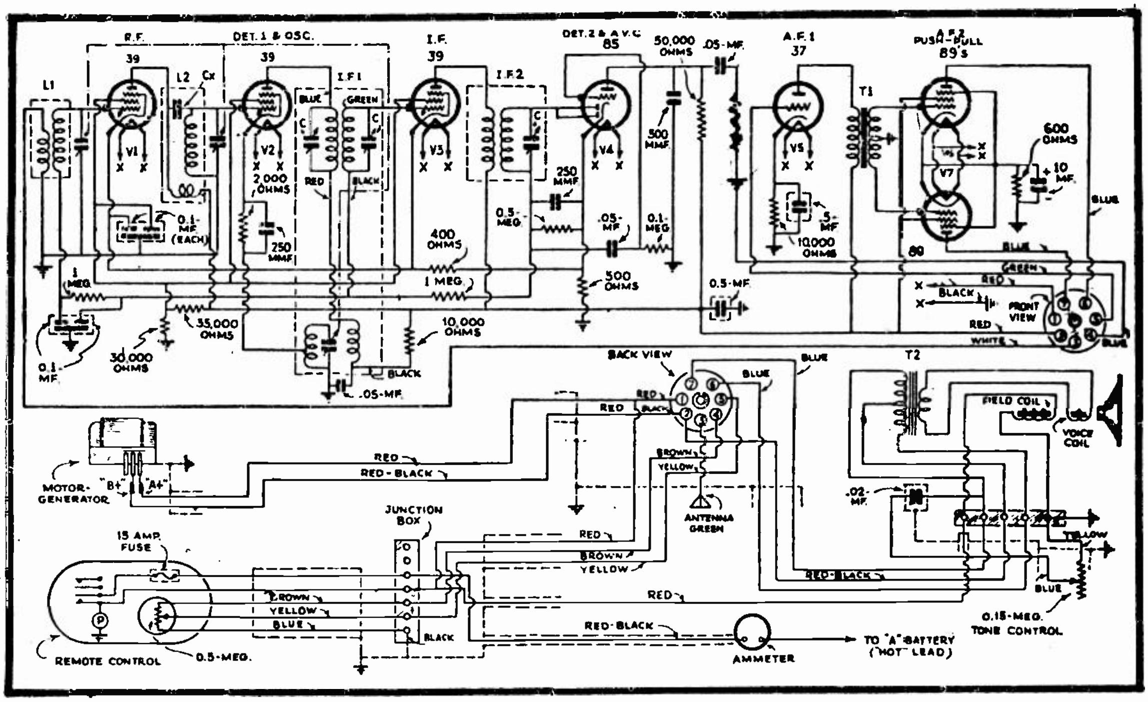

FIG. 12

Circuit Employing the Autodyne Principle.

43 POWER TUBE AND A 25Z5 RECTIFIER.

WITH THE EXCEPTION OF THE NECESSARY PROVISIONS TO MAKE THE COMBINATION A.C-D.C. OPERATION POSSIBLE, YOU WILL FIND THIS CIRCUIT TO FOLLOW THE SAME BASIC PRINCIPLES WHICH HAVE ALREADY BEEN BROUGHT TO YOUR ATTENTION.

A SHORT-WAVE SUPERHETERODYNE

FIG. 15 SHOWS YOU A TYPICAL EXAMPLE OF HOW THE 2A7 TUBE MAY BE USED IN AN EFFICIENT SHORT-WAVE RECEIVER OF THE SUPERHETERODYNE TYPE. NOTICE THAT THIS CIRCUIT HAS AUTOMATIC VOLUME CONTROL FEATURES WITH THE AID OF THE 55 DUPLEX DIODE-TRIODE TUBE.

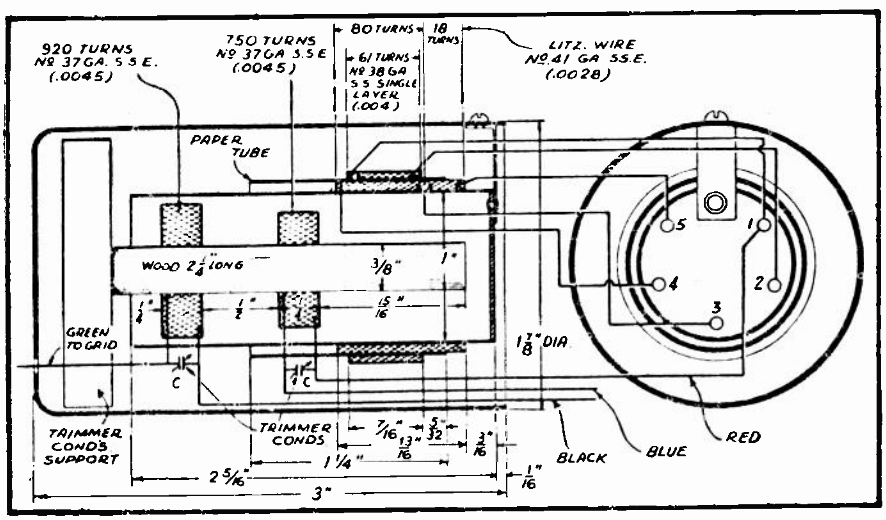

FIG. 13

The Composite Oscillator - I.F. Unit.

THE INTERMEDIATE FREQUENCY IN THIS RECEIVER IS 465 KC. AND THEREFORE THE I.F. TRANSFORMERS WHICH ARE USED

MUST BE PEAKED AT 465 KC. THIS IS A POPULAR INTERMEDIATE FREQUENCY FOR SHORT AND ALL-WAVE SUPERHETERODYNE RECEIVERS.

A SET OF TWO PLUG-IN COILS ARE USED TO COVER EACH FREQUENCY BAND. ONE OF THESE COILS IS USED IN THE FIRST DETECTOR STAGE AND THE OTHER IN THE OSCILLATOR CIRCUIT. TUNING IS ACCOMPLISHED BY MEANS OF A TWO-GANG CONDENSER HAVING A CAPACITY RATING OF 140 MMFD. PER SECTION IN CONJUNCTION WITH AN INDIVIDUAL TUNING CONDENSER OF 140 MMFD. WHICH IS SHUNTED ACROSS THE FIRST DETECTOR SECTION AND THEREFORE SERVES AS A PADDING CONDENSER.

DUE TO THIS ARRANGEMENT OF THE TUNING CONTROLS, THE FIRST DETECTOR AND OSCILLATOR COILS MAY BE CONSTRUCTED ALIKE. THIS MEANS THAT PRACTICALLY ANY STANDARD SET OF FOUR-PRONG SHORT WAVE COILS MAY BE USED. IN OTHER WORDS THE COIL IN THE FIRST DETECTOR CIRCUIT IS USED IN THE CONVENTIONAL MANNER

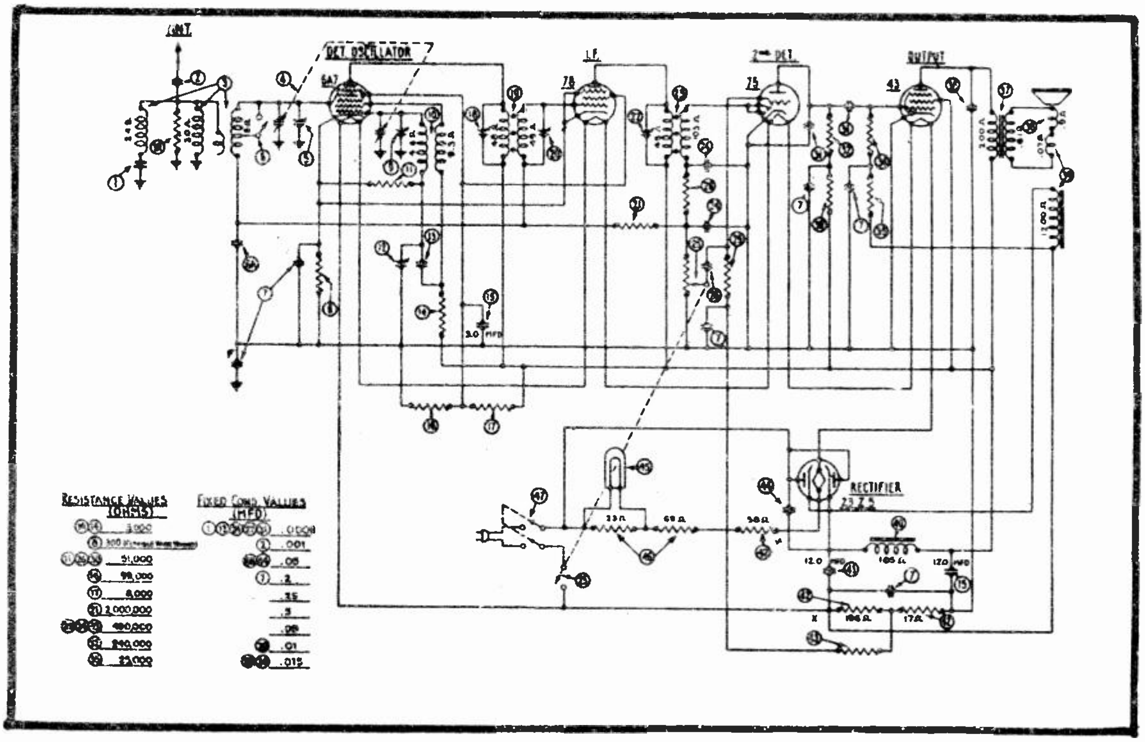

FIG. 14
The Model 54 Philco.

WHILE IN THE OSCILLATOR CIRCUIT THE TUNED WINDING IS CONNECTED ACROSS THE OSCILLATOR TUNING CONDENSER WHEREAS THE TICKLER COIL IS CONNECTED BETWEEN B+ AND THE ANODE GRID OF THE 2A7 TUBE.

TO COVER THE ENTIRE SHORT-WAVE SPECTRUM, THREE SETS OF PLUG-IN COILS WILL BE REQUIRED.

THE REST OF THIS CIRCUIT IS QUITE CONVENTIONAL AND BASED UPON THE SAME BASIC PRINCIPLES WITH WHICH YOU ARE ALREADY FAMILIAR.

NOW THAT YOU HAVE MASTERED THIS PART OF YOUR STUDIES CONCERNING SUPERHETERODYNE RECEIVERS, OUR NEXT STEP WILL BE TO INVESTIGATE THE MOST COMMON TROUBLES AND SERVICE REQUIREMENTS OF THIS TYPE OF RECEIVER. IN THIS

WORK, YOU WILL FIND THAT EVERYTHING WHICH YOU HAVE ALREADY LEARNED ABOUT TROUBLE-SHOOTING IN GENERAL WILL STILL APPLY ONLY THAT IN THE CASE OF THE "SUPER", THERE ARE CERTAIN TYPES OF TROUBLES AND SERVICE ADJUSTMENTS WHICH

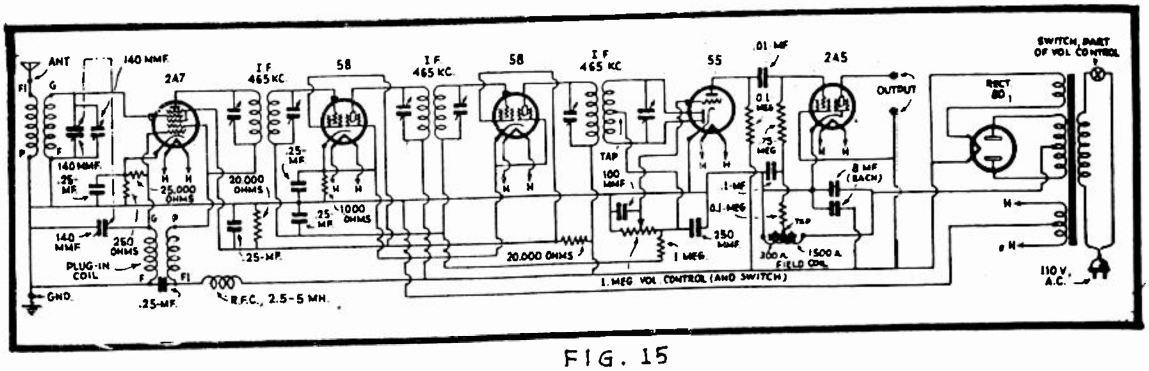

FIG. 15

A Short-Wave Superheterodyne Receiver.

YOU DIDN'T HAVE TO WORRY ABOUT WHEN WORKING ON T.R.F. RECEIVERS.

SINCE THE SUPERHETERODYNE RECEIVER HAS BECOME SO VERY POPULAR AND EXTENSIVELY USED, YOU ARE GOING TO FIND THIS NEXT LESSON TO BE OF SPECIAL VALUE, AS WELL AS INTENSELY INTERESTING.

NO DOUBT, YOU NOW REALIZE MORE THAN EVER BEFORE HOW COMPLETE AND UP-TO-DATE THAT NATIONAL TRAINING REALLY IS AND THAT NOTHING IS BEING OVER-LOOKED TO OFFER OUR STUDENTS THE BEST AND MOST THOROUGH RADIO TRAINING POSSIBLE.

NEW RADIO DEVELOPMENTS ARE CONTINUALLY BEING WORKED OUT AT A MOST ASTOUNDING PACE AND IN ORDER FOR A MAN TO RISE TO THE TOP OF THE RADIO PROFESSION, HE MUST AT ALL TIMES BE ALERT AND READY TO LEARN ABOUT NEW THINGS AS SOON AS THEY APPEAR IN THE INDUSTRY. THERE IS NO LONGER ANY ROOM FOR THE "BACK-NUMBER" TECHNICIAN.

ONE OF THE CHIEF REASONS WHY NATIONAL GRADUATES ARE SO SUCCESSFUL IS THAT OUR COURSE IS AT ALL TIMES UP-TO-DATE, SO THAT UPON GRADUATION, EVERY STUDENT IS THOROUGHLY INFORMED IN RADIO FROM THE EARLIEST DEVELOPMENTS OF THIS INDUSTRY RIGHT UP TO THE DEVELOPMENTS WHICH HAVE JUST OCCURRED AT THE TIME OF HIS GRADUATION.

Examination Questions

Answered Feb 3 41
Fiske

LESSON NO. 54

Money, wealth, all personal possessions can be lost; but Training brings permanent and perpetual benefits.

1. - WHAT ARE THE OPERATING CHARACTERISTICS OF THE 2A7 TUBE?

2. - DRAW A CIRCUIT DIAGRAM, SHOWING HOW THE 2A7 TUBE IS USED IN A SUPERHETERODYNE RECEIVER.

3. - EXPLAIN HOW THE 2A7 TUBE OPERATES IN THE CIRCUIT WHICH YOU HAVE DRAWN IN ANSWER TO QUESTION #2.

4. - HOW DOES THE 6A7 TUBE DIFFER FROM THE 2A7?

5. - WHAT IS THE 1A6 TUBE USED FOR?

6. - WHAT ARE THE CHIEF ADVANTAGES OBTAINED THROUGH THE USE OF AN ELECTRON-COUPLED OSCILLATOR AS EXPLAINED IN THIS LESSON REGARDING THE APPLICATION OF PENTAGRID CONVERTER TUBES TO SUPERHETERODYNE RECEIVERS?

7. - WHAT IS MEANT BY THE EXPRESSION "CONVERSION-CONDUCTANCE" AS USED IN CONNECTION WITH PENTAGRID CONVERTER TUBES?

8. - WHAT IS MEANT BY THE EXPRESSION "TRANSLATION-GAIN" AS USED IN CONJUNCTION WITH PENTAGRID CONVERTER TUBES?

9. - ILLUSTRATE BY MEANS OF A DIAGRAM, THE BASE OR SOCKET CONNECTIONS AS MADE TO THE 2A7 TUBE.

10. - BRIEFLY DESCRIBE THE AUTODYNE SYSTEM AS EMPLOYED IN SOME SUPERHETERODYNE RECEIVERS.

RADIO - TELEVISION

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LESSON NO. 55

• SERVICING SUPERHETERODYNE RECEIVERS •

You are by this time well acquainted with the circuits of superheterodyne receivers, as well as with the testing procedures as applied to receivers in general. There are, however, a number of troubles which are found in superheterodyne receivers which do not as a rule occur in receivers of the T.R.F. type. In addition, the superheterodyne calls for special service requirements which one does not have to deal with when working on T.R.F. receivers.

In this lesson, we are going to deal specifically with superheterodyne servicing, considering the proper method of aligning their tuned circuits, the symptoms of troubles common to superheterodyne circuits, their correction etc.

TUNING CIRCUIT ALIGNMENT

Our first step will beto consicer the proper method of aligning the tuning circuitsof a superheterodyne receiver. To refresh your memory, study Fig. 2 very carefully. Notice especially, that with this system, three different radic frequencies are being handled at the same time. That is, the tuning circuits of the pre-selector and first detector stage are both tuned to the frequency of the incoming signal, the oscillator circuit is tuned to a frequency which is equal to the signal frequency plus the intermediate frequency and as the third distinct frequency, we have the intermediate fre-

FIG. 1

Set-up for a Complete Test.

QUENCY WHICH RESULTS FROM THE BEAT EFFECT BETWEEN THE SIGNAL AND OSCILLATOR FREQUENCIES.

SINCE ALL THREE OF THESE INDIVIDUAL FREQUENCIES ARE SIMULTANEOUSLY PRESENT, IT IS OBVIOUS THAT EACH OF THE TUNED CIRCUITS MUST BE TUNED PRECISELY TO THE FREQUENCY WHICH IT IS EXPECTED TO HANDLE. WHEN THIS IS SO, WE SAY THAT THE TUNED CIRCUITS ARE ALL PROPERLY ALIGNED. YOU MUST ALSO BEAR IN MIND THAT WHEN THE OSCILLATOR TUNING CONDENSER IS GANGED WITH THE TUNING CONDENSER SECTIONS OF THE FIRST DETECTOR AND PRE-SELECTOR STAGES, IT IS STILL MORE DIFFICULT TO MAINTAIN THE PROPER FREQUENCY RELATION THRUOUT THE ENTIRE TUNING RANGE OR TO MAKE THE TUNING CIRCUITS TRACK CORRECTLY.

ALIGNING THE I.F. STAGES

WHENEVER THE TUNING CIRCUITS OF A SUPERHETERODYNE RECEIVER ARE TO BE ALIGNED, THE I.F. STAGES ARE ALIGNED FIRST. TO DO THIS ACCURATELY, A SERVICE OSCILLATOR IS REQUIRED AND WHICH MUST BE CAPABLE OF GENERATING AN R.F. SIGNAL OF THE SAME FREQUENCY TO WHICH THE I.F. TRANSFORMERS IN QUESTION ARE TO BE TUNED. IN A PREVIOUS LESSON, YOU WERE ALREADY INFORMED OF THE CONSTRUCTIONAL FEATURES OF THESE SERVICE OSCILLATORS AND SO AT THIS TIME WE ARE ONLY GOING TO CONSIDER ITS APPLICATION TO SERVICE WORK.

THE SET-UP FOR ALIGNING THE I.F. STAGES OF A SUPERHETERODYNE IS ILLUSTRATED FOR YOU IN FIG. 3. HERE YOU WILL OBSERVE THAT THE GROUND OR "G" TERMINAL OF THE SERVICE OSCILLATOR IS CONNECTED TO THE GROUND TERMINAL OF

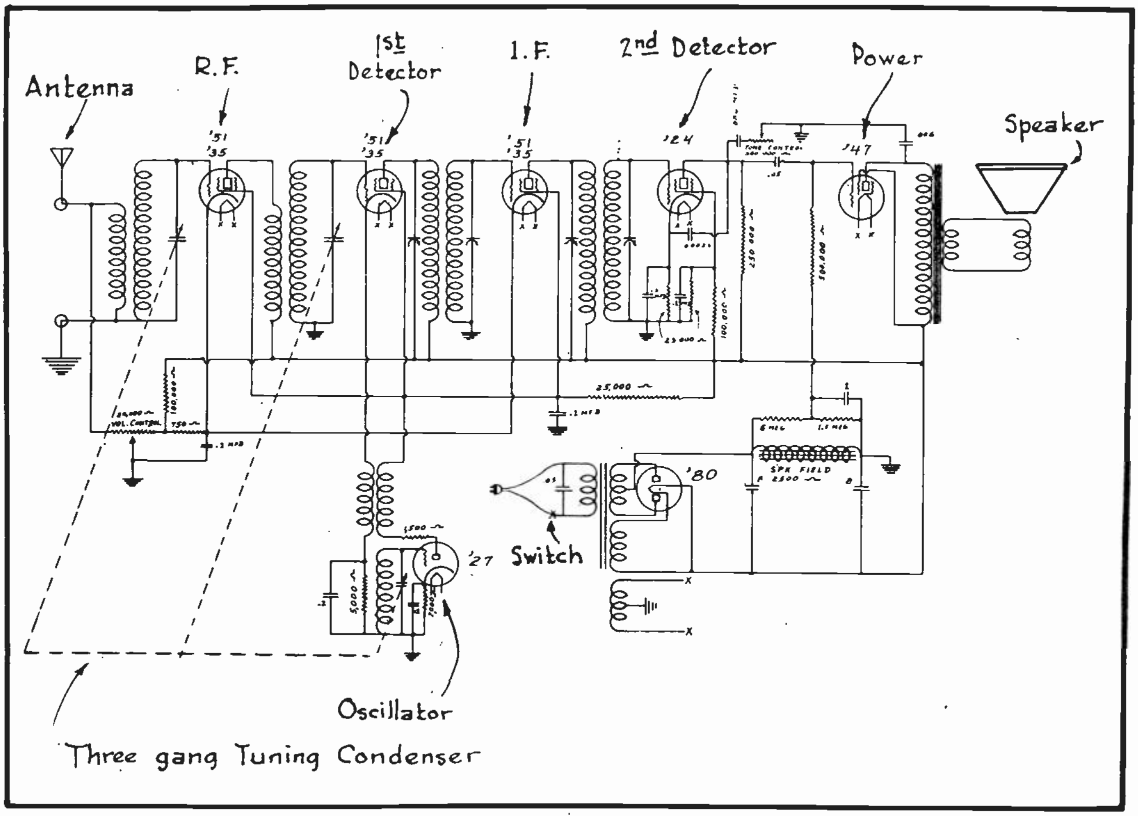

FIG. 2
Circuit Diagram of a 7 Tube Superheterodyne Receiver.

THE RECEIVER. THE CONTROL GRID WIRE IS REMOVED FROM THE CONTROL GRID CAP OF THE FIRST DETECTOR TUBE AND THE "A" OR ANTENNA TERMINAL OF THE SERVICE OSCILLATOR IS CONNECTED TO THE CONTROL GRID CAP OF THE FIRST DETECTOR TUBE. SHIELDED WIRE IS GENERALLY USED FOR THIS ANTENNA TERMINAL WIRE AND ITS SHIELDING SHOULD BE CONNECTED TO THE RECEIVER'S GROUND TERMINAL SO THAT IT WILL BE EFFECTIVELY GROUNDED. THE OUTPUT METER IS CONNECTED ACROSS THE TWO PLATE LEADS OF THE OUTPUT PUSH-PULL TRANSFORMER OR ELSE IF A SINGLE POWER TUBE IS USED, THE OUTPUT METER IS CONNECTED ACROSS THE PLATE OF THE POWER TUBE AND THE CHASSIS.

AN OUTPUT METER IS NOTHING MORE THAN A D.C. MILLIAMMETER MOVING COIL MOVEMENT USED IN CONJUNCTION WITH A COPPER OXIDE RECTIFIER SO THAT A.C. VOLTAGES WILL BE INDICATED ON ITS SCALE. VARIOUS TYPES OF OUTPUT METERS ARE BEING MANUFACTURED, SEVERAL HAVING A MULTIPLE RANGE SCALE RANGING FROM 1.5 TO 150 VOLTS A.C.

THE NEXT STEP IS TO TURN ON THE RECEIVER, AS WELL AS THE SERVICE OSC-

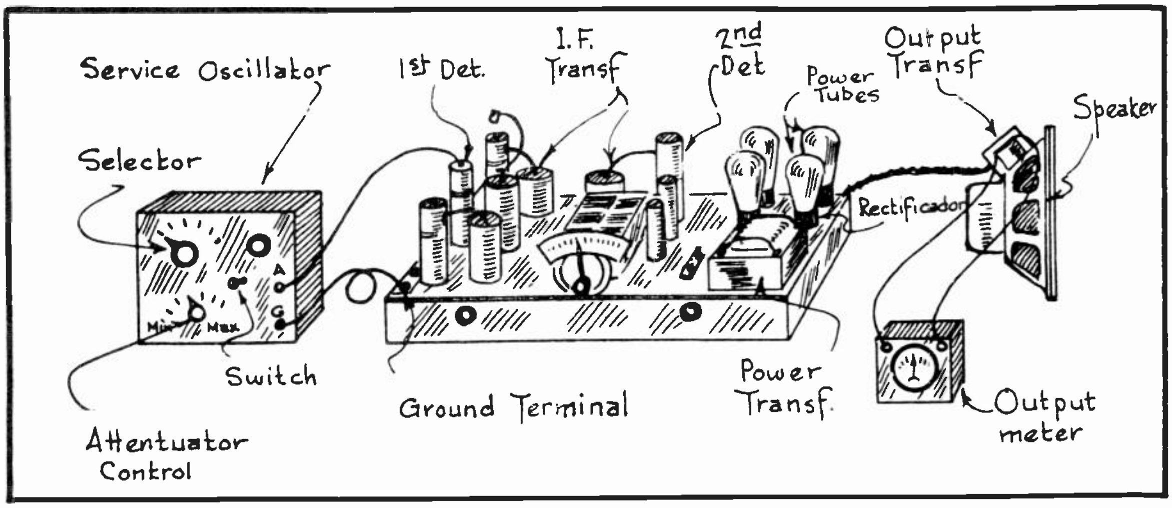

FIG. 3

Set-up for Aligning the I.F. Stages.

ILLATOR AND TO SET THE SERVICE OSCILLATOR DIAL TO THE POSITION CORRESPOND-ING TO THE FREQUENCY FOR WHICH THE I.F. AMPLIFIER OF THE RECEIVER IS DESIGNED.

IF THE SERVICE OSCILLATOR BEING USED HAS AN ATTENTUATOR CONTROL, THEN SET THE RECEIVER'S VOLUME CONTROL TO MAXIMUM VOLUME AND REGULATE THE ATT-ENTUATOR CONTROL ON THE SERVICE OSCILLATOR SO THAT THE INDICATING NEEDLE OF THE OUTPUT METER WILL COME TO REST AT APPROXIMATELY THE CENTER OF ITS SCALE.

THIS DONE, COMMENCE ADJUSTING THE TRIMMER CONDENSER OF THE VARIOUS I.F. TRANSFORMERS FOR MAXIMUM INDICATION ON THE OUTPUT METER. WHEN MAKING THESE ADJUSTMENTS, USE A BAKELITE SCREW DRIVER AND START WITH THE TRIMMER NEAREST THE SECOND DETECTOR, THAT IS, THE TRIMMER CONDENSER WHICH IS CONNECT-ED ACROSS THE SECONDARY WINDING OF THE I.F. TRANSFORMER, WHICH WORKS INTO THE SECOND DETECTOR TUBE. WITH THIS CONDENSER PROPERLY ADJUSTED, CONTINUE ADJUSTING EACH OF THE OTHERS IN TURN, GRADUALLY WORKING TOWARDS THE FIRST DETECTOR TUBE. DO THIS WORK SLOWLY AND WITH SPECIAL CARE IN ORDER TO IN-SURE ACCURACY.

AS THESE CONDENSERS ARE EACH SET NEARER THE RESONANT FREQUENCY, THE

OUTPUT WILL NATURALLY INCREASE, SO IN THIS CASE, THE ATTENTUATOR CONTROL OF THE SERVICE OSCILLATOR CAN BE READJUSTED SO THAT THE INDICATING NEEDLE OF THE OUTPUT METER WILL AGAIN RETURN TO SOMEWHERES NEAR ITS CENTER POSITION ON THE SCALE.

IF NO OUTPUT METER IS AVAILABLE, THE I.F. STAGES CAN BE ALIGNED BY ADJUSTING THE TRIMMER CONDENSERS OF THE I.F. TRANSFORMERS SO THAT THE OSCILLATOR SIGNAL, AS AMPLIFIED BY THE RECEIVER, EMITS A SOUND OF MAXIMUM INTENSITY FROM THE LOUDSPEAKER. THIS METHOD, HOWEVER, IS NOT SO ACCURATE AS WHEN USING AN OUTPUT METER FOR THE SIMPLE REASON THAT A VISIBLE INDICATION IS MORE RELIABLE THAN AN AUDIBLE INDICATION. IN OTHER WORDS, THE EYE CAN MORE READILY DETECT SMALL VARIATIONS IN THE POSITION OF A METER NEEDLE THAN CAN THE EAR DETECT SMALL VARIATIONS IN SOUND INTENSITY.

BE SURE THAT ALL OF THE SHIELD CANS ARE PROPERLY INSTALLED OVER THE TUBES AND I.F. TRANSFORMERS, AS THIS ALIGNING PROCESS IS BEING CARRIED OUT, SINCE THEY HAVE A MOST PRONOUNCED EFFECT UPON TUNING.

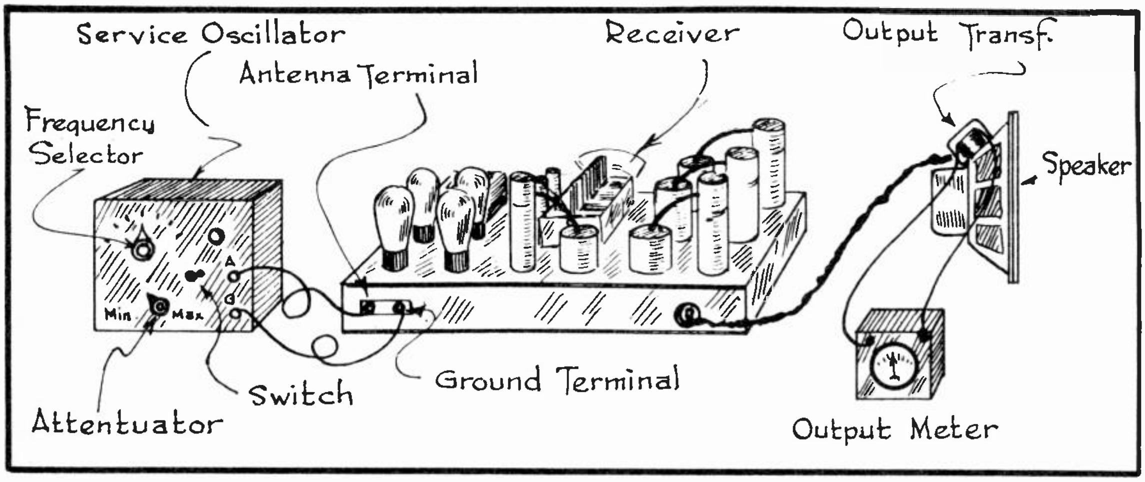

FIG. 4
The "Set-Up" For Aligning the Receiver's Oscillator.

AFTER THE I.F. STAGES ARE ALL ALIGNED CORRECTLY, TURN OFF THE SERVICE OSCILLATOR AND THE RECEIVER, DISCONNECT THE OSCILLATOR'S ANTENNA TERMINAL FROM THE CONTROL GRID CAP OF THE FIRST DETECTOR TUBE AND RECONNECT THE CONTROL GRID WIRE TO THE FIRST DETECTOR TUBE.

YOU ARE NOW READY TO ADJUST THE TUNING CIRCUIT OF THE OSCILLATOR.

ALIGNING THE OSCILLATOR

THE SET-UP OF THE EQUIPMENT FOR ALIGNING THE OSCILLATOR IS ILLUSTRATED IN FIG. 4. NOTICE THAT THE "A" OR ANTENNA TERMINAL OF THE SERVICE OSCILLATOR IS CONNECTED TO THE ANTENNA TERMINAL OF THE RECEIVER, WHILE THE "G" OR GROUND TERMINAL OF THE SERVICE OSCILLATOR IS CONNECTED TO THE GROUND TERMINAL OF THE RECEIVER. IT IS ALSO IMPORTANT TO GROUND THE SHIELDING OF THE ANTENNA LEAD-WIRE TO THE RECEIVER'S GROUND TERMINAL. THE OUTPUT METER IS CONNECTED TO THE CIRCUIT THE SAME AS ALREADY DESCRIBED FOR ALIGNING THE I.F. STAGES.

THE ADJUSTMENTS FOR THE OSCILLATOR TUNING CIRCUIT IN THE CONVENTIONAL TYPE OF SUPERHETERODYNE RECEIVER ARE POINTED OUT TO YOU IN FIG. 5. HERE

YOU WILL SEE THAT THE COMPENSATOR CONDENSER, WHICH IS BUILT INTO THE OSCILLATOR SECTION OF THE GANG TUNING CONDENSER, IS USED AS THE "HIGH FREQUENCY TRIMMER," WHEREAS THE OTHER TRIMMER CONDENSER WHICH IS CONNECTED ACROSS THE PADDING CONDENSER IS USED AS THE "LOW FREQUENCY TRIMMER". WITH THIS POINT IN MIND, LET US NOW CONTINUE WITH THE ADJUSTMENT OF THIS PORTION OF THE RECEIVER.

WE COMMENCE BALANCING THE RECEIVER'S OSCILLATOR CIRCUIT BY FIRST ADJUSTING THE HIGH-FREQUENCY TRIMMER. TO DO THIS, SET THE FREQUENCY SELECTOR OF THE SERVICE OSCILLATOR SO THAT THIS APPARATUS WILL PRODUCE A 1400 KC. SIGNAL FREQUENCY, SET THE VOLUME CONTROL OF THE RECEIVER TO ITS MAXIMUM POSITION AND ITS TUNING DIAL TO THE 1400 KC. POSITION.

TURN "ON" THE SWITCH OF BOTH THE RECEIVER AND THE SERVICE OSCILLATOR AND ADJUST THE ATTENTUATOR OF THE SERVICE OSCILLATOR UNTIL A ONE-HALF SCALE READING IS OBTAINED ON THE OUTPUT METER. IF THE RECEIVER IS BADLY OUT OF ADJUSTMENT, THEN THIS METER READING MAY BE DIFFICULT TO OBTAIN BUT IF SUCH BE THE CASE, THE SIGNAL AS COMING FROM THE SPEAKER CAN BE USED AS A TEMPORARY GUIDE OR ELSE HEADPHONES MAY BE CONNECTED ACROSS THE PRIMARY OF THE OUTPUT TRANSFORMER IN PLACE OF THE METER AND THE OSCILLATOR SIGNAL HEARD THROUGH THEM.

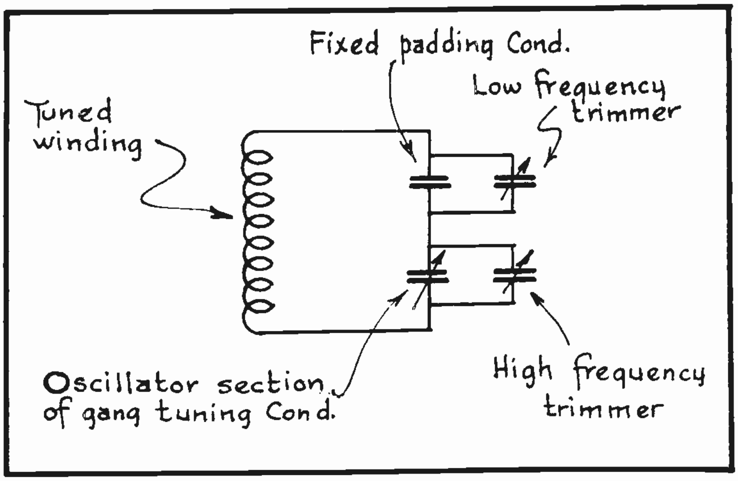

FIG. 5
The Oscillator Adjustments.

ADJUST THE HIGH-FREQUENCY TRIMMER CONDENSER OF THE RECEIVER'S OSCILLATOR CIRCUIT CAREFULLY FOR MAXIMUM READING ON THE OUTPUT METER OR FOR MAXIMUM SIGNAL VOLUME IN THE SPEAKER OR HEADPHONES IF THESE ARE BEING USED AS INDICATORS. AFTER MAKING THIS ADJUSTMENT, TURN THE TUNING DIAL OF THE RECEIVER SLIGHTLY BOTH WAYS FROM ITS 1400 KC. SETTING AND NOTE WHETHER OR NOT ANY INCREASE IN THE METER READING OR SOUND VOLUME IS OBTAINED. IF SO, THEN THE R.F. AND FIRST DETECTOR TRIMMER CONDENSERS MUST BE ADJUSTED AS WILL BE DESCRIBED SHORTLY.

AFTER THE RECEIVER'S OSCILLATOR HAS THUS BEEN ADJUSTED FOR THE HIGH FREQUENCY SETTING, THE NEXT STEP IS TO ADJUST THE RECEIVER OSCILLATOR AT THE LOW FREQUENCY END OF THE DIAL. TO DO THIS, LEAVE THE SERVICE OSCILLATOR AND OUTPUT METER OR HEADPHONE CONNECTION JUST AS THEY ARE BUT SET THE FREQUENCY SELECTOR OF THE SERVICE OSCILLATOR TO THE 700 KC. POSITION AND ALSO SET THE TUNING DIAL OF THE RECEIVER TO THE 700 KC. POSITION. NOW ADJUST THE "LOW FREQUENCY TRIMMER" FOR MAXIMUM READING ON THE OUTPUT METER OR MAXIMUM SIGNAL STRENGTH IN THE HEADPHONES OR SPEAKER. AFTER THIS LOW FREQUENCY TRIMMER HAS BEEN PROPERLY ADJUSTED, IT IS ADVISABLE TO AGAIN RE-CHECK THE HIGH FREQUENCY ADJUSTMENT IN CASE THAT IT HAS BECOME AFFECTED BY THE LOW FREQUENCY ADJUSTMENT AND TO MAKE ANY FINAL CORRECTION AS FOUND NECESSARY.

TO BALANCE THE R.F. AND FIRST DETECTOR STAGES, LEAVE THE SERVICE OSC-

ILLATOR AND OUTPUT METER CONNECTIONS AS THEY ARE, SET THE FREQUENCY SELECTOR OF THE SERVICE OSCILLATOR TO THE 1400 KC. POSITION AND ALSO SET THE TUNING DIAL OF THE RECEIVER TO THE 1400 KC. POSITION. THEN ADJUST THE TRIMMER OR COMPENSATOR CONDENSERS OF THE R.F. AND FIRST DETECTOR SECTIONS OF THE GANG TUNING CONDENSER SO AS TO OBTAIN THE MAXIMUM READING ON THE OUTPUT METER.

AFTER THE ENTIRE SET HAS ONCE BEEN ALIGNED IN THIS MANNER, IT IS ADVISABLE TO RECHECK THE OSCILLATOR, FIRST DETECTOR AND R.F. ADJUSTMENTS OF THE RECEIVER OVER THE ENTIRE TUNING RANGE BY SETTING THE SERVICE OSCILLATOR AT ABOUT FOUR OR FIVE DIFFERENT BROADCAST FREQUENCIES APPROXIMATELY EQUALLY DISTRIBUTED OVER THE TUNING RANGE BETWEEN THE LOW AND HIGH FREQUENCIES SETTINGS FOR WHICH THE ADJUSTMENTS WERE ALREADY MADE. IF ANY FURTHER ADJUSTMENTS ARE REQUIRED IN THIS MEDIUM RANGE OF FREQUENCIES, THEY CAN BE MADE BY CAREFULLY BENDING THE SLOTTED ROTOR PLATES OF THE PROPER TUNING CONDENSER SECTION EITHER TOWARD OR AWAY FROM THE ADJACENT STATOR PLATE. REMEMBER THAT THE CAPACITY IS INCREASED BY BENDING THE ROTOR PLATE INWARD AND DECREASED BY BENDING THE ROTOR PLATE OUTWARD.

WITH THE ENTIRE SET PROPERLY ALIGNED, THE SERVICE OSCILLATOR CAN BE TURNED OFF AND DISCONNECTED FROM THE RECEIVER. THE PERFORMANCE OF THE RECEIVER SHOULD THEN BE CHECKED BY TUNING IN AS MANY BROADCAST PROGRAMS AS POSSIBLE.

SUPERHETERODYNE TROUBLES

NOW LET US CONTINUE WITH AN INVESTIGATION OF THE DIFFERENT TYPES OF TROUBLES WHICH ARE PECULIAR AND RATHER COMMON TO SUPERHETERODYNE RECEIVERS. IN ANALYZING THESE TROUBLES, WE SHALL NOT CONSIDER THOSE CONDITIONS WHICH ARE COMMON TO ALL TYPES OF RECEIVERS SUCH AS A DEFECTIVE POWER SUPPLY, TUBES, AND GENERAL CIRCUIT TROUBLES AS DEFECTIVE RESISTORS, CONDENSERS, ETC. ABOUT WHICH YOU ARE ALREADY FAMILIAR. WE ARE ALSO GOING TO ABSUME THAT THE RECEIVER IS PROPERLY DESIGNED AND CORRECTLY CONSTRUCTED.

POOR SENSITIVITY

POOR SENSITIVITY ON ONE END OF THE BAND AS COMPARED TO THE OTHER END, OR ON BOTH ENDS AS COMPARED TO THE MIDDLE, IS ALMOST INVARIABLY A SIGN OF IMPROPER TRACKING ON THE PART OF THE GANG TUNING CONDENSER AND CAN BE CORRECTED BY ALIGNING THE OSCILLATOR, FIRST DETECTOR AND PRE-SELECTOR STAGES OF THE RECEIVER AS ALREADY EXPLAINED IN THIS LESSON.

LACK OF SENSITIVITY ALL OVER THE BAND, PROVIDED ALL OTHER THINGS ARE CORRECT, USUALLY INDICATES THAT THE I.F. CIRCUITS ARE NOT PROPERLY TUNED AND SO IN THIS CASE IT IS NECESSARY TO RETURN THEM TO THE EXACT FREQUENCY FOR WHICH THEY ARE DESIGNED TO OPERATE.

WHISTLES

IF A WHISTLING SOUND IS EMITTED BY THE SPEAKER AS THE RECEIVER DIAL IS SET TO BRING IN DIFFERENT STATIONS, THIS IS CAUSED EITHER BY THE I.F. STAGES BEING TUNED TO SOME OTHER FREQUENCY THAN THAT FOR WHICH THEY ARE DESIGNED OR ELSE BY INSUFFICIENT SELECTIVITY IN THE R.F. TUNING CIRCUITS.

A SIMPLE WAY TO DETERMINE WHICH OF THESE TWO CONDITIONS MAY BE

THE CAUSE IS TO TEMPORARILY SHORT CIRCUIT THE OSCILLATOR TUNING CONDENSER AND THEN ROTATE THE DIAL WITH THE VOLUME CONTROL TURNED WELL UP. UNDER THESE CONDITIONS, NO STATIONS SHOULD BE HEARD, IN FACT THE RECEIVER SHOULD BE ABSOLUTELY SILENT. IF STATIONS ARE HEARD AT SOME POINTS WITHOUT THE OSCILLATOR CIRCUIT WORKING, THEN THE I.F. TRANSFORMERS ARE NOT TUNED PROPERLY. ON THE OTHER HAND, IF THE RECEIVER IS SILENT DURING THIS TEST WHEN THE OSCILLATOR IS INOPERATIVE BUT WHISTLES WHEN THE OSCILLATOR IS WORKING, THEN THE SELECTIVITY OF THE TUNING CIRCUITS PRECEDING THE FIRST DETECTOR TUBE IS INSUFFICIENT.

THIS WOULD REALLY BE DUE TO FAULTY DESIGN AND SO IF NOT ENOUGH CHASSIS SPACE IS AVAILABLE TO INCORPORATE A BAND SELECTOR OR ADDITIONAL TUNED CIRCUIT IN THE R.F. SECTION OF THE RECEIVER, THE NEXT BEST THING IS TO TRY USING A SHORTER ANTENNA OR TO CONNECT A .0005 MFD. FIXED CONDENSER IN SERIES WITH THE ANTENNA LEAD-IN WIRE AND THE ANTENNA TERMINAL OF THE RECEIVER. ANOTHER MORE OR LESS MAKE-SHIFT REMEDY WOULD BE TO USE AN EXTERNAL WAVE-TRAP.

REPEAT POINTS

SOMETIMES, YOU MAY RUN ACROSS A SUPERHETERODYNE WHERE THE SAME STATION CAN BE HEARD ONCE AT THE PROPER PLACE ON THE TUNING DIAL AND AGAIN AT ANOTHER POINT ON THE DIAL AT ABOUT 350 KC. OFF THE PROPER PLACE FOR THE STATION. THIS CONDITION MAY BE REMEDIED BY THE SAME METHOD AS OUTLINED FOR "WHISTLING" OR ELSE BY IMPROVING THE SHIELDING OF THE RECEIVER IF SUCH BE REQUIRED.

DEAD SPOTS

SOME SUPERHETERODYNES WHICH AREN'T WORKING PROPERLY WILL FUNCTION SATISFACTORILY OVER ONE PORTION OF THE BAND, GENERALLY THE HIGH FREQUENCY END, BUT STOP WORKING ON OTHER PORTIONS OF THE BAND. THIS IS USUALLY DUE TO THE OSCILLATOR TUBE HAVING INCORRECT VOLTAGES SO THAT IT STOPS OSCILLATING IN SPOTS AND SOMETIMES, THE OSCILLATOR TUBE ITSELF IS AT FAULT.

THE REMEDY IS TO CHECK THE OSCILLATOR TUBE VOLTAGES AND TO MAKE ANY CHANGES OR REPAIRS IN THE CIRCUIT AS MAY BE NECESSARY TO BRING THE VOLTAGES TO THE VALUES REQUIRED FOR THE TYPE OSCILLATOR TUBE BEING USED AS PER THE TUBE MANUFACTURER'S SPECIFICATIONS.

GENERAL TROUBLE - SHOOTING

THE GENERAL PROCEDURE FOR TESTING A SUPERHETERODYNE WHICH DOES NOT OPERATE PROPERLY, OR AT ALL, IS TO FIRST MAKE A GENERAL CHECK WITH AN ANALYZER, MEASURING ALL OF THE VOLTAGES AVAILABLE AT THE DIFFERENT TUBE SOCKETS AND COMPARING THEM WITH THE CORRECT VALUES AS PER MANUFACTURER'S SPECIFICATIONS. IF ANY OF THESE VOLTAGES ARE LACKING OR ARE INCORRECT, THEN OF COURSE THE PARTICULAR CIRCUIT IN QUESTION WOULD BE FURTHER CHECKED ACCORDING TO THE METHODS WITH WHICH YOU ARE ALREADY FAMILIAR AND THE NECESSARY STEPS TAKEN TO CORRECT THE FAULTY CONDITION.

IF THE NATURE OF THE TROUBLE HAPPENS TO BE SUCH THAT AN ORDINARY ANALYZER CHECK DOES NOT INDICATE THE TROUBLE, THEN THE SUPERHETERODYNE RECEIVER CAN BE DIVIDED INTO SECTIONS AND TESTED AS SHALL NOW BE EXPLAINED SO AS TO LOCALIZE THE TROUBLE DOWN TO ONE SECTION OF THE RECEIVER. YOU WILL FIND THE SYSTEM WHICH IS NOW GOING TO BE EXPLAINED TO BE SOMEWHAT

SIMILAR TO THE STAGE ELIMINATION TESTS WHICH WERE DESCRIBED IN YOUR LESSON #22 FOR LOCATING THE DEFECTIVE STAGE IN A T.R.F. RECEIVER.

SECTIONAL TESTS ON SUPERHETERODYNES

IF NO SIGNALS COME FROM THE SPEAKER WHEN THE RECEIVER IS TUNED TO RESONANCE WITH SOME STATION, THEN YOU CAN BEGIN BY PLUGGING A PAIR OF HEADPHONES INTO ONE FILAMENT HOLE AND THE CONTROL GRID HOLE OF A POWER TUBE SOCKET AS ILLUSTRATED IN FIG. 6, OR INTO THE CATHODE AND CONTROL GRID HOLES OF THE POWER TUBE SOCKET, DEPENDING UPON THE TYPE OF POWER TUBE BEING USED. IF THE SIGNAL IS HEARD HERE BUT DOES NOT REACH THE SPEAKER, THEN THE TROUBLE IS IN THE POWER STAGE, OUTPUT TRANSFORMER OR IN THE SPEAKER ITSELF.

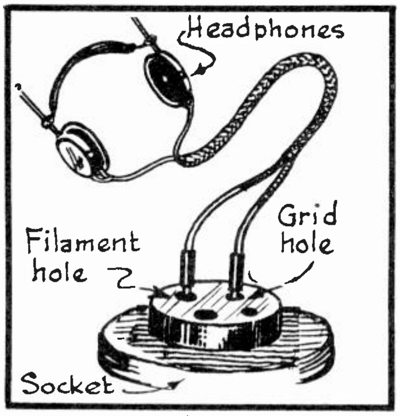

FIG. 6
Testing the Power Stage.

YOU CAN CONTINUE THIS A.F. STAGE ELIMINATION TEST, ELIMINATING ONE A.F. STAGE AT A TIME AS YOU WORK TOWARDS THE DETECTOR, THE SAME AS EXPLAINED FOR THIS SAME TEST IN YOUR LESSON #22.

SHOULD THIS SERIES OF TESTS INDICATE THAT THE A.F. SECTION OF THE RECEIVER IS NOT AT FAULT, THEN THE NEXT STEP IS TO CONNECT A SERVICE OSCILLATOR TO THE FIRST DETECTOR TUBE IN THE SAME MANNER AS ALREADY DESCRIBED IN THIS LESSON FOR ALIGNING THE I.F. STAGES. SET THE SERVICE OSCILLATOR IN OPERATION AND TUNE IT TO THE FREQUENCY FOR WHICH THE I.F. STAGES OF THE RECEIVER ARE DESIGNED AND LISTEN FOR ITS SIGNAL IN THE LOUDSPEAKER.

IF THE SERVICE OSCILLATOR SIGNAL COMES THROUGH O.K., THEN EITHER THE RECEIVER'S OSCILLATOR, PRE-SELECTOR STAGE OR THE TUNING CIRCUIT OF THE FIRST DETECTOR ARE AT FAULT. SHOULD THE SIGNAL OF THE SERVICE OSCILLATOR NOT BE HEARD IN THE SPEAKER, THEN SUSPECT THE TROUBLE AS BEING EITHER IN THE I.F. OR SECOND DETECTOR STAGES OF THE RECEIVER.

IN CASE THAT NONE OF THESE TESTS HAVE DISCLOSED THE FAULTY SECTION, THEN YOU CAN DISCONNECT THE SERVICE OSCILLATOR, RECONNECT THE FIRST DETECTOR CONTROL GRID WIRE AND NEXT ELIMINATE THE PRE-SELECTOR STAGE OR CIRCUITS BY DISCONNECTING THE ANTENNA LEAD-IN WIRE, AND INSERTING IT INTO THE PLATE HOLE OF THE R.F. TUBE SOCKET AS ILLUSTRATED IN FIG. 7. IN THIS WAY, THE SIGNALS WILL BE FED DIRECTLY INTO THE FIRST DETECTOR STAGE WITHOUT HAVING TO FIRST PASS THROUGH THE PRE-SELECTOR CIRCUIT.

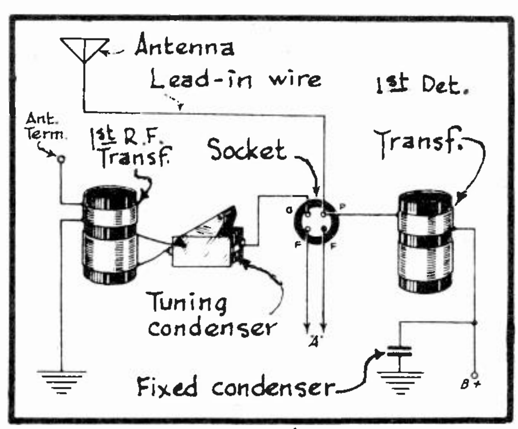

FIG. 7
Eliminating the R.F. Stage.

IF THIS CONNECTION PERMITS A SIGNAL TO BE TUNED IN BUT WHICH WAS NOT POSSIBLE WITH THE ORIGINAL ANTENNA CONNECTION, THEN THE TROUBLE IS LOCATED IN THE R. F. OR PRE-SELECTOR CIRCUIT. WHISTLING GENERALLY OCCURS IN CON-

JUNCTION WITH THE INCOMING SIGNAL WHEN THIS TEST IS MADE BUT THIS IS QUITE NORMAL IN THAT ELIMINATION OF THE PRE-SELECTOR CIRCUITS PERMITS INTER-STATION INTERFERENCE.

SHOULD THIS TEST FAIL TO PERMIT SIGNALS TO BE HEARD, THEN THE TROUBLE IS LOCATED EITHER IN THE FIRST DETECTOR STAGE OR ELSE IN THE OSCILLATOR CIRCUIT. THE OPERATION OF THE OSCILLATOR CAN BE CHECKED EASILY BY CONNECTING AN EXTERNAL OSCILLATOR TO THE RECEIVER IN ORDER TO REPLACE THAT OF THE RECEIVER.

THE TEST OSCILLATOR

IN FIG. 8 A CIRCUIT DIAGRAM OF AN OSCILLATOR SUITABLE FOR THIS PURPOSE IS ILLUSTRATED FOR YOU. THIS OSCILLATOR IS BUILT UP AS AN INDIVIDUAL UNIT AND ITS TUNING CIRCUIT IS DESIGNED TO COVER THE BROADCAST BAND. IN OTHER WORDS, IF THE TUNING CONDENSER BEING USED HAS A CAPACITY RATING OF .00035 MFD, THEN THE TUNED WINDING MAY CONSIST OF ABOUT 136 TURNS OF #30 B&S ENAMELLED WIRE WOUND ON A TUBULAR COIL FORM 1" IN DIAMETER. THE PLATE WINDING MAY THEN BE WOUND WITH ABOUT 25 TURNS OF THE SAME WIRE AND CLOSELY COUPLED TO THE TUNED WINDING.

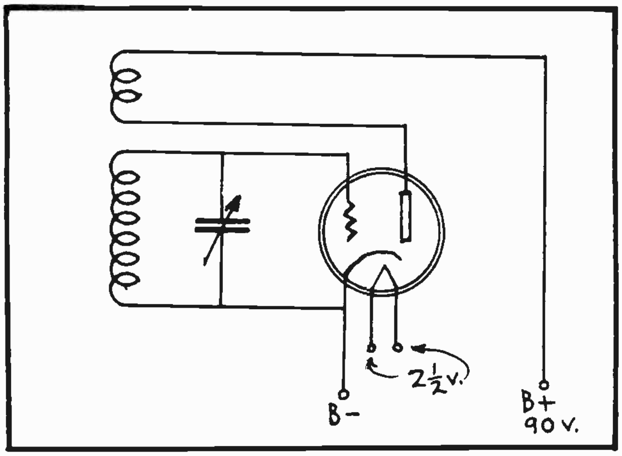

FIG. 8
The Test Oscillator.

THE TUBE USED MAY BE A -27 OR A -56 AND THE NECESSARY OPERATING VOLTAGES OBTAINED DIRECTLY FROM THE RECEIVER UNDER TEST, IF OF THE A.C. TYPE, SIMPLY BY CONNECTING THE B- TERMINAL OF THE TEST OSCILLATOR TO THE GROUND TERMINAL OF THE RECEIVER, THE 2½V. TERMINALS OF THE TEST OSCILLATOR TO A 2½ VOLT A.C. CIRCUIT IN THE RECEIVER AND THE B+ 90V. TERMINAL OF THE TEST OSCILLATOR TO A POINT OF CORRESPONDING D.C. VOLTAGE IN THE RECEIVER.

FIG. 9 SHOWS YOU HOW THIS SAME TYPE OF TEST OSCILLATOR MAY BE MADE SELF-POWERED SO THAT ITS OPERATION CAN BE INDEPENDENT OF THE RECEIVER. THE TUBES USED ARE A PAIR OF 37'S -- ONE FOR A RECTIFIER AND THE OTHER AS THE OSCILLATOR. THE SAME COIL AND CONDENSER COMBINATION CAN BE USED AS ALREADY SPECIFIED FOR THE OSCILLATOR OF FIG. 8. THE FILTER CHOKE MAY BE ANY STANDARD 30 HENRY FILTER CHOKE, AN OLD A.F. CHOKE, OR EVEN THE PRIMARY WINDING OF AN OLD A.F. TRANSFORMER LEAVING ITS SECONDARY UNUSED.

SO MUCH FOR THE CONSTRUCTION OF THE TEST OSCILLATOR AND NOW FOR ITS APPLICATION TO OUR TROUBLE SHOOTING JOB. TO USE THIS OSCILLATOR, TURN ON THE RECEIVER AND "KILL" THE RECEIVER'S OSCILLATOR CIRCUIT BY REMOVING THE OSCILLATOR TUBE FROM ITS SOCKET. NOW TAKE A LONG PIECE OF INSULATED HOOK-UP WIRE, LOOP ONE END OF IT LOOSELY AROUND THE TUNED COIL OF THE TEST OSCILLATOR AND CONNECT ITS OTHER END TO THE CONTROL GRID CONNECTION OF THE RECEIVER'S FIRST DETECTOR TUBE, BUT THIS TIME, DON'T DISCONNECT THE RECEIVER'S CONTROL GRID WIRE FROM THE FIRST DETECTOR AS YOU DID WHEN ALIGNING THE I.F. STAGES WITH THE SERVICE OSCILLATOR.

BY MAKING THE CONNECTIONS IN THIS MANNER, YOU WILL HAVE THE TEST OSCILLATOR COUPLED TO THE FIRST DETECTOR STAGE SO THAT IT WILL NOW TAKE THE PLACE OF THE RECEIVER'S OSCILLATOR WHICH IS AT THIS TIME INOPERATIVE. THIS DONE, SET BOTH THE RECEIVER AND TEST OSCILLATOR IN OPERATION AND MANIPULATE THE TUNING DIAL OF THE RECEIVER, AS WELL AS THAT OF THE TEST OSCILLATOR, UNTIL A STATION SIGNAL OR THAT GENERATED BY A SERVICE OSCILLATOR COMES THROUGH.

IF THE RECEIVER NOW PERFORMS SATISFACTORILY, THEN THE TEST SHOWS THAT THE RECEIVER'S OSCILLATOR OR ITS COUPLING TO THE FIRST DETECTOR STAGE IS AT FAULT. SHOULD THE RECEIVER STILL BE INOPERATIVE UNDER THESE CONDITIONS THEN SUSPECT THE FIRST DETECTOR STAGE AS CAUSING THE TROUBLE.

AFTER ONCE HAVING LOCATED IN WHAT SECTION OF THE RECEIVER THE TROUBLE EXISTS, IT BECOMES A SIMPLE PROBLEM TO ANALYZE THAT PARTICULAR PART OF THE SET IN DETAIL — CHECKING FOR CONTINUITY, DEFECTIVE RESISTORS, CONDENSERS,

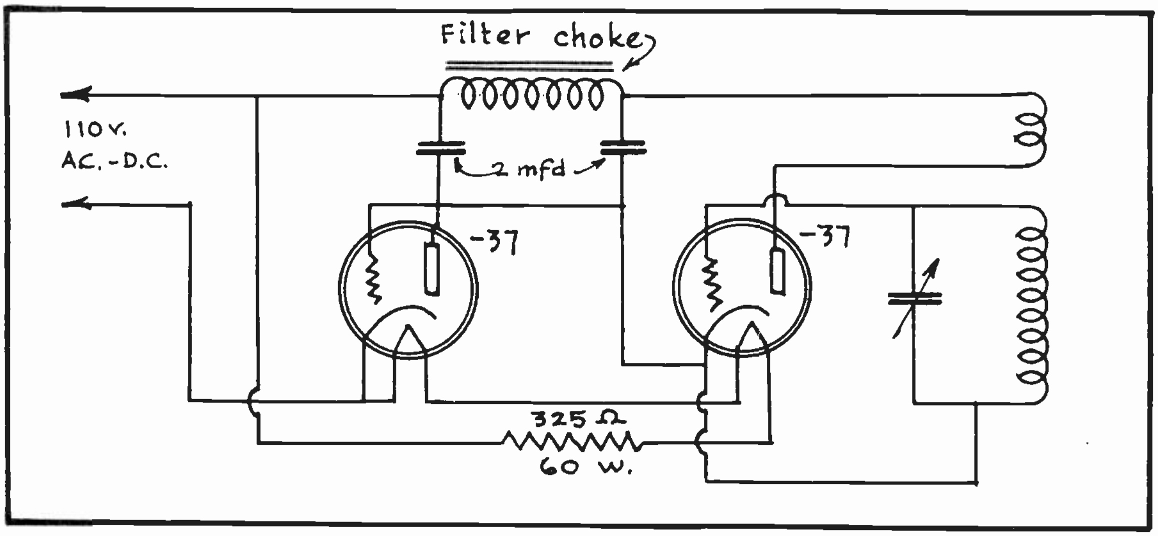

FIG. 9
The Self-powered Test Oscillator.

WINDINGS ETC. ACCORDING TO THE PARTICULAR CIRCUIT IN QUESTION.

SPECIAL SUGGESTIONS

BEAR IN MIND THAT WHEN YOU WANT TO CONNECT A SERVICE OSCILLATOR TO A SUPERHETERODYNE RECEIVER EMPLOYING A PENTAGRID CONVERTER TUBE WHILE ALIGNING THE I.F. STAGES, THEN THE CONNECTIONS ARE MADE AS ILLUSTRATED IN FIG. 10. IN OTHER WORDS, IN THIS CASE, THE FIRST DETECTOR AND OSCILLATOR SECTIONS OF THE RECEIVER BOTH WORK WITH THE SAME TUBE AND THE CAP CONNECTION OF THE TUBE CORRESPONDS TO THE CONTROL GRID INTO WHICH THE TUNED CIRCUIT OF THE FIRST DETECTOR OPERATES. THEREFORE, THE CONTROL GRID WIRE OF THE RECEIVER IS DISCONNECTED FROM THIS TUBE CAP AND THE ANTENNA LEAD OF THE SERVICE OSCILLATOR IS CONNECTED TO THE TUBE CAP. THE GROUND CONNECTION OF THE SERVICE OSCILLATOR IS MADE AS USUAL.

SHOULD YOU WISH TO CHECK THE OSCILLATOR IN A SUPERHETERODYNE WITH THE AID OF A TEST OSCILLATOR WHEN A COMBINATION FIRST DETECTOR TUBE AND OSCILLATOR IS USED IN THE RECEIVER, THEN IT WILL OF COURSE BE IMPRACTICAL TO KILL THE RECEIVER'S OSCILLATOR DURING THE TEST BY REMOVING THE OSCILL-

ATOR TUBE FROM ITS SOCKET, SINCE BY DOING SO, THE FIRST DETECTOR TUBE WOULD ALSO BE REMOVED. THEREFORE, TO MAKE THE SAME OSCILLATOR TEST IN A CASE AS THIS, THE RECEIVER'S OSCILLATOR CIRCUIT CAN BE MADE INOPERATIVE, BY LEAVING THE OSCILLATOR-FIRST DETECTOR TUBE IN ITS SOCKET AND TEMPORARILY SHORT CIRCUITING THE OSCILLATOR SECTION OF THE GANG TUNING CONDENSER. THE TEST CAN THEN BE CONDUCTED BY COUPLING THE TEST OSCILLATOR TO THE CONTROL GRID OF THE FIRST DETECTOR TUBE SECTION AS ALREADY EXPLAINED IN THIS LESSON.

IN THOSE SUPERHETERODYNE RECEIVERS WHERE A GANG TUNING CONDENSER IS USED WITH A SPECIAL OSCILLATOR SECTION SO THAT NO SERIES PADDING CONDENSER IS USED IN THE OSCILLATOR CIRCUIT, THEN THE LOW FREQUENCY TRIMMER CONDENSER ILLUSTRATED IN FIG. 5 OF THIS LESSON IS NOT USED. THEREFORE, WHEN ALIGNING THE OSCILLATOR STAGE IN RECEIVERS OF THIS TYPE, ONLY THE TRIMMER OR COMPENSATOR CONDENSER OF THE OSCILLATOR SECTION OF THE GANG CONDENSER NEED BE ADJUSTED. THE OUTER ROTOR PLATES OF THIS CONDENSER SECTION CAN THEN BE BENT AS FOUND NECESSARY IN ORDER TO OBTAIN PROPER TRACKING OVER ALL PORTIONS OF THE BAND.

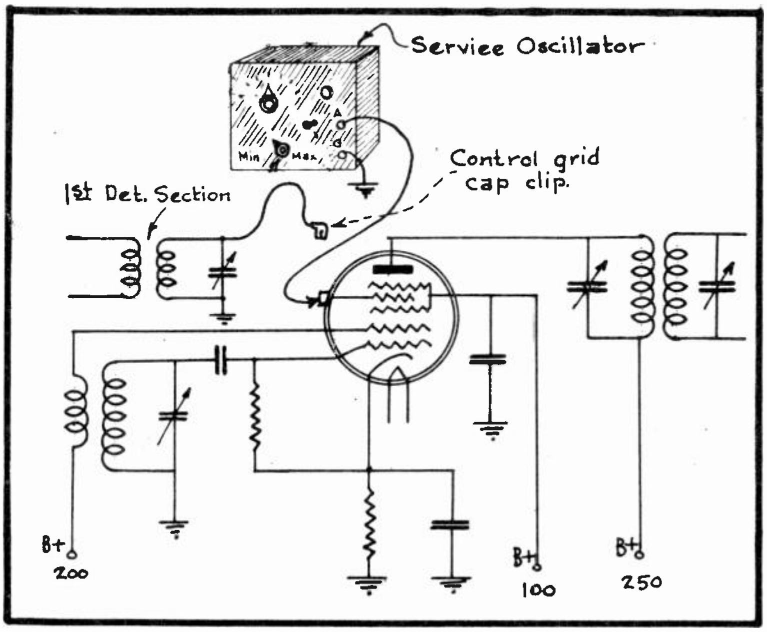

FIG. 10
Service Oscillator Connection to a Pentagrid Converter Tube.

YOU SHOULD FIND THE SUGGESTIONS OFFERED IN THIS LESSON TO BE QUITE HELPFUL WHEN YOU FIND IT NECESSARY TO WORK ON SUPERHETERODYNE RECEIVERS. RADIO MEN, WHO ARE NOT PROPERLY TRAINED, HESITATE WHEN CONFRONTED WITH A SUPERHETERODYNE RECEIVER WHICH DOES NOT OPERATE PROPERLY. YOU, HOWEVER, ARE RECEIVING A MOST THOROUGH INSTRUCTION ON THIS TYPE OF RECEIVER SO THAT YOU MAY BE MOST FAMILIAR WITH SUPERHETERODYNES AND THOROUGHLY QUALIFIED TO HANDLE ITS PROBLEMS EFFICIENTLY. IT IS THIS TYPE OF KNOWLEDGE WHICH GIVES YOU COMPLETE CONFIDENCE IN YOUR ABILITY AS A RADIO TECHNICIAN.

Examination Questions

LESSON NO. 55

Answered Feb 7, 19

The future holds no obstacle
for the man who is prepared.

1. - WHAT IS THE ORDER IN WHICH THE DIFFERENT TUNING SECTIONS OF A SUPERHETERODYNE RECEIVER SHOULD BE ALIGNED -- THAT IS, WHICH PART SHOULD BE ALIGNED FIRST, WHICH SECOND ETC.?

2. - DESCRIBE THE METHOD FOR ALIGNING THE I.F. STAGES OF A SUPERHETERODYNE RECEIVER.

3. - EXPLAIN THE METHOD FOR ALIGNING THE TUNING CIRCUIT OF THE SUPERHETERODYNE'S OSCILLATOR, SO THAT IT WILL TRACK PROPERLY OVER THE ENTIRE TUNING RANGE.

4. - DESCRIBE THE METHOD FOR ALIGNING THE R.F. OR PRE-SELECTOR AND FIRST DETECTOR TUNING CIRCUITS OF A SUPERHETERODYNE RECEIVER.

5. - WHAT MAY CAUSE WHISTLING SOUNDS TO BE EMITTED FROM THE SPEAKER OF A SUPERHETERODYNE RECEIVER?

6. - WHAT ARE SOME OF THE PROBABLE CAUSES FOR POOR SENSITIVITY IN A SUPERHETERODYNE RECEIVER?

7. - WHAT IS THE MOST PROBABLE CAUSE FOR "DEAD SPOTS" AT DIFFERENT POINTS OF THE RECEIVER DIAL?

8. - HOW CAN YOU DETERMINE IF THE I.F. SECTION OF A SUPERHETERODYNE RECEIVER IS OPERATING PROPERLY?

9. - DESCRIBE A SIMPLE TEST WHEREBY YOU CAN DETERMINE WHETHER THE OSCILLATOR SECTION OF A SUPERHETERODYNE RECEIVER IS OPERATING PROPERLY OR NOT.

10. - HOW CAN YOU DETERMINE WHETHER OR NOT THE R.F. OR PRE-SELECTOR SECTION OF A SUPERHETERODYNE RECEIVER IS OPERATING PROPERLY?

RADIO - TELEVISION

Practical Training

NATIONAL SCHOOLS

Established 1905

Los Angeles, California

J. A. ROSENKRANZ, Pres.

LESSON NO. 56

• FILTER SYSTEMS •

FROM ALL THAT YOU HAVE LEARNED SO FAR REGARDING RADIO RECEIVERS AND ASSOCIATED EQUIPMENT, YOU WILL REALIZE HOW EXTENSIVELY FILTER SYSTEMS ARE USED IN THIS WORK. YOU HAVE SEEN HOW WE EMPLOYED FILTER CIRCUITS IN CONJUNCTION WITH POWER PACKS IN ORDER TO SMOOTH OUT THE CURRENT AFTER IT HAS BEEN RECTIFIED FOR "B" PURPOSES; HOW VARIOUS TYPES OF R.F. AND A.F. FILTER SYSTEMS ARE USED IN RECEIVERS AND AMPLIFIERS TO SEPARATE CERTAIN FREQUENCIES FROM OTHERS; HOW THE BAND-PASS PRINCIPLE IS APPLIED TO SELECTOR CIRCUITS ETC.

NOW THAT YOU HAVE A GOOD IDEA AS TO HOW THESE DIFFERENT TYPES OF FILTER SYSTEMS ARE APPLIED IN RADIO PRACTICE, WE SHALL PROCEED AT THIS TIME WITH THE VARIOUS DESIGN PROBLEMS WHICH ARISE WITH CIRCUITS OF THIS TYPE.

WE CAN CLASSIFY FILTER SYSTEMS INTO FOUR DISTINCT GROUPS, NAMELY: (1) LOW-PASS FILTERS; (2) HIGH-PASS FILTERS; (3) BAND-PASS FILTERS AND (4) BAND-SUPPRESSION FILTERS. NOW LET US CONTINUE BY STUDYING EACH OF THESE SYSTEMS IN DETAIL.

LOW-PASS FILTERS

LOW-PASS FILTERS ARE DESIGNED TO PASS ALL FREQUENCIES BELOW A DEFINITE FREQUENCY WHICH IS KNOWN AS THE CUT-OFF FREQUENCY AND TO SUBSTANTIALLY REDUCE OR "ATTENTUATE" THE AMPLITUDE OF CURRENTS OF ALL FREQUENCIES ABOVE THE PREDETERMINED CUT-OFF FREQUENCY. THIS TYPE OF FILTER WILL ALSO PERMIT A DIRECT CURRENT TO FLOW THROUGH IT WITHOUT APPRECIABLE OPPOSITION.

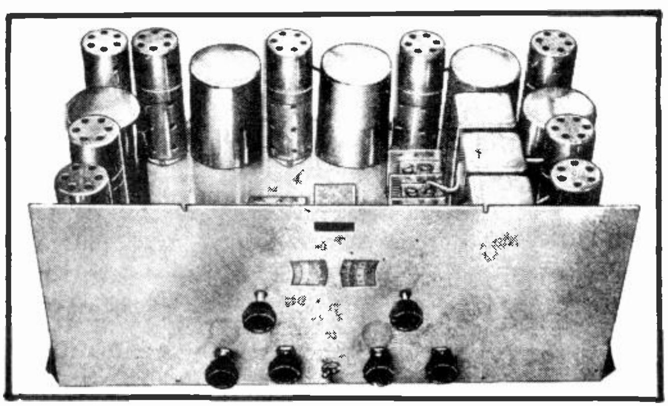

FIG. 1
Filter Circuits Are Extensively Used in Modern Receivers.

IN FIG. 2 YOU ARE SHOWN

a typical example of a low-pass filter. You will no doubt immediately recognize it as being the type of filter which is extensively used in the power pack of A.C. operated receivers in order to filter the "B" current after it has been rectified.

Although you have already been told what the filter system of the power pack etc. accomplished, yet until now we haven't gone into details as to just how this filtering process was accomplished. Therefore, this will be our first point of discussion at this time.

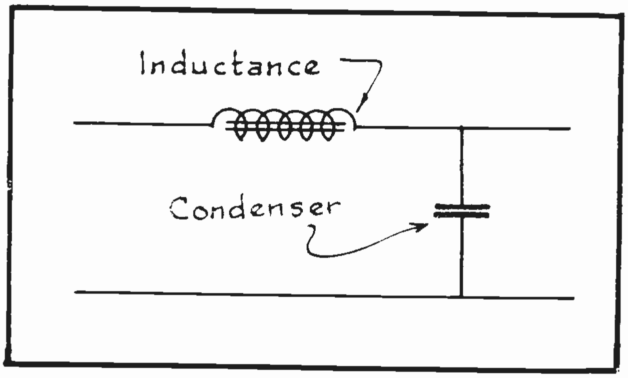

FIG. 2
A Low-Pass Filter.

LOW-PASS FILTER ACTION

For the sake of simplicity, we shall assume first that the E.M.F. as applied to the filter is of the D.C. type. In Fig. 3, we have a diagram which illustrates clearly the conditions existing in the system in which the filter is being used. The source of E.M.F. is in this case being considered as a D.C. generator which is connected to one end of the filter known as the SOURCE END, while a resistor is connected across the other end of the filter which is known as the LOAD END.

By inspection, you can readily see that the E.M.F. tends to force a flow of current through the load and that the inductance is connected in series with the source of E.M.F. and the load, whereas the condenser is connected in parallel with the load or "shunted across it", as we generally say. With this point in mind, it is clear that if a D.C. E.M.F. is applied to the system, the inductance will offer no opposition towards its flow other than its ohmic resistance which is quite low, whereas the condenser prevents any current from flowing across its plates. Therefore, under these conditions, all current which is caused to flow by the E.M.F. must flow through the load.

Now let us see what happens when an alternating E.M.F. is applied to the system. An inductance, you will recall, offers a definite opposition towards the flow of either an alternating or a pulsating direct current and the higher the frequency of this current, the greater will be the opposition offered by the inductance. A condenser, on the other hand, permits a flow of alternating or pulsating current and the higher the frequency of the current, the less will be the opposition offered by the condenser.

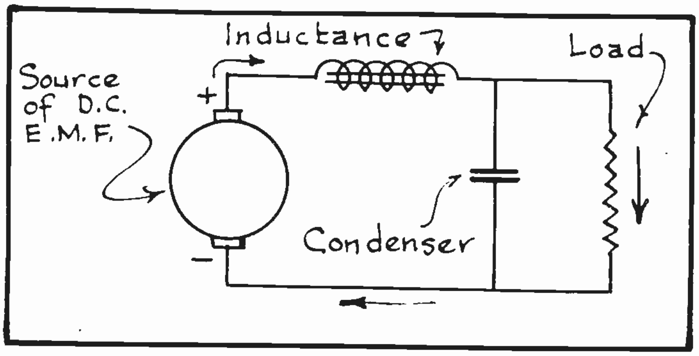

FIG. 3
Passage of D.C. Through the Filter.

With the A.C. voltage source applied to the filter, conditions become as illustrated in Fig. 4. Assuming the generator voltage as having the polarity designated at one particular instant

AND THAT THE FREQUENCY OF THE GENERATED E.M.F. IS SUCH AS TO BE OPPOSED BY THE FILTER, WE FIND THAT AT THE SAME TIME THAT THE INDUCTANCE OPPOSES AN INCREASE OF CURRENT FLOW AS THE GENERATOR VOLTAGE RISES IN A POSITIVE DIRECTION, THERE WILL BE A FLOW OF ELECTRONS IN THE DIRECTION INDICATED BY THE ARROWS (ELECTRONS FLOW FROM NEGATIVE TOWARDS POSITIVE). THESE ELECTRONS ARE LEAVING THE UPPER CONDENSER PLATE, PASSING THROUGH THE INDUCTANCE, A.C. GENERATOR, AND BEING COLLECTED BY THE LOWER CONDENSER PLATE. COMPARATIVELY FEW OF THESE ELECTRONS PASS THRU THE LOAD, SINCE IN ACTUAL PRACTICE, THE LOAD RESISTANCE IS MUCH HIGHER THAN THE CAPACITIVE REACTANCE OF THE CONDENSER. IN THIS WAY, THE CONDENSER ASSISTS THE INDUCTANCE IN REDUCING THE FLOW OF CURRENT THROUGH THE LOAD AT THIS FREQUENCY.

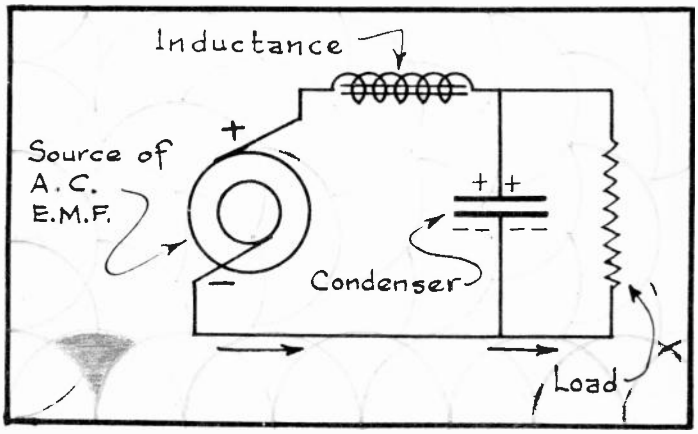

FIG. 4
Action of Filter Towards A.C.

AS THE GENERATED E.M.F. REACHES ITS PEAK VALUE AND COMMENCES TO DECREASE, THE COLLAPSING MAGNETIC FIELD AROUND THE INDUCTANCE GENERATES A SELF-INDUCED E.M.F. IN THE INDUCTANCE WHOSE POLARITY IS SUCH AS TO KEEP THE FLOW OF ELECTRONS INTO THE LOWER CONDENSER PLATE AS HERETOFORE.

FINALLY, WHEN THE APPLIED E.M.F. REACHES A VALUE OF ZERO AND THE MAGNETIC FIELD AROUND THE INDUCTANCE DIES DOWN, THE CONDENSER WILL DISCHARGE FROM THE LOWER PLATE TOWARDS ITS UPPER PLATE AND AS THE GENERATOR E.M.F. REVERSES, IT TENDS TO DRIVE A STILL GREATER NUMBER OF ELECTRONS TOWARDS THE UPPER CONDENSER PLATE AS INDICATED BY THE ARROWS IN FIG. 5, SO THAT THE UPPER CONDENSER PLATE BECOMES NEGATIVELY CHARGED.

AFTER REACHING ITS PEAK VALUE IN THIS DIRECTION, THE VOLTAGE AGAIN APPROACHES ZERO AS DOES ALSO THE MAGNETIC FIELD AROUND THE INDUCTANCE AND THE SELF-INDUCED VOLTAGE GENERATED BY THIS COLLAPSING FIELD KEEPS THE ELECTRON FLOW IN THE SAME DIRECTION. FINALLY, THE GENERATED VOLTAGE COMMENCES TO BUILD UP IN THE OPPOSITE DIRECTION AND THE ELECTRON FLOW AGAIN OCCURS AS IN FIG. 4. THIS PROCESS OR CYCLE OF EVENTS CONTINUES IN THIS ORDER REPEATEDLY AS THE A.C. E.M.F. IS APPLIED.

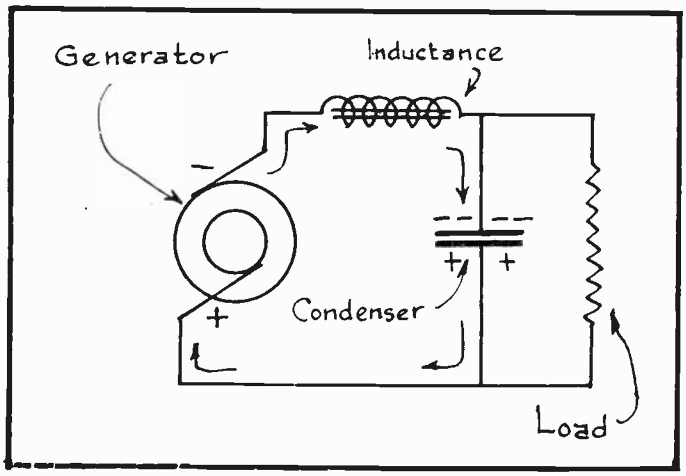

FIG. 5
Reverse Electron Flow.

THE IMPORTANT FACT TO REMEMBER ABOUT THIS SYSTEM WHEN SUBJECTED TO A.C. OR PULSATING D.C. VOLTAGES IS THAT ALTHOUGH THE INDUCTANCE ALONE OPPOSES VARIATIONS IN CURRENT FLOW AND REDUCES THE FLOW OF ELECTRONS THROUGH THE CIRCUIT, YET WITHOUT THE AID OF THE CONDENSER, SOME OF THIS CURRENT WOULD BE

FLOWING THROUGH THE LOAD. HOWEVER, BY USING THE CONDENSER IN COMBINATION WITH THE INDUCTANCE, THE CONDENSER SERVES TO "STORE" AN APPRECIABLE NUMBER OF ELECTRONS EACH TIME THAT THE APPLIED E.M.F. REVERSES OR VARIES IN VALUE AND IN THIS WAY BY-PASSES THEM AROUND THE LOAD SO THAT THE CURRENT THROUGH THE LOAD IS REDUCED MATERIALLY AT THIS FREQUENCY. FURTHERMORE, THIS EFFECT WILL BE STILL MORE PRONOUNCED WHEN THE CONDENSER REACTANCE IS MUCH LESS THAN THE RESISTANCE OR IMPEDANCE OF THE LOAD WHICH IT IS SHUNTING AND WHICH IS THE CASE IN ACTUAL PRACTICE WHERE A FILTER OF THIS TYPE IS USED.

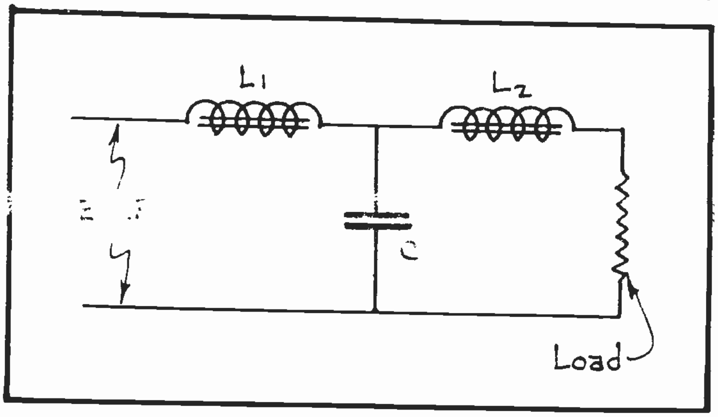

FIG. 6
The T Type Filter.

AT FREQUENCIES BELOW THE CUT-OFF FREQUENCY, THE OPPOSITION AND BY-PASSING EFFECT BECOMES LESS, SO THAT A GREATER PERCENTAGE OF CURRENT MAY PASS THRU THE LOAD WHILE AT FREQUENCIES ABOVE THE CUT-OFF FREQUENCY, THE OPPOSITION AND BY-PASSING EFFECT BECOMES GREATER SO THAT A SMALLER PERCENTAGE OF CURRENT PASSES THROUGH THE LOAD.

T-TYPE LOW-PASS FILTERS

ALTHOUGH THE SINGLE SECTION FILTER AS JUST DESCRIBED HAS A DEFINITE EFFECT UPON REDUCING THE FLOW OF CURRENT THROUGH THE LOAD ABOVE THE CUT-OFF FREQUENCY, YET IT DOESN'T OFFER A VERY SHARP REDUCTION OF CURRENT AT THE CUT-OFF FREQUENCY. IN ORDER TO MAKE THE CUT-OFF MORE ABRUPT OR SHARPER AT THE DESIRED CUT-OFF FREQUENCY, ANOTHER INDUCTANCE CAN BE CONNECTED IN SERIES WITH THE LOAD SIDE OF THE FILTER AS ILLUSTRATED IN FIG. 6.

THIS SYSTEM IS KNOWN AS A "T-TYPE" FILTER, IN THAT THE TWO INDUCTANCES L_1 AND L_2, TOGETHER WITH CONDENSER C TAKE THE SHAPE OF THE LETTER "T".

IN ORDER TO GIVE A STILL SHARPER FREQUENCY CUT-OFF, TWO OF THESE T-SECTIONS CAN BE CONNECTED TOGETHER AS ILLUSTRATED IN FIG. 7. HERE WE HAVE INDUCTANCE L_1 AND L_2 TOGETHER WITH CONDENSER C_1 FORMING ONE T-SECTION, WHILE INDUCTANCES L_3 AND L_4 WITH CONDENSER C_2 FORM THE SECOND T-SECTION.

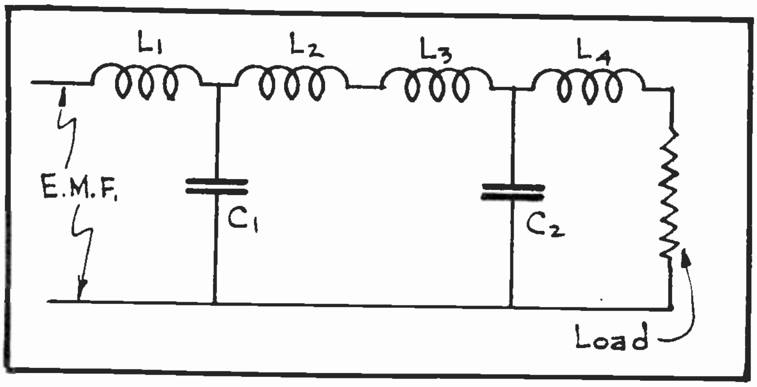

FIG. 7
The Two-Section T-Filter.

BY STUDYING FIG. 7, YOU WILL READILY NOTE THAT HERE WE HAVE A COMBINED INDUCTANCE WHICH IS EQUAL TO THE SUM OF THE TWO SECTION INDUCTANCES CONNECTED IN SERIES AT THEIR CENTER. IF THE INDUCTIVE VALUES OF L_1 - L_2 - L_3 AND L_4 ARE

ALL EQUAL, THEN THE COMBINED INDUCTANCE OF L_2 AND L_3 WILL BE TWICE THAT OF THE INDIVIDUAL INDUCTANCES L_1 AND L_4 OR TO PUT IT ANOTHER WAY THE OUTER INDIVIDUAL INDUCTANCES L_1 AND L_4 EACH HAVE ONE-HALF THE INDUCTANCE VALUE OF THE SERIES CONNECTED INDUCTANCE L_2 AND L_3 WHICH ARE INCLUDED AT THE CENTER OF THE SYSTEM.

THIS IS A HANDY RULE TO REMEMBER BECAUSE IT IS FOLLOWED IN PRACTICE. QUITE OFTEN, IN PRACTICE, THE TWO CHOKES L_2 AND L_3 ARE REPLACED BY A SINGLE CHOKE AS ILLUSTRATED IN FIG. 8 AND IN THIS CASE, EACH OF THE END CHOKES ARE GIVEN AN INDUCTANCE RATING EQUAL TO ONE-HALF THAT OF THE CENTER CHOKE.

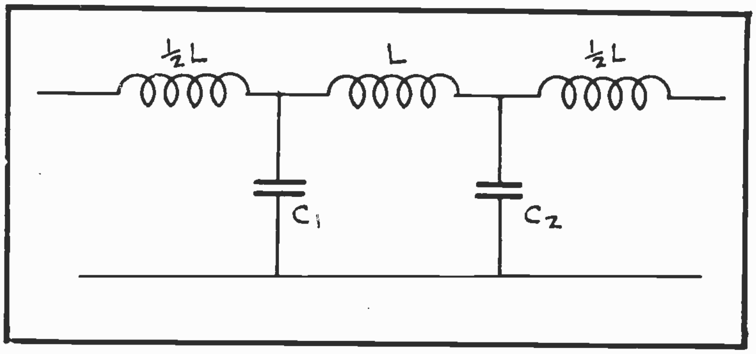

FIG. 8
Two-Section T-Filter With Single Center Inductance.

FOR THE SAKE OF SIMPLICITY, WE SHALL DESIGNATE THE CENTER INDUCTANCE OF THIS SYSTEM AS L AND THE TWO END INDUCTANCES AS $\frac{1}{2}$ L.

IN SOME INSTANCES, EVEN THREE-SECTION T-FILTERS ARE USED, SUCH AS THE ONE SHOWN IN FIG. 9. WITH THIS TYPE OF FILTER, IT IS ALSO THE PRACTICE TO MAKE THE TWO END CHOKES L_1 AND L_4 EQUAL TO ONE-HALF THE INDUCTANCE VALUES OF L_2 AND L_3.

THE GREATER THE NUMBER OF FILTER SECTIONS USED, THE SHARPER WILL BE THE FREQUENCY CUT-OFF. FREQUENTLY, A SINGLE SECTION IS SUFFICIENT, WHILE AT OTHER TIMES TWO OR THREE SECTIONS ARE REQUIRED. THIS DEPENDS LARGELY UPON HOW SHARP THE FREQUENCY CUT-OFF MUST BE FOR THE PARTICULAR PROBLEM IN QUESTION, IN ADDITION TO THE ALLOWABLE COST FOR THIS PART OF THE EQUIPMENT.

THE "PI"-TYPE LOW-PASS FILTER

IN FIG. 10 YOU ARE SHOWN ANOTHER FORM OF FILTER CIRCUIT WHERE A CONDENSER SHUNTS THE LINE AT EACH END OF THE INDUCTANCE. THIS IS KNOWN AS A "PI" FILTER, SINCE ITS CIRCUIT DIAGRAM SOMEWHAT RESEMBLES THE SYMBOL π. THIS TYPE OF FILTER OPERATES UPON THE SAME PRINCIPLES AS ALREADY EXPLAINED FOR THE T-TYPE FILTER, ONLY THAT THERE ARE NOW TWO CONDENSERS PER SECTION CONNECTED ACROSS THE LINE.

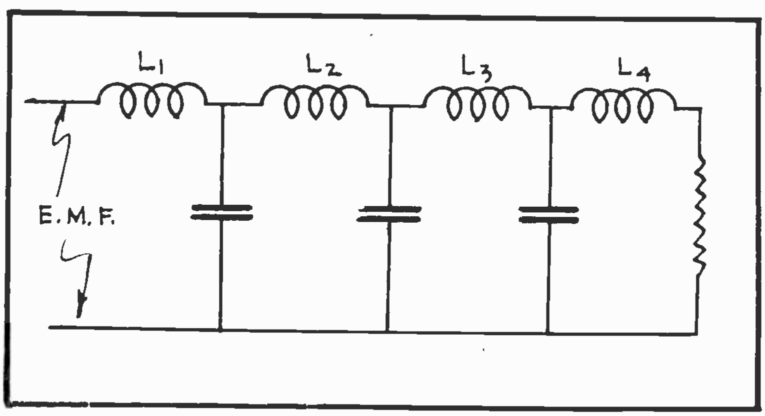

FIG. 9
A Three-Section T-Filter.

THE "T" AND "PI" FILTER EACH HAVE THEIR DISTINCT ADVANTAGES, THE T-TYPE FILTER BEING MORE DESIRABLE FOR CONSTANT VOLTAGE CIRCUITS WHILE THE "PI"-TYPE FILTER IS

MORE DESIRABLE WHEN A MORE NEARLY CONSTANT CURRENT IS REQUIRED.

IN THIS CASE ALSO, THE FREQUENCY CUT-OFF CAN BE MADE SHARPER BY INCREASING THE NUMBER OF FILTER SECTIONS IN THE SYSTEM. IN FIG. 11, FOR INSTANCE, WE HAVE TWO "PI" SECTIONS CONNECTED END TO END. UNDER THESE CONDITIONS, CONDENSERS C_2 AND C_3 ARE CONNECTED IN PARALLEL WHICH MEANS THAT IF ALL OF THE INDIVIDUAL CONDENSERS HAVE THE SAME CAPACITY RATING, THE CAPACITANCE AT THE JUNCTION WILL BE EQUAL TO THE CAPACITY OF C_2 PLUS C_3. THIS ALSO MEANS THAT THE CAPACITANCE AT THE POINT OF JUNCTION IS EQUAL TO TWICE THE CAPACITANCE AT EITHER END OF THE FILTER.

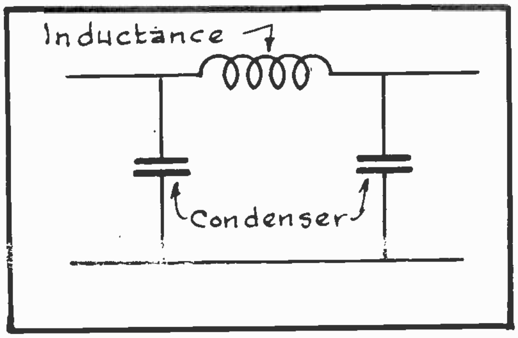

FIG. 10
A Single-Section "PI" Filter.

THIS SAME EFFECT MAY BE OBTAINED BY USING A SINGLE CONDENSER OF TWICE THE CAPACITIVE VALUE AT THE JUNCTION POINT OF THE SERIES CONNECTED INDUCTANCES AS SHOWN IN FIG. 12. THE CENTER CONDENSER C WILL IN THIS CASE HAVE TWICE THE CAPACITY RATING OF THE TWO END CONDENSERS WHICH FOR THE SAKE OF SIMPLICITY ARE HERE DESIGNATED AS $\frac{1}{2}$ C. INDUCTANCES L_1 AND L_2 ARE EQUAL IN VALUE.

FIG. 13 SHOWS YOU HOW A THREE-SECTION PI-FILTER IS ARRANGED. HERE THE THREE INDUCTANCES EACH HAVE THE SAME VALUE AND THE TWO END CONDENSERS EACH HAVE ONE-HALF THE CAPACITY OF THE CONDENSERS WHICH ARE USED IN THE CENTER OR "REPEATING SECTIONS" OF THE FILTER. THIS IS DESIGNATED IN FIG. 13 BY THE FACT THAT THE TWO CENTER CONDENSERS ARE BOTH MARKED "C" WHILE THE TWO END CONDENSERS ARE EACH MARKED AS $\frac{1}{2}$C.

HAVING CONSIDERED THE OPERATION AND CONSTRUCTIONAL FEATURES OF THE VARIOUS FORMS OF LOW-PASS FILTERS, YOU ARE NOW PREPARED TO ENTER INTO THE DETAILS REGARDING THE DESIGN PROBLEMS OF THESE SYSTEMS.

LOW-PASS FILTER DESIGN

THE FIRST POINT TO BEAR IN MIND REGARDING SUCH A FILTER DESIGN IS THAT IN ORDER FOR THE FILTER TO BE MOST EFFICIENT FOR ITS PARTICULAR TYPE, THE FILTER SHOULD TERMINATE AT THE SOURCE AND AT THE LOAD IN AN IMPEDANCE WHICH IS APPROXIMATELY EQUAL TO THE "CHARACTERISTIC IMPEDANCE" OF THE FILTER.

IF THE NATURE OF THE PROBLEM HAPPENS TO BE SUCH THAT THE LOAD AND SOURCE IMPEDANCE ARE KNOWN AND ARE ALREADY EQUAL, THEN THIS SAME IMPEDANCE VALUE IS CHOSEN AS THE CHARACTERISTIC IMPEDANCE OF THE FILTER WHICH IS BEING DESIGNED. SHOULD EITHER THE LOAD OR SOURCE IMPEDANCE BUT NOT BOTH BE ALREADY FIXED AND OF KNOWN VALUE, THEN THIS SAME VALUE CAN BE ASSUMED AS BEING THE DESIRED CHARACTERISTIC IMPEDANCE OF THE FILTER AND THE RE-

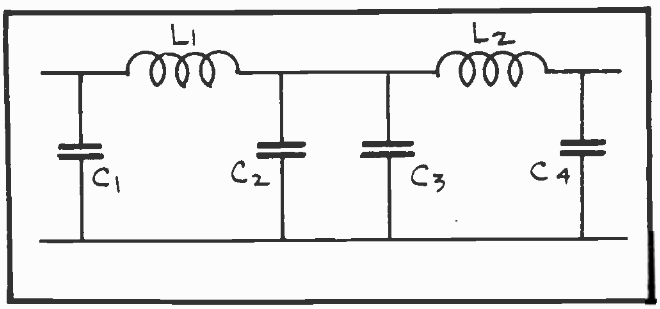

FIG. 11
A Two-Section "PI" Filter.

MAINING TERMINAL IMPEDANCE ADJUSTED TO THIS VALUE.

TO DETERMINE THE INDUCTANCE AND CONDENSER VALUES TO USE FOR A LOW-PASS FILTER OF A GIVEN CUT-OFF FREQUENCY, USE THE FOLLOWING FORMULAS:

$$\text{INDUCTANCE IN HENRIES} = \frac{0.3183 \times \text{CHARACTERISTIC IMPEDANCE IN OHMS}}{\text{CUT-OFF FREQUENCY IN CYCLES PER SEC.}}$$

$$\text{CAPACITY IN FARADS} = \frac{0.3183}{\text{CUT-OFF FREQUENCY IN CYCLES PER.SEC.} \times \text{CHARACTERISTIC IMPEDANCE IN OHMS}}$$

EXAMPLE:- IN FIG. 14 WE ARE ILLUSTRATING A SAMPLE PROBLEM WHERE A LOW PASS FILTER IS INSTALLED IN THE PLATE CIRCUIT OF A VACUUM TUBE WHICH IS HANDLING BOTH RADIO FREQUENCY AND AUDIO FREQUENCY ENERGY. THE FILTER IS TO BE USED TO PREVENT THE R.F. FROM GETTING INTO THE FOLLOWING A.F. AMPLIFYING STAGE, WHILE AT THE SAME TIME PERMITTING THE A.F. TO PASS OVER TO THE FOLLOWING STAGES OF AUDIO FREQUENCY AMPLIFICATION UNMOLESTED.

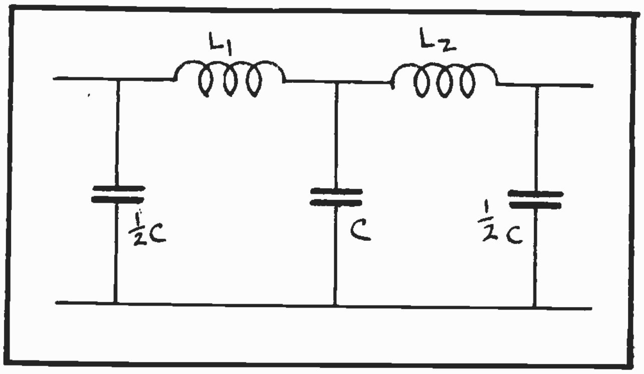

FIG. 12

Another Two-Section "PI" Filter.

WE SHALL ASSUME THAT THE LOAD RESISTOR OF THIS CIRCUIT HAS A RESISTANCE VALUE OF 50,000 OHMS AND THAT THE PLATE CIRCUIT RESISTANCE OF THE TUBE IS 250,000 OHMS. IN ADDITION, WE SHALL CONSIDER THE HIGHEST AUDIO FREQUENCY TO BE PASSED BY THE FILTER AS BEING 20,000 CYCLES AND THEREFORE CHOOSE THIS AS OUR CUT-OFF FREQUENCY.

IN ORDER FOR THE FILTER TO WORK AT MAXIMUM EFFICIENCY, THE SOURCE IMPEDANCE SHOULD BE EQUAL TO THE LOAD IMPEDANCE. THIS CAN BE ACCOMPLISHED BY CONNECTING THE RESISTOR R_2 IN PARALLEL WITH THE TUBE'S PLATE RESISTANCE.

THE TOTAL RESISTANCE OF TWO PARALLEL CONNECTED RESISTANCES YOU WILL RECALL AS BEING DETERMINED BY THE FORMULA: $R = \frac{R_1 \times R_2}{R_1 + R_2}$. HENCE SINCE "R" IN THIS CASE IS TO BE EQUAL TO THE PLATE LOAD RESISTOR OR 50,000 OHMS, AND THE TUBE'S PLATE CIRCUIT RESISTANCE R_1 IS ALREADY SET AT 250,000 OHMS, THEN THE VALUE OF R_2 CAN BE FOUND BY USING THE PARALLEL RESISTANCE FORMULA IN THE FORM $R_2 = \frac{RR_1}{R_1 - R} =$ $\frac{50,000 \times 250,000}{250,000 - 50,000} = \frac{1,250,000,000}{200,000} =$ 62,500 OHMS. FROM THIS WE SEE THAT BY CONNECTING THE 62,500 OHM RESISTOR R_2 IN PARALLEL WITH THE TUBE'S PLATE CIRCUIT RESISTANCE, THE "SOURCE IMPEDANCE" WILL BE EQUAL TO THE LOAD IMPEDANCE WITH RESPECT TO THE FILTER, OR ALSO 50,000 OHMS. THE CHARACTERISTIC IMPEDANCE

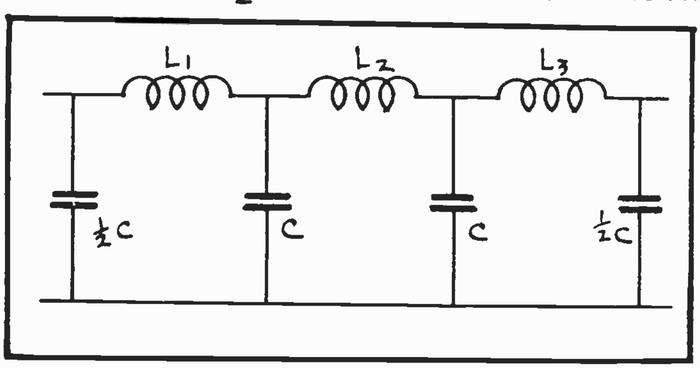

FIG. 13

A Three-Section "PI" Filter.

OF THE FILTER SHOULD THEREFORE ALSO BE EQUAL TO 50,000 OHMS.

WITH THIS VALUE DETERMINED, THE INDUCTANCE VALUE FOR THE FILTER CAN BE FOUND BY USING THE FORMULA: $\text{INDUCTANCE} = \frac{0.3183 \times \text{CHARACTERISTIC IMPED.}}{\text{CUT-OFF FREQUENCY}} = \frac{0.3183 \times 50{,}000}{20{,}000} = \frac{15{,}915}{20{,}000} = .79$ HENRIES. THIS VALUE CORRESPONDS TO "L" IN OUR FILTER DIAGRAMS.

TO FIND THE VALUE OF EACH FILTER CONDENSER, USE THE FORMULA: $\text{CAPACITY} = \frac{0.3183}{\text{CUT-OFF FREQUENCY} \times \text{CHARACTERISTIC IMPEDANCE}} = \frac{0.3183}{20{,}000 \times 50{,}000} =$ .0000000003183 FARADS = .0003183 OR APPROXIMATELY .00032 MFDS. THIS VALUE CORRESPONDS TO "C" IN OUR FILTER DIAGRAMS.

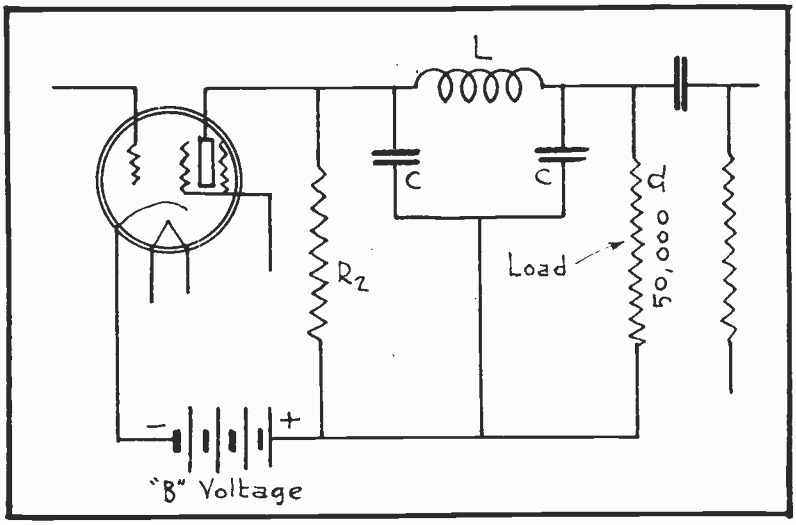

FIG. 14
Calculating the Filter.

WHEN CONSTRUCTING THE FILTER, ITS RESISTANCE SHOULD BE KEPT DOWN TO AS LOW A VALUE AS POSSIBLE SINCE RESISTANCE TENDS TO OPPOSE EVEN THOSE CURRENTS OF THE FREQUENCY BAND WHICH IT IS DESIRED TO PASS AND PREVENTS A SHARP CUT-OFF. ALSO REMEMBER THAT THE CURRENT WHICH IS SUPPRESSED BY THE FILTER IS NEVER REDUCED TO ABSOLUTE ZERO AT ANY FREQUENCY, ALTHOUGH A ZERO CURRENT CAN BE MORE NEARLY APPROACHED BY EMPLOYING A SERIES OF PROPERLY DESIGNED FILTER SECTIONS. FURTHERMORE, THE DESIGN CONSTANTS ARE WORKED OUT IN THE SAME MANNER WHETHER THE FILTER BE OF THE "T" OR "PI" TYPE AND THE CHOICE OF THE TYPE DEPENDS UPON THE ADVANTAGES MOST DESIRED FROM THEM AND WHICH WERE MENTIONED FOR EACH TYPE EARLIER IN THIS LESSON.

IN THE AVERAGE TYPE OF R.F. FILTER SUCH AS USED IN THE PLATE CIRCUIT OF THE DETECTOR TUBE IN A RECEIVER SO AS TO SUPPRESS RADIO FREQUENCY CURRENTS WHILE AT THE SAME TIME PERMIT THE AUDIO FREQUENCY CURRENTS TO PASS THROUGH SATISFACTORILY, A FREQUENCY OF 10,000 CYCLES PER SECOND IS GENERALLY CHOSEN AS BEING THE HIGHEST FREQUENCY TO BE PASSED FREELY AND FREQUENCIES ABOVE 20,000 CYCLES TO BE SUPPRESSED MATERIALLY.

IN THE CASE OF POWER PACK FILTERS, DIRECT CURRENT AND ALL CURRENTS HAVING A FREQUENCY UP TO ABOUT 20 CYCLES PER SECOND ARE GENERALLY OFFERED FREE PASSAGE. ALL FREQUENCIES ABOVE 20 CYCLES SHOULD BE BLOCKED — THIS WILL REJECT THE UNDESIRABLE 60 AND 120 CYCLE "HUM FREQUENCIES."

HIGH-PASS FILTERS

ALTHOUGH THE HIGH-PASS FILTER ALSO EMPLOYS A CONDENSER IN CONJUNCTION WITH AN INDUCTANCE, YET THESE TWO COMPONENTS ARE ARRANGED IN A DIFFERENT

MANNER AS ILLUSTRATED IN FIG. 15. BY ANALYZING THIS CIRCUIT, YOU WILL NOTICE THAT HERE THE CONDENSER IS CONNECTED IN SERIES WITH THE LINE AND THE INDUCTANCE IS SHUNTED ACROSS THE LOAD, OR JUST THE REVERSE AS FOUND IN THE LOW-PASS FILTER.

NOW THEN, THE CONDENSER OPPOSES THE PASSAGE OF D.C. AND LOW FREQUENCY CURRENT BUT ITS OPPOSITION DECREASES RAPIDLY AS THE FREQUENCY INCREASES. THIS MEANS THAT THE HIGHER THE FREQUENCY, THE EASIER WILL IT BE FOR THE CURRENTS TO GET FROM THE SOURCE TOWARD THE LOAD SIDE OF THE FILTER AND VICE VERSA.

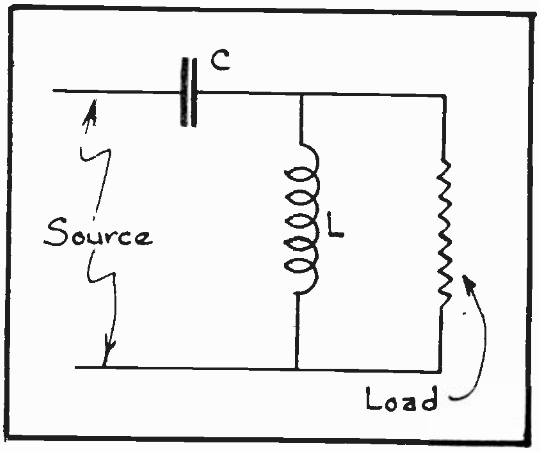

FIG. 15
A High-Pass Filter

THESE HIGH FREQUENCY CURRENTS WHICH ARE EFFECTIVE AT THE LOAD END OF THE CONDENSER FIND IT DIFFICULT TO PASS THROUGH THE INDUCTANCE AND MUST THEREFORE PASS THROUGH THE LOAD WHOSE RESISTANCE VALUE IS MUCH LESS TO THESE HIGHER FREQUENCY CURRENTS THAN IS THE REACTANCE OF THE INDUCTANCE TOWARDS THESE SAME FREQUENCIES. BESIDES THIS, IF SOME OF THE LOWER FREQUENCIES SHOULD REACT THROUGH THE CONDENSER, THE REACTANCE OF THE INDUCTANCE WOULD BE QUITE LOW IN COMPARISON TO THE LOAD RESISTANCE SO THAT IT WILL PRACTICALLY SHORT CIRCUIT THESE LOW FREQUENCY CURRENTS AROUND THE LOAD AND MATERIALLY REDUCE THEIR FLOW THROUGH THE RATHER HIGH-RESISTANCE LOAD. IN ORDER FOR THIS FILTER TO WORK MOST EFFECTIVELY, THE REACTANCE OF THE CHOKE SHOULD BE LOW IN VALUE AS COMPARED TO THE LOAD RESISTANCE AT THE LOWER FREQUENCIES.

HIGH-PASS FILTERS CAN ALSO BE ARRANGED AFTER THE T-PATTERN AND AN EXAMPLE OF SUCH IS ILLUSTRATED IN FIG. 16. BY THUS SHUNTING THE INDUCTANCE ACROSS THE LOAD FROM A POINT BETWEEN THE TWO CONDENSERS, THE LOW FREQUENCIES FIND IT STILL MORE DIFFICULT TO REACH THE LOAD ON ACCOUNT OF THE ADDITIONAL OPPOSITION OFFERED BY THE SECOND CONDENSER C_2, WHEREAS THE HIGHER FREQUENCIES CAN CONTINUE ON THROUGH TO THE LOAD. THIS WILL RESULT IN A STILL SHARPER FREQUENCY CUT-OFF THAN WHEN THE SECOND CONDENSER C_2 IS OMITTED.

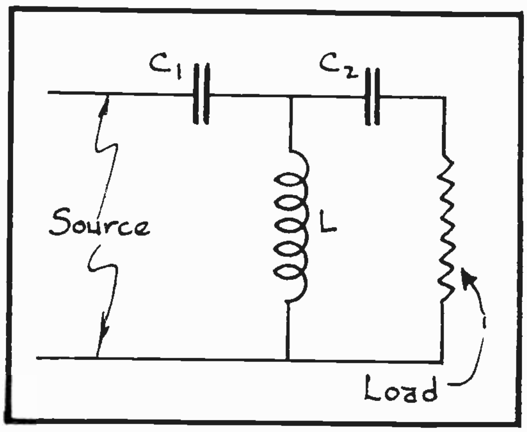

FIG. 16
T-Type High-Pass Filter.

FIG. 17 ILLUSTRATES A "DOUBLE-T", HIGH-PASS FILTER IN WHICH THE TWO CONDENSERS C_2 AND C_3 ARE INCLUDED BETWEEN THE TWO INDUCTANCES. IF THE CAPACITIVE VALUES OF ALL THESE CONDENSERS ARE ALIKE, THEN THE COMBINED CAPACITY OF C_2 AND C_3 WILL BE JUST ONE-HALF THAT OF THE INDIVIDUAL CAPACITIES C_1 AND C_4. THEREFORE, IF IT IS DESIRED TO REPLACE CONDENSERS C_2 AND C_3 BY A SINGLE CONDENSER AS IN FIG. 18, THEN THIS SINGLE CONDENSER SHOULD HAVE JUST HALF THE CAPACITY OF THE TWO END CONDENSERS. THIS RELATION IS INDICATED IN FIG. 18 BY THE FACT THAT THE CENTER CONDENSER IS MARKED AS C AND THE TWO END CONdensers as 2 C. The values of the two inductances are equal.

It is also possible to have a "pi-type" high-pass filter as shown in Fig. 19. Here the filter is terminated at each end by an inductance with a condenser installed between them in one side of the line. In this case, the first choke or L_1 serves as a shunt around the load for low frequency and direct currents directly at the input or source end of the filter, at the same time that the condenser C rejects them.

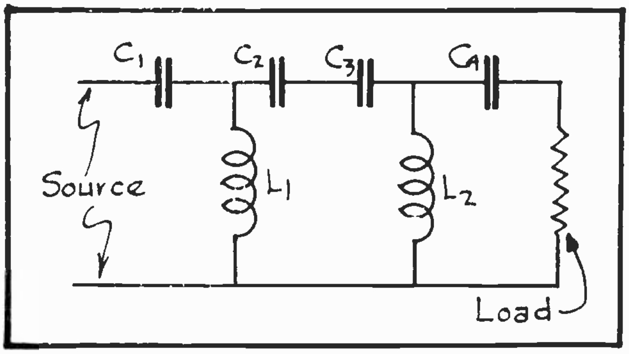

FIG. 17

A Double-T High-Pass Filter.

What currents of these unwanted low frequencies should be effective at the load side of C will again have the opportunity of being shunted around the load by the second inductance L_2. The high frequency currents, however, must pass through the load.

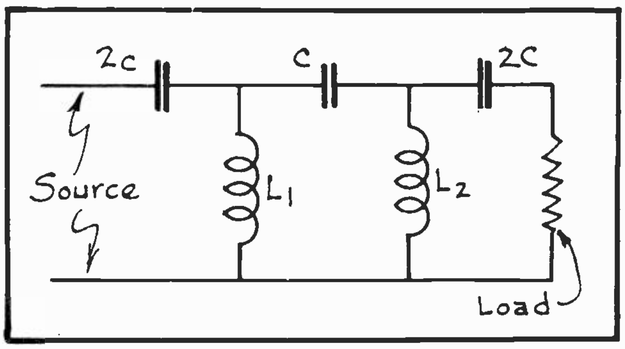

FIG. 18

A Double-T With Common Capacity.

Here again the cut-off can be made sharper by adding another section and so in Fig. 20 we have the two-section pi-type high-pass filter. With this arrangement, the two inductances L_2 and L_3 are connected in parallel which means that their combined inductance becomes only half that of inductances L_1 and L_4 individually, provided of course that all four of these inductances individually have the same value.

With conditions being such, it is clear that if the two inductances L_2 and L_3 are to be replaced with a single inductance as in the two-section, "pi" high-pass filter with the common inductance shown in Fig. 21, then this common inductance L in Fig. 21 should have just one-half the inductance value of the two outer individual inductances. For convenience, we can say that the common inductance has a value of "L", while the two outer inductances each have a value of 2L.

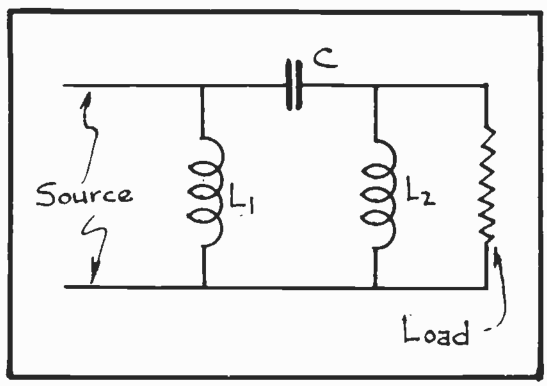

FIG. 19

The "PI" Type High-Pass Filter.

POWER PACK FILTER CHOKES

Before concluding this lesson and while we are still considering the subject of filter systems, it is advisable to present several facts concerning power pack filter chokes which you will find to be of interest.

AS YOU ALREADY KNOW, FILTER CHOKES FOR THIS PURPOSE CONSIST OF MANY TURNS OF FINE WIRE WOUND ON A LAMINATED STEEL CORE SO THAT THE CHOKE WILL HAVE A RATHER HIGH INDUCTANCE VALUE -- USUALLY FROM 15 TO 30 HENRIES. WHEN SELECTING SUCH A CHOKE, IT IS ALSO OF GREAT IMPORTANCE TO TAKE INTO ACCOUNT THE TOTAL D.C. CURRENT WHICH THE CHOKE WILL BE REQUIRED TO PASS AT FULL-LOAD, FOR NOT ONLY WILL A CURRENT OVERLOAD BE UNDESIRABLE FROM THE STANDPOINT OF EXCEEDING THE SAFE CURRENT-CARRYING CAPACITY OF THE PARTICULAR WIRE SIZE BEING USED, BUT IN ADDITION, THE INDUCTANCE VALUE OF THE CHOKE DECREASES MATERIALLY AS THE CURRENT FLOW THROUGH IT INCREASES BEYOND A CERTAIN POINT. IN OTHER WORDS, IF A CHOKE IS RATED AS HAVING AN INDUCTANCE OF 30 HENRIES, THEN THIS VALUE APPLIES ONLY WHEN A DEFINITE D.C. CURRENT IS PASSING THROUGH THE CHOKE WINDING.

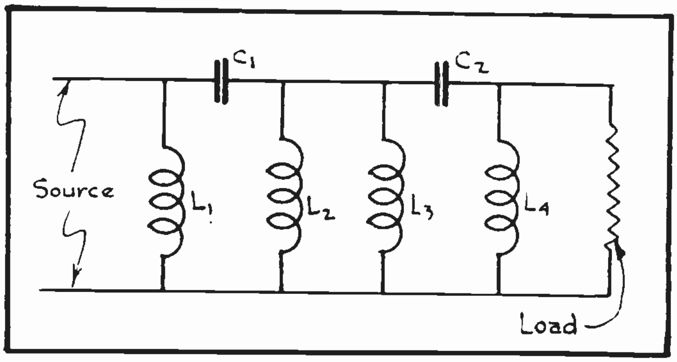

FIG. 20

A Two-Section "PI" High-Pass Filter.

SHOULD THE CURRENT LOAD BE INCREASED ABOVE THIS RATED CURRENT VALUE SUFFICIENTLY, THEN THE INDUCTANCE OF THE CHOKE MAY DROP DOWN TO 15 HENRIES OR SO. ANY APPRECIABLE REDUCTION IN THE INDUCTANCE RATING OF A FILTER CHOKE WILL IMPAIR THE FILTERING ACTION CONSIDERABLY WHICH WILL RESULT IN A GREATER HUM OUTPUT. THIS IS WORTHWHILE REMEMBERING BECAUSE IT WILL IMPRESS UPON YOUR MIND THE IMPORTANCE OF SELECTING FILTER CHOKES FROM THE STANDPOINT OF THEIR INDUCTANCE RATING AT A SPECIFIC CURRENT LOAD.

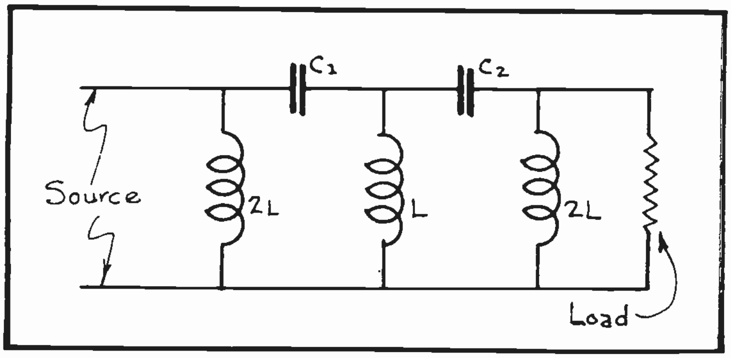

FIG. 21

A Two-Section "PI" High-Pass Filter With Common Inductance.

IN THE NEXT LESSON YOU ARE GOING TO LEARN STILL MORE ABOUT VARIOUS TYPES OF FILTER SYSTEMS AS EMPLOYED IN RADIO. HERE YOU WILL FIND THE BASIC FORMULAS FOR DESIGNING HIGH-PASS FILTERS, BAND-PASS FILTERS ETC., AS WELL AS BEING BETTER ACQUAINTED WITH SUCH ELECTRICAL CHARACTERISTICS AS MUTUAL INDUCTANCE, COEFFICIENT OF COUPLING AND OTHER FEATURES OF INTEREST AND IMPORTANCE.

Examination Questions

LESSON NO. 56

Ans feb 7, 41

"A man is either made or marred for life by the use he makes of his leisure time. Bind together your spare hours by the cord of some definite purpose and you know not how much you may accomplish.

1. - WHAT FOUR TYPES OF FILTER SYSTEMS ARE FREQUENTLY EMPLOYED IN RADIO PRACTICE?

2. - WHAT IS A LOW-PASS FILTER EXPECTED TO ACCOMPLISH?

3. - ILLUSTRATE A T-TYPE LOW-PASS FILTER SECTION BY MEANS OF A DIAGRAM.

4. - ILLUSTRATE A PI-TYPE LOW-PASS FILTER SECTION BY MEANS OF A CIRCUIT DIAGRAM.

5. - WHAT IS MEANT BY THE "CHARACTERISTIC IMPEDANCE" OF A FILTER?

6. - WHAT IS A HIGH-PASS FILTER EXPECTED TO ACCOMPLISH?

7. - ILLUSTRATE BY MEANS OF A DIAGRAM A SIMPLE HIGH-PASS FILTER AND EXPLAIN HOW IT FUNCTIONS.

8. - WOULD YOU CLASSIFY A POWER PACK FILTER AS BEING A LOW-PASS FILTER OR A HIGH-PASS FILTER? EXPLAIN YOUR ANSWER.

9. - WHEN DESIGNING A FILTER, IS IT ADVISABLE THAT THE SOURCE, LOAD, AND CHARACTERISTIC IMPEDANCE OF THE FILTER ALL BE EQUAL?

10. - WHAT IS THE FORMULA FOR CALCULATING THE INDUCTANCE OF THE CHOKE TO BE USED IN A LOW-PASS FILTER?

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LESSON NO. 57

HIGH-PASS AND BAND-PASS FILTER DESIGN

IN THIS LESSON, YOU ARE GOING TO CONTINUE THE STUDY OF FILTER SYSTEMS AND WE SHALL BEGIN WITH THE DESIGN PROCEDURE AS APPLIED TO THE HIGH-PASS FILTERS WHICH WERE DESCRIBED TO YOU IN THE PREVIOUS LESSON.

IN ORDER TO CALCULATE THE INDUCTIVE AND CAPACITIVE VALUES FOR A HIGH-PASS FILTER OF EITHER THE "T" OR "PI" TYPES, WE HAVE TWO HANDY FORMULAS AVAILABLE. HERE THEY ARE:

$$\text{INDUCTANCE IN HENRIES} = \frac{0.07958 \times \text{CHARACTERISTIC IMPEDANCE IN OHMS}}{\text{CUT-OFF FREQUENCY IN CYCLES}}$$

$$\text{CAPACITY IN FARADS} = \frac{0.07958}{\text{CUT-OFF FREQUENCY IN CYCLES} \times \text{CHARACTERISTIC IMPEDANCE IN OHMS.}}$$

THE CHARACTERISTIC IMPEDANCE FOR HIGH-PASS FILTERS IS DETERMINED IN THE SAME MANNER AS ALREADY DESCRIBED FOR LOW-PASS FILTERS IN THE PRECEDING LESSON AND FOR MOST EFFECTIVE RESULTS, THE SOURCE IMPEDANCE, LOAD IMPEDANCE AND THE CHARACTERISTIC IMPEDANCE OF THE FILTER SHOULD ALL BE APPROXIMATELY EQUAL.

IN FIG. 1 WE HAVE ILLUSTRATED A PRACTICAL EXAMPLE, SHOWING THE APPLICATION OF A HIGH-PASS FILTER TO A RADIO CIRCUIT AND FOR WHICH WE SHALL NOW WORK OUT A SAMPLE DESIGN.

THE HIGH-PASS FILTER IN THIS CIRCUIT IS CONNECTED BETWEEN THE PLATE AND GRID CIRCUITS OF TWO TUBES IN AN R.F.

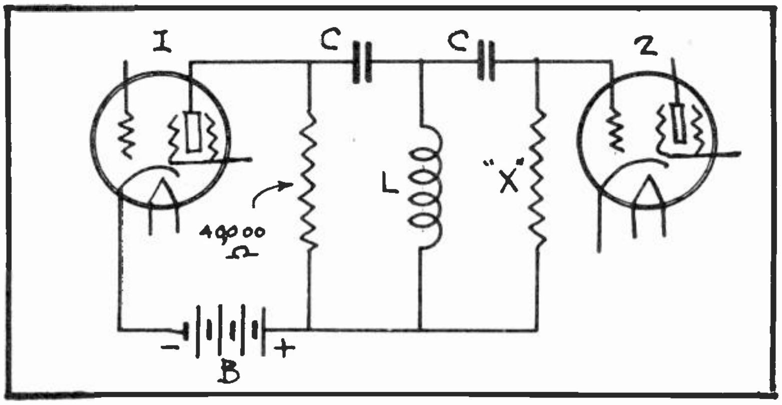

FIG. 1
Application of a High-Pass Filter.

AMPLIFIER. RADIO AND AUDIO FREQUENCIES ARE BOTH BEING FED INTO THE AMPLIFIER AND IT IS DESIRED TO SEPARATE THEM AND ONLY AMPLIFY THE RADIO FREQUENCIES. IN OTHER WORDS, THE AUDIO FREQUENCIES ARE TO BE REJECTED OR SUPPRESSED BY THIS FILTER, WHILE THE RADIO FREQUENCIES ARE TO BE TRANSFERRED FROM THE PLATE CIRCUIT OF TUBE #1 TO THE GRID CIRCUIT OF TUBE #2.

WE SHALL ASSUME THAT THE PLATE CIRCUIT RESISTANCE "RP" OF TUBE #1 IS 250,000 OHMS, THAT THE PLATE COUPLING RESISTOR HAS A VALUE OF 40,000 OHMS AND THAT THE CUT-OFF FREQUENCY IS TO BE SET AT THE UPPER LIMIT OF AUDIBILITY OR 20,000 CYCLES.

NOW THEN, OUR FIRST STEP WILL BE TO DETERMINE THE EFFECTIVE SOURCE IMPEDANCE. SINCE THE PLATE COUPLING RESISTOR IS CONNECTED IN PARALLEL WITH THE TUBE'S PLATE CIRCUIT RESISTANCE, THE EFFECTIVE IMPEDANCE AT THIS POINT CAN BE FOUND BY APPLYING OUR FORMULA FOR TWO PARALLEL RESISTORS OR $R = \frac{R_1 \times R_2}{R_1 + R_2}$ WHERE $R_1 = 250,000$ OHMS AND $R_2 = 40,000$ OHMS. HENCE $R =$

$$\frac{250,000 \times 40,000}{250,000 + 40,000} = \frac{10,000,000,000}{290,000} = 34,483 \text{ OHMS.}$$

THE CHARACTERISTIC IMPEDANCE OF THE FILTER SHOULD THEREFORE ALSO BE CHOSEN AS 34,483 OHMS AND SUBSTITUTING THIS VALUE IN OUR FORMULA FOR CALCULATING THE FILTER INDUCTANCE WE HAVE:

$$\text{INDUCTANCE IN HENRIES} = \frac{0.07958 \times \text{CHARACTERISTIC IMPEDANCE}}{\text{CUT-OFF FREQUENCY}} = \frac{0.07958 \times 34,483}{20,000} =$$

$$\frac{2744.16}{20,000} = .14 \text{ HENRIES (APPROX.) OR 140 MILLIHENRIES.}$$

$$\text{CAPACITY IN FARADS} = \frac{0.07958}{\text{CUT-OFF FREQ.} \times \text{CHARACTERISTIC IMPEDANCE}} =$$

$$\frac{0.07958}{20,000 \times 34,483} = \frac{0.07958}{689,660,000} = .0000000001 \text{ FARADS OR 0.0001 MFDS. (APPROX.)}$$

BEAR IN MIND THAT THE INDUCTIVE AND CAPACITIVE VALUES AS DETERMINED BY THESE TWO FORMULAS CORRESPOND TO THE CONSTANTS "L" AND "C" AS DESIGNATED IN THE SAMPLE HIGH-PASS FILTERS WHICH WERE ILLUSTRATED IN THE PREVIOUS LESSON. WHEN DOUBLE SECTION FILTERS ARE USED, THEN THE VALUES 2L AND 2C MUST BE TAKEN INTO ACCOUNT ACCORDING TO THE PARTICULAR TYPE OF FILTER AS ALREADY POINTED OUT IN THE PRECEDING LESSON.

SINCE IN THE CIRCUIT OF FIG. 1, THE SOURCE AND CHARACTERISTIC IMPEDANCE ARE BOTH 34,483 OHMS, THE LOAD IMPEDANCE OR RESISTANCE VALUE OF "X" SHOULD ALSO BE APPROXIMATELY 34,483 OHMS. THE GRID-CATHODE RESISTANCE WITHIN TUBE #2 IS OF A VERY HIGH VALUE AND SO WE SHALL FOR THE SAKE OF SIMPLICITY CONSIDER ITS PARALLEL EFFECT UPON RESISTOR "X" AS BEING NEGLIGIBLE.

BAND-PASS CIRCUITS

HAVING SO FAR STUDIED BOTH THE LOW AND HIGH-PASS FILTER SYSTEMS INDIVIDUALLY, YOU CAN NO DOUBT SEE THE POSSIBILITIES FOR COMBINING THESE TWO DISTINCT FILTERS IN SUCH A MANNER THAT EACH WILL OFFER ITS OWN CUT-OFF FREQUENCY, RESULTING IN THE PASSAGE OF A FREQUENCY BAND EXTENDING BETWEEN THESE TWO CUT-OFF POINTS AND A SUPPRESSION OF ALL OTHER FREQUENCIES.

IN FIG. 2, FOR INSTANCE, WE HAVE SUCH A COMBINATION WHERE THE SOURCE

FEEDS INTO A LOW-PASS FILTER, WHICH IS FOLLOWED BY A HIGH-PASS FILTER BEFORE THE LOAD IS FINALLY REACHED. ASSUMING THAT THE HIGH-PASS FILTER IS DESIGNED FOR A 600 KC. CUT-OFF AND THE LOW-PASS FILTER FOR AN 800 KC. CUT-OFF, THEN ALL FREQUENCIES BELOW 600 KC. AS WELL AS ALL FREQUENCIES ABOVE 800 KC. WILL BE SUPPRESSED AND ONLY A BAND OF 800 MINUS 600 OR 200 KC. WILL PASS THROUGH THE FILTER--HENCE THE EXPRESSION "BAND-PASS FILTER" IS ASSOCIATED WITH THIS SYSTEM.

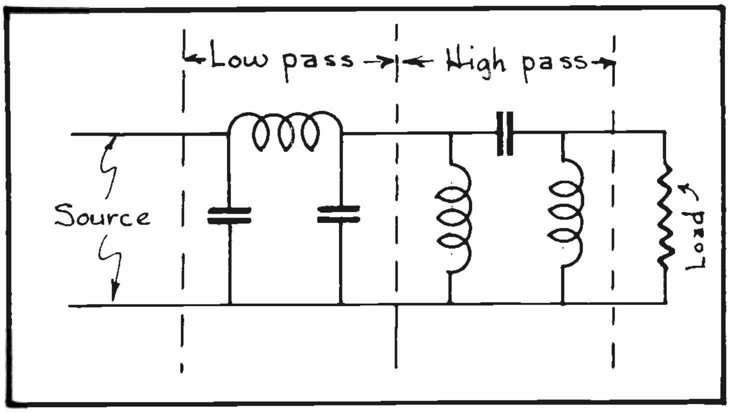

FIG. 2
Producing Band-Pass Effect.

IN FIG. 3 YOU ARE SHOWN A TYPICAL EXAMPLE OF A BAND-PASS FILTER AS SOMETIMES USED IN PRACTICE. HERE THE SERIES CONDENSERS ARE DESIGNATED AS "C" AND THE PARALLEL CONDENSERS AS "C_1".

IN WORKING OUT THE DESIGN OF SUCH A BAND PASS FILTER WE WOULD TAKE INTO ACCOUNT FIRST, THE SOURCE AND LOAD IMPEDANCE (EQUALIZING THEM) AND TO SET THE CHARACTERISTIC IMPEDANCE OF THE FILTER TO THIS SAME VALUE. THE NEXT POINT TO CONSIDER IS THE LOWER AND UPPER CUT-OFF FREQUENCIES. THE VALUE FOR C IN THE FILTER OF FIG. 3 CAN THEN BE DETERMINED BY USING THE FORMULA: $C = \frac{F_1 + F_2}{4\pi F_1 F_2 Z}$ WHERE C = CAPACITY IN FARADS; F_1 = LOWER FREQUENCY CUT-OFF IN CYCLES PER SECOND; F_2 = HIGHER FREQUENCY CUT-OFF IN CYCLES PER SECOND; AND Z = CHARACTERISTIC IMPEDANCE OF THE FILTER EXPRESSED IN OHMS. IN OTHER WORDS, TO FIND THE VALUE OF "C", ADD F_1 TO F_2 AND DIVIDE THIS SUM BY THE PRODUCT YOU OBTAIN AFTER MULTIPLYING TOGETHER 4 TIMES 3.14 TIMES F_1 TIMES F_2 TIMES Z.

TO FIND THE VALUE OF C_1 IN FIG. 3 USE THE FORMULA: $C_1 = \frac{F_1}{\pi F_2 (F_2 - F_1) Z}$.
TO WORK OUT THIS PROBLEM, SUBTRACT F_1 FROM F_2 AND MULTIPLY THIS DIFFERENCE BY Z TIMES π TIMES F_2. THEN DIVIDE F_1 BY THIS FINAL PRODUCT.

THE VALUE FOR THE INDUCTANCE "L" IN FIG. 3 IS FOUND BY USING THE FORMULA: $L = \frac{(F_2 - F_1) Z}{4\pi F_1 F_2}$. THAT IS, SUBTRACT F_1 FROM F_2 AND MULTIPLY THIS DIFFERENCE BY Z. DIVIDE THE NUMBER THUS OBTAINED BY THE PRODUCT OBTAINED UPON MULTIPLYING 4 TIMES 3.14 TIMES F_1 TIMES F_2. THE INDUCTANCE WILL BE EXPRESSED IN HENRIES.

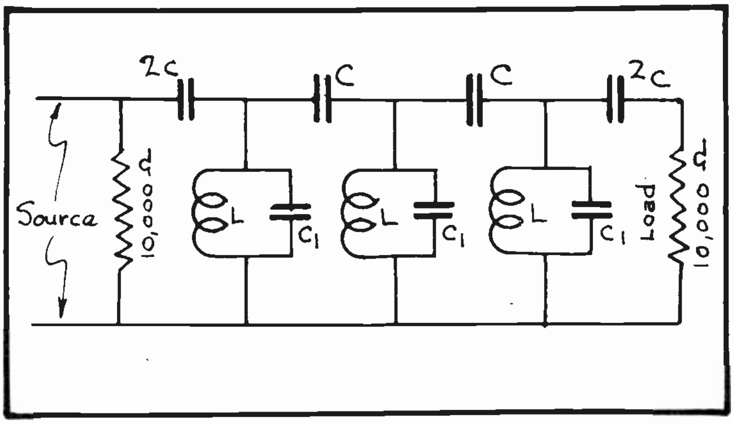

FIG. 3
A Typical Band-Pass Filter.

FUNDAMENTAL RELATIONS IN BAND-PASS CIRCUITS

YOU ARE NOW READY TO STUDY SOME MORE INTEREST-

ING RELATIONS BETWEEN THE CIRCUIT CONSTANTS AS EMPLOYED IN BAND-PASS SYSTEMS SUCH AS USED IN BAND SELECTOR CIRCUITS OF THE TYPE ILLUSTRATED IN FIG. 4, WHERE THE COMMON INDUCTANCE L IS USED AS THE COUPLING COIL OR COUPLING INDUCTANCE.

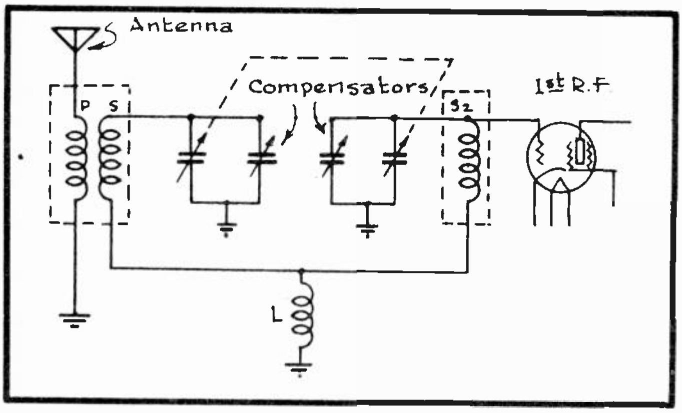

FIG. 4
A Band-Pass Circuit With Coupling Coil.

FIRST, LET US CONSIDER THE COEFFICIENT OF COUPLING OF SUCH A CIRCUIT. THE COEFFICIENT OF COUPLING IS A NUMBER WHICH EXPRESSES TO WHAT EXTENT THE LINES OF FORCE ORIGINATING AROUND ONE WINDING ALSO ENCIRCLE A SECOND WINDING WHICH IS INDUCTIVELY COUPLED TO THE FIRST. TO ILLUSTRATE THIS POINT, LET US REFER TO FIG. 5. HERE THE MAGNETIC FIELD WHICH ORIGINATES AROUND COIL #1 ALSO INTERLINKS WITH COIL #2. IF CONDITIONS WERE SUCH THAT ALL OF THE LINES OF FORCE WERE UTILIZED BY COIL #2, THEN WE WOULD SAY THAT THERE WAS UNITY COUPLING BETWEEN THEM OR THAT THE COEFFICIENT OF COUPLING WAS 1. THE LETTER "K" IS GENERALLY USED TO DESIGNATE THE COEFFICIENT OF COUPLING.

IN ACTUAL PRACTICE, HOWEVER, THERE IS ALWAYS A CERTAIN AMOUNT OF MAGNETIC LEAKAGE SO THAT NOT ALL OF THE MAGNETIC FIELD PRODUCED BY COIL #1 IS UTILIZED BY COIL #2. THEREFORE, THE COEFFICIENT OF COUPLING BECOMES LESS THAN 1 AND IS GENERALLY EXPRESSED AS A DECIMAL FRACTION SUCH .2 OR .5 ETC. OR AS A PERCENTAGE AS 3%, 8% ETC. IN GOOD IRON-CORE TRANSFORMERS, THE COEFFICIENT OF COUPLING IS QUITE HIGH - FREQUENTLY REACHING A VALUE OF .98 OR 98%. HOWEVER, IN AIR-CORE TRANSFORMERS, WHERE THE MAGNETIC LEAKAGE IS MUCH MORE PRONOUNCED, THE COEFFICIENT OF COUPLING MAY REACH SUCH A LOW VALUE AS .1 OR LESS.

IN A CIRCUIT AS ILLUSTRATED IN FIG. 6, WHERE A COMMON INDUCTANCE "LM" IS CONNECTED ACROSS THE CIRCUIT AS HERE SHOWN, THE COEFFICIENT OF COUPLING BETWEEN THE TWO WINDINGS "L_1" AND "L_2" CAN BE APPROXIMATELY DETERMINED BY THE FOLLOWING FORMULA.

COEFFICIENT OF COUPLING OR $K = \frac{LM}{\sqrt{(L_1+LM)(L_2+LM)}}$

WHERE LM = THE INDUCTANCE OF THE COUPLING COIL EXPRESSED IN MICROHENRIES, L_1 = THE INDUCTANCE OF WINDING L_1 EXPRESSED IN MICROHENRIES AND L_2 = THE INDUCTANCE OF WINDING L_2 EXPRESSED IN MICROHENRIES.

IF THE CIRCUITS ARE CAPACITIVELY COUPLED AS IN FIG. 7, THEN THE COEFFICIENT OF COUPLING CAN BE DETERMINED BY THE FORMULA:
COEFFICIENT OF COUPLING OR K =

$\frac{\sqrt{C_1C_2}}{\sqrt{(C_M+C_1)(C_M+C_2)}}$ IN WHICH C_1 = THE CAPACITY OF CONDENSER C_1 EXPRESSED IN MFDS; C_2 = THE CAP-

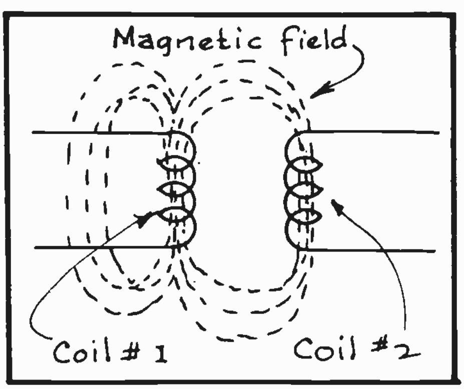

FIG. 5
Two Inductively Coupled Windings.

ACITY OF CONDENSER C_2 EXPRESSED IN MFDS. AND CM = THE CAPACITY OF THE COUPLING CONDENSER IN MFDS.

NOW THEN, ASSUMING THAT EACH OF THE TWO TUNED CIRCUITS INDIVIDUALLY ARE RESONATED AT THE SAME FREQUENCY, WHICH IS THE CASE IN BAND SELECTOR CIRCUITS, THEN THE DIFFERENCE BETWEEN THE LOWER AND UPPER FREQUENCIES PASSED OR THE WIDTH OF BAND PASSED, EXPRESSED IN KILOCYCLES, CAN BE FOUND WITH THE AID OF THE FOLLOWING FORMULA: WIDTH OF BAND PASSED = RESONANT FREQUENCY OF THE TUNED CIRCUITS MULTIPLIED BY THE COEFFICIENT OF COUPLING.

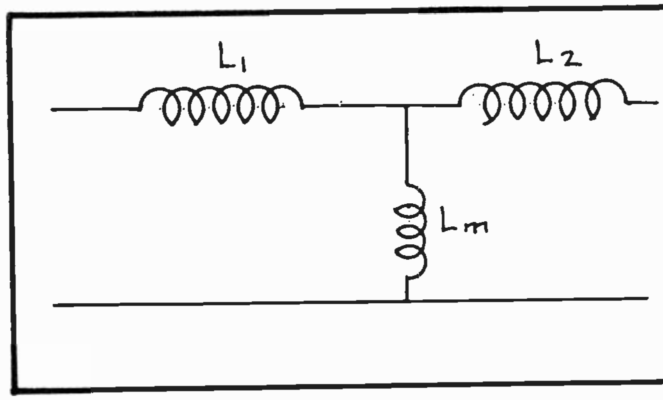

FIG. 6
Circuit With Common Coupling Inductance.

AS YOU WILL RECALL FROM YOUR PREVIOUS STUDIES REGARDING BAND-PASS OR BAND-SELECTOR CIRCUITS, THE SELECTIVITY CURVE AS OBTAINED WITH THIS TYPE OF CIRCUIT HAS A RESONANCE PEAK TOWARD EITHER SIDES OF THE FUNDAMENTAL RESONANT FREQUENCY AS SHOWN IN FIG. 8. THE RELATION WHICH THESE TWO PEAK FREQUENCIES BEAR TO THE FUNDAMENTAL RESONANT FREQUENCY IS EXPRESSED BY THE FOLLOWING TWO FORMULAS:

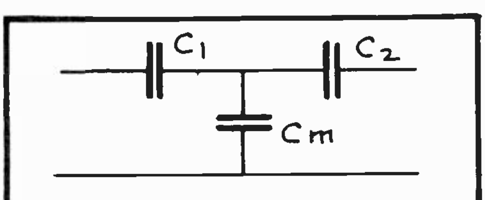

FIG. 7
Band-Pass Circuit With Capacitive Coupling

$$\text{HIGHER FREQUENCY PEAK IN KILOCYCLES} = \frac{\text{RESONANT FREQUENCY IN KILOCYCLES}}{\sqrt{1 - \text{COEFFICIENT OF COUPLING}}}$$

$$\text{LOWER FREQUENCY PEAK IN KILOCYCLES} = \frac{\text{RESONANT FREQUENCY IN KILOCYCLES}}{\sqrt{1 + \text{COEFFICIENT OF COUPLING}}}$$

COMPLETE BAND-PASS RECEIVERS

WHEN A BAND-PASS CIRCUIT IS EMPLOYED ONLY IN THE FIRST R.F. STAGE OF A RECEIVER IN WHICH RATHER SHARPLY TUNED CIRCUITS FOLLOW AS IN FIG. 9, OR WHEN STRAIGHT TUNED R.F. CIRCUITS OF THE CONVENTIONAL TYPE ARE USED IN THE FOLLOWING R.F. STAGES, THEN THE BAND-PASS CIRCUIT AT THE INPUT END OF THE RECEIVER IS GENERALLY REFERRED TO AS BEING A BAND-SELECTOR CIRCUIT. IN THIS CASE, THE REGULAR BAND-PASS FEATURES ARE OBTAINED IN THE BAND SELECTOR CIRCUIT ITSELF WHICH MEANS THAT THE FOLLOWING CIRCUITS MAY DECREASE MATERIALLY THE WIDTH OF THE BAND PASSED BY THE BAND SELECTOR CIRCUIT. ALTHOUGH THE NARROWING EFFECT OF THE BAND WILL NOT BE QUITE AS APPARENT AS WHEN EVEN THE INPUT CIRCUITS ARE SHARP TUNING, YET NEVERTHELESS IT WILL EXIST.

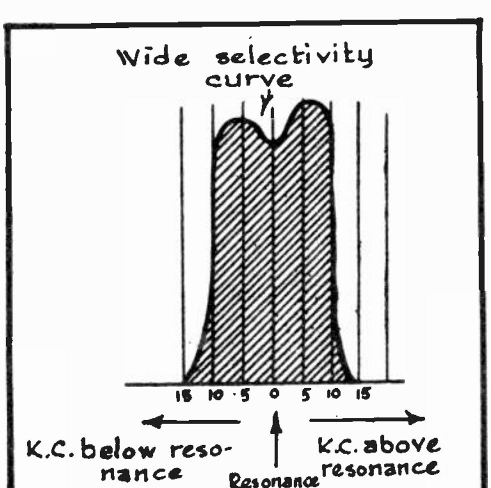

FIG. 8
The Selectivety Curve.

IF THE BAND-PASS FEATURE IS TO BE RETAINED THROUGHOUT THE ENTIRE R.F. SECTION OF THE RECEIVER, THEN ONE METHOD OF ACCOMPLISHING THIS IS ILLUSTRATED IN FIG. 10 WHERE ALL OF THE TUNING CIRCUITS IN THE R.F. SECTION OF THE RECEIVER ARE OF THE BAND-PASS TYPE, EACH BEING DESIGNED TO PASS THE SAME BAND OF FREQUENCIES SIMULTANEOUSLY. THE R.F. AMPLIFIER OF THE RECEIVER THEN BECOMES A TRUE BAND-PASS SYSTEM.

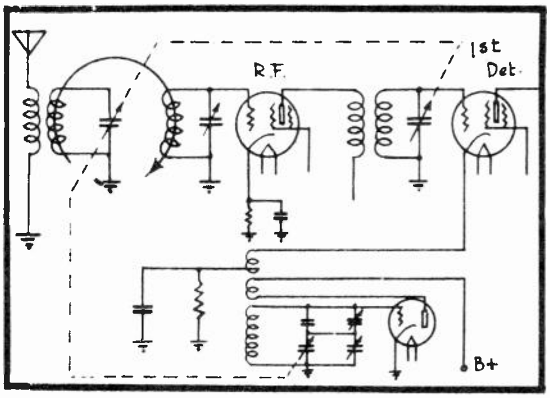

FIG. 9
Application of the Band-Pass Circuit.

BEAR IN MIND THAT ALL OF THE VARIABLE CONDENSERS HERE SHOWN ARE REGULAR TUNING CONDENSERS WHICH TUNE BOTH THE PLATE AND GRID CIRCUIT WINDINGS AND THAT ALTHOUGH THESE SYMBOLS APPEAR AS BEING SIMILAR TO I.F. TRANSFORMERS AS USED IN SUPERHETERODYNE RECEIVERS, YET THEY DIFFER GREATLY IN ACTUAL CONSTRUCTION.

A STILL DIFFERENT METHOD OF OBTAINING BAND-PASS CHARACTERISTICS THRU AN R.F. AMPLIFIER IS ILLUSTRATED FOR YOU IN FIG. 11. THIS IS THE SYSTEM WHICH WAS EMPLOYED IN SPARTON RECEIVERS AND AS YOU WILL OBSERVE, IT IS SOMEWHAT DIFFERENT FROM THE CIRCUITS WHICH YOU HAVE STUDIED SO FAR.

TO BEGIN WITH, A REGULAR BAND-SELECTOR CIRCUIT IS USED BETWEEN THE ANTENNA INPUT AND THE FIRST R.F. TUBE. THIS IS FOLLOWED BY SUCCESSIVE R.F. STAGES WHICH ARE COUPLED TOGETHER BY MEANS OF UNTUNED R.F. TRANSFORMERS. THUS ALL FREQUENCY SELECTION IS TAKEN CARE OF IN THE BAND SELECTOR PRECEDING THE FIRST R.F. TUBE AND THE FOLLOWING STAGES SERVE ONLY TO AMPLIFY THE SIGNAL ALREADY SELECTED.

IN FIG. 12 ANOTHER CIRCUIT IS SHOWN WHICH WAS DESIGNED IN ORDER TO OBTAIN THE ADVANTAGES OFFERED BY BAND-PASS CIRCUITS. IN THIS INSTANCE, A CAPACITIVELY-COUPLED BAND-PASS CIRCUIT IS BEING USED AHEAD OF THE FIRST R.F. TUBE. THIS IS FOLLOWED BY AN UNTUNED R.F. STAGE AFTER WHICH ANOTHER BAND-PASS COUPLING IS INCLUDED BETWEEN THE SECOND AND THIRD R.F. TUBES.

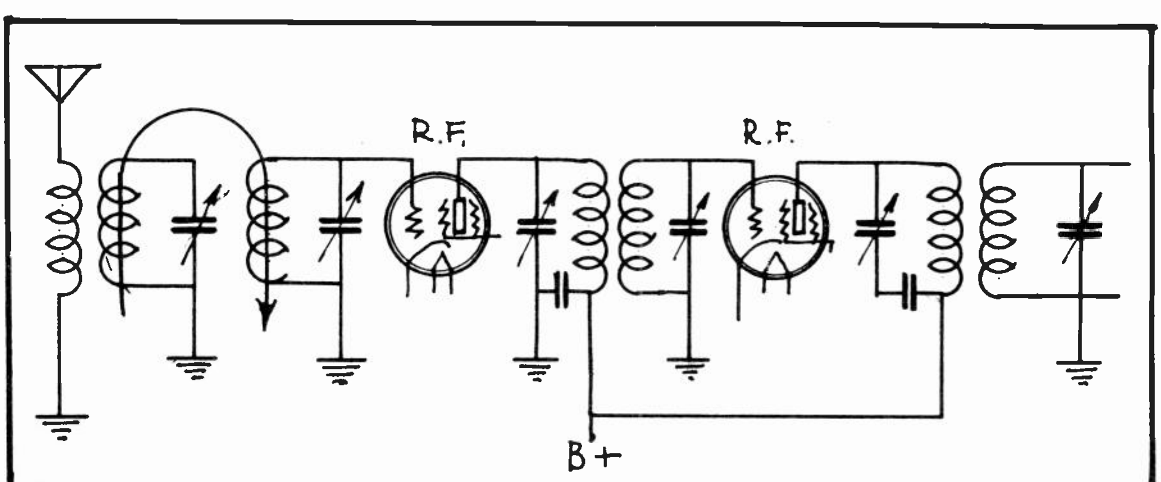

FIG. 10
Circuit With Complete Band-Pass.

THE FOLLOWING R.F. AND THE DETECTOR TUBE ARE BEING OPERATED FROM R.F. TRANSFORMERS OF THE CONVENTIONAL TYPE HAVING TUNED SECONDARY WINDINGS. THE OUTPUT OF THIS TUNER CAN THEN BE CONNECTED TO ANY SUITABLE A.F. AMPLIFIER.

MAGNITUDE OF MUTUAL INDUCTANCE

IN THE EARLY PART OF THE COURSE DEALING WITH THE BASIC ELECTRICAL PRINCIPLES, YOU LEARNED WHAT IS MEANT BY THE EXPRESSION "MUTUAL INDUCTANCE". AT THIS TIME, HOWEVER, YOU ARE GOING TO BE TOLD MORE ABOUT THIS PROPERTY.

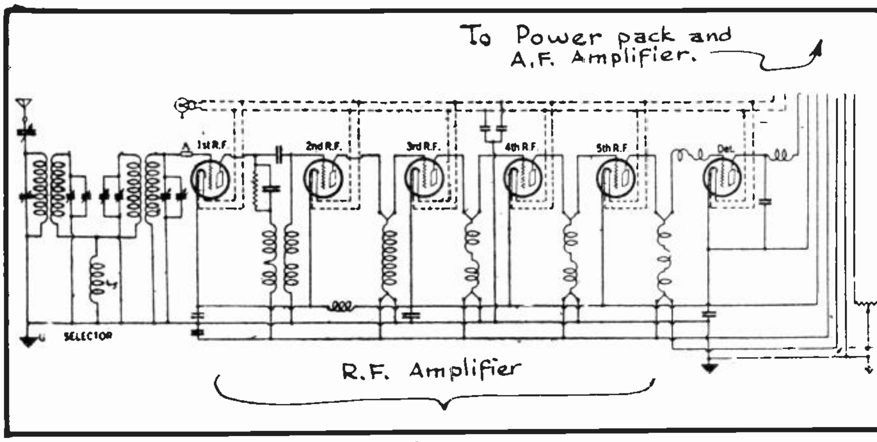

FIG. 11
The Sparton Band-Pass Circuit.

IN FIG. 13, FOR INSTANCE, WE HAVE TWO SIMILAR COILS WHICH ARE INDUCTIVELY COUPLED TO EACHOTHER IN SUCH A MANNER SO THAT THE MAGNETIC FIELDS OF THE TWO COILS DO NOT OPPOSE ONE ANOTHER. WE THEN SAY THAT THE TWO COILS ARE CONNECTED SERIES AIDING. THE FOLLOWING RELATION THEN HOLDS GOOD:- $L_a = L_1 + L_2 + 2M$ OR $M = \frac{L_a - L_1 - L_2}{2}$ WHERE L_1 = INDUCTANCE OF COIL #1; L_2 = INDUCTANCE OF COIL #2; L_a = TOTAL INDUCTANCE OFFERED BY THE SERIES AIDING CONNECTION AND M = MUTUAL INDUCTANCE EXPRESSED IN THE SAME UNITS AS L_1 AND L_2.

ANOTHER INTERESTING FACT TO REMEMBER ABOUT COILS CONNECTED IN THE SERIES AIDING ARRANGEMENT IS THAT IF UNITY COUPLING EXISTS, THEN THE TOTAL INDUCTANCE OF THE TWO COILS WILL BE FOUR TIMES THE INDUCTANCE OF EITHER ONE OF THE TWO COILS ALONE. IN OTHER WORDS, THE TWO INDIVIDUAL INDUCTANCES WOULD IN THIS CASE BECOME EQUIVALENT TO A SINGLE INDUCTANCE OF DOUBLE THE NUMBER OF TURNS AND SINCE THE INDUCTANCE OF A COIL DEPENDS UPON THE SQUARE OF THE NUMBER OF TURNS; DOUBLING THE NUMBER OF TURNS INCREASES THE INDUCTANCE FOUR TIMES.

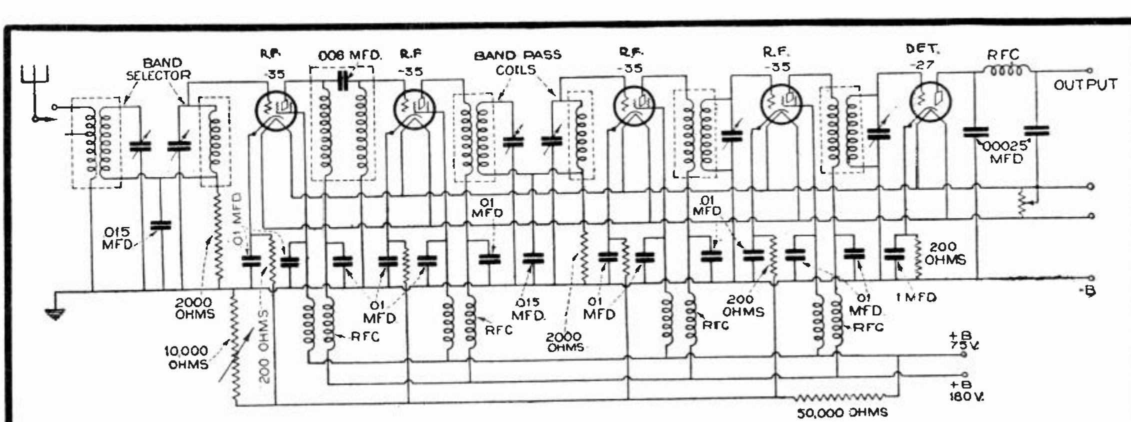

FIG. 12
A Special R. F. Tuner

SHOULD THE SAME TWO COILS BE CONNECTED TOGETHER AS ILLUSTRATED IN FIG. 14 SO THAT THEIR FIELDS REACT SO AS TO OPPOSE ONE ANOTHER, THEN WE SAY THAT THE COILS ARE CONNECTED SERIES OPPOSING. UNDER THESE CONDITIONS IF UNITY COUPLING EXISTS, AND THE FIELDS OF THE TWO COILS ARE EQUAL IN VALUE, THEN THE TOTAL INDUCTANCE BECOMES ZERO BECAUSE THE TWO FIELDS WILL NEUTRALIZE EACHOTHER.

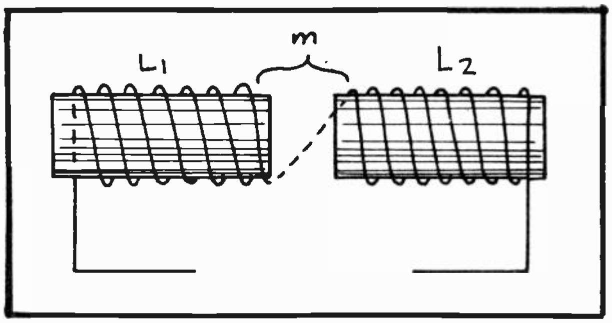

FIG. 13
A Series-Aiding Connection.

THE RELATION WHICH EXISTS BETWEEN THE TWO COILS WHEN THEY ARE CONNECTED SERIES-OPPOSING AND THE COUPLING IS LESS THAN UNITY IS EXPRESSED BY THE FOLLOWING FORMULA: $L_o = L_1 + L_2 - 2M$ OR $M = \frac{L_1 + L_2 - L_o}{2}$, WHERE L_o=TOTAL INDUCTANCE OF THE SERIES OPPOSING COIL CONNECTIONS; L_1 = INDUCTANCE OF COIL #1; L_2 = INDUCTANCE OF COIL #2 AND M = MUTUAL INDUCTANCE.

DETERMINING MUTUAL INDUCTANCE BY MEASUREMENT

THE TASK OF DETERMINING THE MUTUAL INDUCTANCE BETWEEN TWO COILS BY ACTUAL MEASUREMENT CAN BE ACCOMPLISHED WITH THE AID OF THE WHEATSTONE BRIDGE BY USING THE SAME SET-UP AS WAS ALREADY DESCRIBED IN A PREVIOUS LESSON FOR INDUCTANCE MEASUREMENT. THE TWO COUPLED COILS UNDER TEST ARE CONSIDERED AS THE SINGLE UNKNOWN INDUCTANCE AND COMPARED WITH A STANDARD INDUCTANCE.

FIRST, THESE TWO COUPLED COILS ARE CONNECTED IN THE SERIES- AIDING ARRANGEMENT AND THE RESULTING INDUCTANCE MEASURED ON THE "BRIDGE". THIS VALUE IS CALLED La. THEN THE TWO COILS ARE CONNECTED IN THE SERIES-OPPOSING ARRANGEMENT AND THE TOTAL INDUCTANCE IS AGAIN MEASURED AND CALLED L_o. THE MUTUAL INDUCTANCE CAN THEN BE FOUND FROM THE RELATION: $M = \frac{La - Lo}{4}$. THE VALUE OF M WILL BE EXPRESSED IN THE SAME INDUCTANCE UNITS AS USED FOR La AND Lo.

A DEFINITE RELATION EXISTS BETWEEN THE COEFFICIENT OF COUPLING BETWEEN TWO COUPLED COILS AND THEIR INDIVIDUAL INDUCTANCE VALUES AND THE MUTUAL INDUCTANCE BETWEEN THEM. THIS RELATION IS GIVEN BY THE FORMULA: $K = \frac{M}{\sqrt{L_1 \cdot L_2}}$ OR $M = K\sqrt{L_1 \; L_2}$, WHERE K = COEFFICIENT OF COUPLING; M = MUTUAL INDUCTANCE BETWEEN THE TWO COILS; WHILE L_1 AND L_2 ARE THE INDIVIDUAL INDUCTANCE VALUES OF THE TWO COILS.

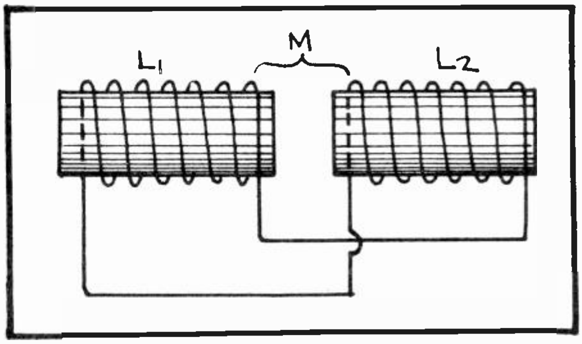

FIG. 14
Series-Opposing Connection.

TUNED POWER PACK FILTERS

IN SOME COMMERCIAL A.C. RECEIVERS, YOU WILL FIND THE FILTER OF THE POWER PACK ARRANGED IN THE MANNER

ILLUSTRATED IN FIG. 15. HERE YOU WILL NOTICE THAT A FIXED CONDENSER C IS CONNECTED ACROSS ONE OF THE FILTER CHOKES L_1. THIS CONNECTION OFFERS A PARALLEL RESONANCE CIRCUIT WHICH WILL GREATLY SUPPRESS THE PASSAGE OF SOME UNWANTED FREQUENCY THROUGH THE FILTER. FOR INSTANCE, SOMETIMES A 120 CYCLE HUM IS QUITE OBJECTIONABLE IN A RECEIVER OR AMPLIFIER AND SO BY RESONATING SOME PARTICULAR SECTION OF THE POWER PACK FILTER TO THIS HUM FREQUENCY, WHICH IS PRODUCED THRU RECTIFICATION OF THE A.C. SUPPLY, IT CAN BE ATTENTUATED.

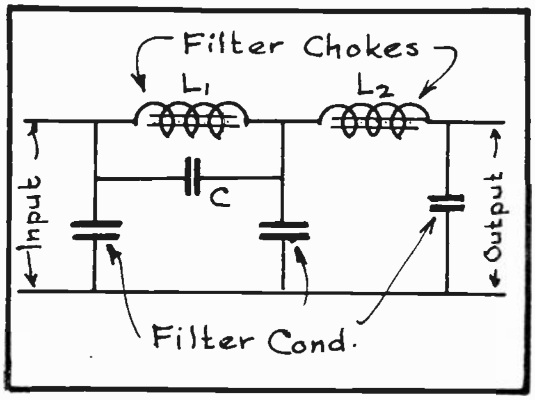

FIG. 15
The Tuned Filter

IN ORDER TO DETERMINE THE VALUE OF "C" WHICH IS NECESSARY IN ORDER TO TUNE THE FILTER SECTION SO AS TO REJECT AN UNWANTED FREQUENCY, THE FOLLOWING FORMULA CAN BE EMPLOYED: $C = \frac{25,300}{F^2 \times L_1}$. HERE "C" IS EXPRESSED IN MFDS.; F = FREQUENCY TO BE SUPPRESSED IN CYCLES AND L_1 = THE INDUCTANCE OF FILTER CHOKE L_1 IN HENRIES.

THIS FORMULA IS ONLY APPROXIMATE BUT NEVERTHELESS IS SUFFICIENTLY ACCURATE FOR PRACTICAL PURPOSES BECAUSE THIS RESONANCE CIRCUIT DOESN'T ACTUALLY TUNE VERY SHARP IN PRACTICE DUE TO THE COMPARATIVELY HIGH RESISTANCE WHICH IS PRESENT.

THE REASON WHY A PARALLEL RESONANCE CIRCUIT OFFERS MAXIMUM IMPEDANCE TOWARDS THE RESONANT FREQUENCY CAN BE EXPLAINED AS FOLLOWS:

BY CONSIDERING THE CIRCUIT WHICH IS ILLUSTRATED IN FIG. 16, THE SAME A.C. VOLTAGE IS APPLIED ACROSS BOTH THE CONDENSER C AND THE INDUCTANCE L, BUT THE CURRENTS THROUGH THESE TWO BRANCHES ARE GOVERENED BY THE REACTANCE OF THE BRANCH.

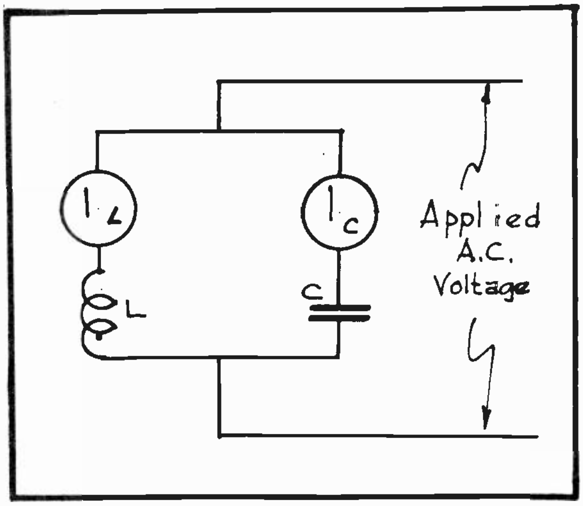

FIG. 16
The Parallel Resonant Frequency.

IN OTHER WORDS,

$I_L = \frac{E}{X_L}$ AND $I_C = \frac{E}{X_C}$, WHERE I_L = THE CURRENT THROUGH THE INDUCTANCE; I_C = THE CURRENT THROUGH THE CONDENSER; X_L = INDUCTIVE REACTANCE; X_C = CAPACITIVE REACTANCE AND E = THE APPLIED LINE VOLTAGE.

AT THE RESONANT FREQUENCY, THE CAPACITIVE REACTANCE IS EQUAL TO THE INDUCTIVE REACTANCE AND SO WITH A GIVEN APPLIED VOLTAGE, $I_L = I_C$ AT RESONANCE.

IN A PARALLEL RESONANT CIRCUIT, THE TWO CURRENTS I_L AND I_C ARE OUT OF PHASE — I_C HAVING A NEGATIVE SIGN AND I_L A POSITIVE

SIGN. NEGLECTING RESISTANCE, THE LINE CURRENT WILL BE EQUAL TO THE ALGEBRAIC SUM OF I_L AND I_C WHICH ACTUALLY MEANS THAT THE LINE CURRENT IS EQUAL TO I_L MINUS I_C. THEN SINCE $I_L = I_C$ AT RESONANCE, THE LINE CURRENT WILL BE EQUAL TO ZERO.

THE IMPEDANCE OF THE CIRCUIT AS A WHOLE, THAT IS, THE IMPEDANCE INTO WHICH THE SOURCE OF E.M.F. FORCES CURRENT, WILL BE THE RATIO OF THE VOLTAGE TO THE CURRENT AS USUAL: $Z = \frac{E}{I}$. THEREFORE, IF NO CURRENT FLOWS AS JUST SHOWN, THE CIRCUIT HAS INFINITE IMPEDANCE.

ACTUALLY IN PRACTICE THERE IS ALWAYS SOME RESISTANCE IN THE CIRCUIT. THIS MAY BE AN ADDITIONAL SHUNT PATH, OR IT MAY EXIST IN ONE OR BOTH OF THE OTHER BRANCHES. FOR THIS REASON, THE CURRENT THROUGH THE CIRCUIT DOES NOT FALL TO ABSOLUTE ZERO BUT PASSES THROUGH A MINIMUM VALUE. CONSEQUENTLY, THE IMPEDANCE OF THE PARALLEL RESONANT CIRCUIT DOES NOT QUITE BECOME INFINITE AT THE RESONANT FREQUENCY, SO WE SIMPLY SAY THAT ITS IMPEDANCE IS MAXIMUM AT THE RESONANT FREQUENCY.

WIDTH OF RESONANCE CURVE FOR TUNING CIRCUITS

IN FIG. 17 WE HAVE A TYPICAL RESONANCE CURVE FOR A SERIES RESONANCE CIRCUIT AS USED IN THE TUNING CIRCUITS OF ORDINARY R.F. AMPLIFIERS AND WITH WHICH YOU ARE ALREADY FAMILIAR. HERE THE CURRENTS THROUGH THE TUNED CIRCUIT ARE PLOTTED ON A GRAPH AGAINST THE FREQUENCIES TOWARDS BOTH SIDES OF RESONANCE AND WITH A GIVEN APPLIED A.C. SIGNAL VOLTAGE.

AS YOU WILL RECALL, THE CURRENT FLOW THROUGH A SERIES RESONANCE CIRCUIT IS MAXIMUM AT THE RESONANT FREQUENCY AND DROPS OFF BOTH SIDES OF RESONANCE. THE WIDTH OF SUCH A RESONANCE CURVE AT A POINT WHERE THE CURRENT THROUGH THE CIRCUIT IS EQUAL TO .707 TIMES THE CURRENT AT RESONANCE CAN BE CALCULATED BY MEANS OF THE FOLLOWING FORMULA: $f_2 - f_1 = \frac{R f_r}{L\omega}$ WHERE f_2 = FREQUENCY ABOVE RESONANCE IN CYCLES; f_1 = FREQUENCY BELOW RESONANCE IN CYCLES; R = D.C. RESISTANCE OF THE TUNING CIRCUIT; f_r = RESONANT FREQUENCY IN CYCLES; L = INDUCTANCE OF THE TUNED WINDING EXPRESSED IN HENRIES AND $\omega = 2\pi f$.

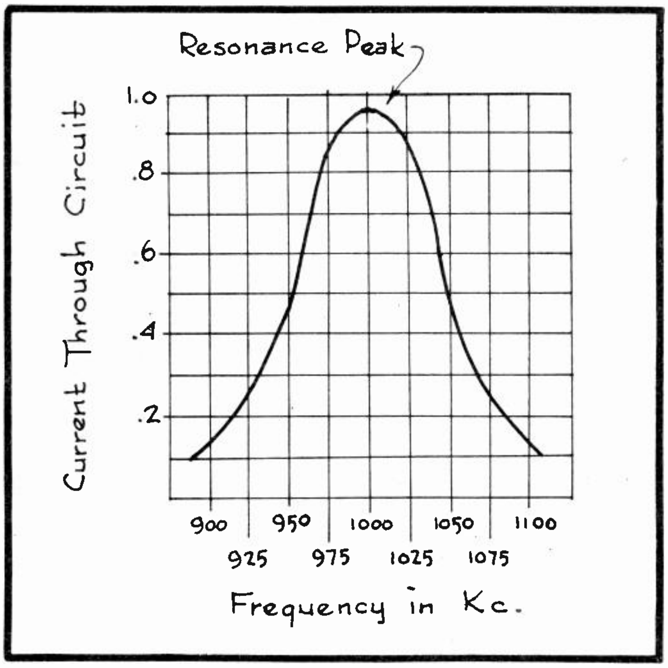

FIG. 17

The Resonance Curve.

AS A TYPICAL EXAMPLE, LET US ASSUME THAT THE TUNED WINDING OF A CERTAIN TUNED CIRCUIT IN AN R.F. AMPLIFIER HAS AN INDUCTANCE OF 250 MICROHENRIES, THAT THE D.C. RESISTANCE OF THE TUNING CIRCUIT IS 10 OHMS AND THAT THE RESONANT FREQUENCY IS 600 Kc.

THE WIDTH OF THE RESON-

ANCE CURVE AT A POINT EQUIVALENT TO .707 TIMES THE CURRENT AT RESONANCE WILL THEN BE CALCULATED AS FOLLOWS:

$$f_2 - f_1 = \frac{R f_r}{L \omega} = \frac{10 \times 600{,}000}{.00025 \times 6.28 \times 600{,}000} = \frac{6{,}000{,}000}{942} = 6369$$

CYCLES (APPROXIMATELY). IN OTHER WORDS, THE WIDTH OF THE RESONANCE CURVE OR THE WIDTH OF THE FREQUENCY BAND PASSED AT THIS POINT WILL BE ABOUT 6.4 Kc.

HAVING COMPLETED THIS LESSON, YOU SHOULD NOW HAVE A GOOD UNDERSTANDING OF THE DIFFERENT TYPES OF FILTER SYSTEMS, INCLUDING THEIR THEORY OF OPERATION, APPLICATION, AND BASIC DESIGN FORMULAS, AS WELL AS A KNOWLEDGE OF OTHER RADIO-PHYSICS PRINCIPLES OF IMPORTANCE. ALL OF THIS TECHNICAL INFORMATION IS OF GREAT VALUE AND SHOULD HELP YOU TREMENDOUSLY TOWARDS REACHING THE HIGHER RANKS OF THE RADIO PROFESSION.

IN THE FOLLOWING LESSON, YOU ARE GOING TO LEARN ABOUT SOME MORE VALUABLE RADIO TESTING EQUIPMENT, INCLUDING VACUUM TUBE VOLTMETERS, A.F. OSCILLATORS ETC. SO THAT YOUR KNOWLEDGE OF TESTING EQUIPMENT MAY BE MOST COMPLETE.

Do Your Best—Always

When you work, work. Put the whole mind and heart in it. Know nothing else. Do everything the very best. Distance everybody about you. This will not be hard, for the other fellows are not trying much. Master details and difficulties. Be always ready for the next step up. If a bookkeeper, be an expert. If a machinist, know more than the boss. If an office man, surprise the employer by model work. If in school, go to the head and stay there. All this is easy when the habit of conquering takes possession.

Be yourself the leader, not the trailer. Set the standard as conscience dictates. Then you will mold instead of being molded.

Examination Questions

LESSON NO. 57

Ans Feb 7 4

"Responsibilities gravitate to the person who can shoulder them, and Power flows to the man who knows how."

1. - WHAT IS THE BASIC FORMULA FOR CALCULATING THE INDUCTANCE VALUE OF A SINGLE SECTION T OR PI TYPE HIGH-PASS FILTER?

2. - WHAT IS THE BASIC FORMULA FOR CALCULATING THE CAPACITIVE VALUE OF A SINGLE SECTION T OR PI TYPE HIGH-PASS FILTER?

3. - WHAT IS A BAND-PASS CIRCUIT EXPECTED TO ACCOMPLISH?

4. - WHAT IS THE BASIC FORMULA FOR CALCULATING THE CAPACITIVE VALUE "C" OF A BAND-PASS CIRCUIT?

5. - WHAT IS THE BASIC FORMULA FOR CALCULATING THE INDUCTANCE VALUE "L" OF A BAND-PASS CIRCUIT?

6. - WHAT IS MEANT BY THE EXPRESSION COEFFICIENT OF COUPLING?

7. - HOW CAN THE COEFFICIENT OF COUPLING BE DETERMINED IN A BAND-PASS CIRCUIT SUCH AS ILLUSTRATED IN FIG. 6 OF THIS LESSON?

8. - HOW CAN YOU CALCULATE THE WIDTH OF THE BAND PASSED BY A CIRCUIT SUCH AS ILLUSTRATED IN FIG. 6 OF THIS LESSON?

9. - HOW CAN THE HIGHER AND LOWER FREQUENCY PEAKS BE CALCULATED FOR A BAND-PASS CIRCUIT AS FREQUENTLY USED IN A BAND-SELECTOR STAGE OF COMMERCIAL RECEIVERS?

10. - HOW CAN THE MUTUAL INDUCTANCE BETWEEN TWO INDUCTIVELY COUPLED COILS BE DETERMINED BY ACTUAL MEASUREMENT?

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LESSON NO. 58

V. T. VOLTMETERS & SPECIAL OSCILLATORS

THERE ARE STILL A NUMBER OF POPULAR TESTING DEVICES USED IN RADIO AND WHICH WERE NOT YET EXPLAINED TO YOU -- AMONG THESE BEING THE VACUUM TUBE, VOLTMETER, A.F. OSCILLATOR, GRID-DIP OSCILLATOR ETC. THESE TESTERS ARE, HOWEVER, EXPLAINED TO YOU THOROUGHLY IN THIS LESSON. WE SHALL CONSIDER FIRST THE VACUUM TUBE VOLTMETER OR "V.T. VOLTMETER", AS IT IS GENERALLY CALLED.

THE V.T. VOLTMETER

THE DISADVANTAGE ENCOUNTERED WHEN MAKING A.C. VOLTAGE MEASUREMENTS IN RADIO CIRCUITS CARRYING VERY SMALL CURRENT VALUES WITH AN ORDINARY A.C.

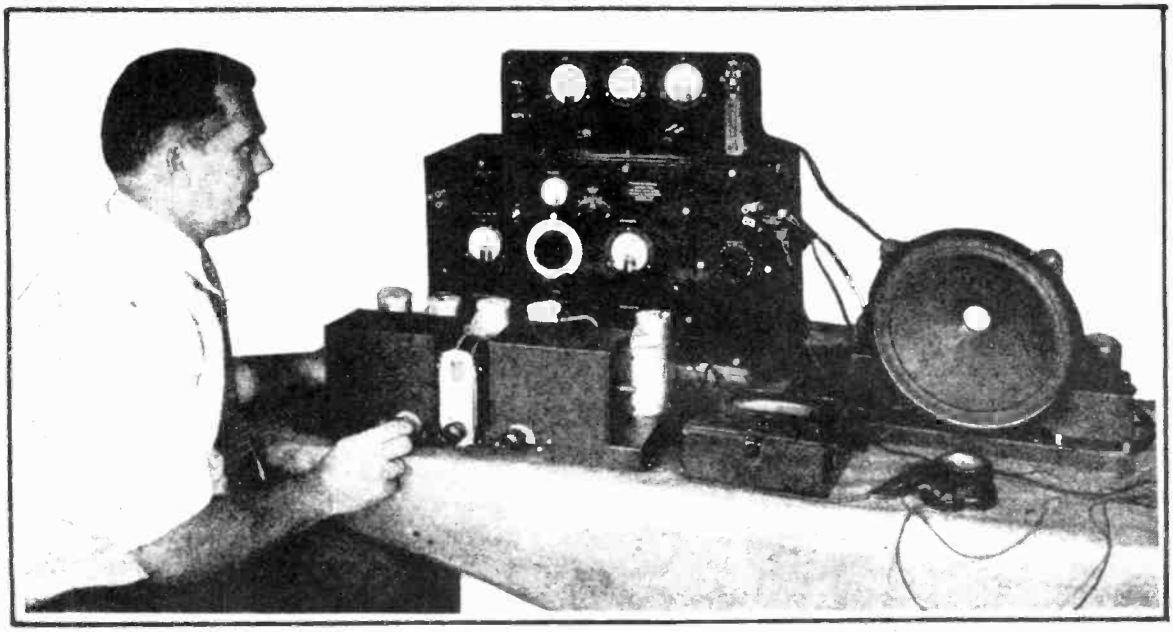

FIG. 1

Measuring the Performance of a Receiver.

VOLTMETER IS THAT SO MUCH ENERGY MUST BE SUPPLIED TO THE METER IN ORDER TO ACTUATE ITS MOVEMENT. SINCE THIS ENERGY MUST BE SUPPLIED BY THE CIRCUIT UNDER TEST AND VERY LITTLE OF IT IS PRESENT TO START WITH, IT STANDS TO REASON THAT THE OPERATION OF THE CIRCUIT IS FAR FROM NORMAL DURING THE TIME THE MEASUREMENT IS BEING MADE AND THIS NATURALLY RESULTS IN A MEASURED VALUE WHICH IS FAR FROM ACCURATE.

FURTHERMORE, MEASUREMENTS AS MADE WITH THE ORDINARY A.C. METER ARE IN TERMS OF "EFFECTIVE VALUES" AND QUITE OFTEN "PEAK VALUES" ARE OF GREATER INTEREST TO THE ENGINEER IN THAT THESE ARE RESPONSIBLE FOR SUCH CONDITIONS AS OVER-LOADING OF A TUBE IN A CIRCUIT ETC.

THE V.T. VOLTMETER SOLVES BOTH OF THESE PROBLEMS REMARKABLE WELL. TO BEGIN WITH, NO APPRECIABLE ENERGY FROM THE CIRCUIT UNDER TEST IS REQUIRED WHILE TAKING A MEASUREMENT; IT CAN BE CALIBRATED DIRECTLY FOR READING A.C. PEAK VALUES; WILL MEASURE VOLTAGES ACROSS HIGH-IMPEDANCE CIRCUITS ACCURATELY FROM ABOUT .1 VOLT UP TO ANY DESIRABLE VALUE; CAN BE USED AS AN OUTPUT METER; FOR MEASURING THE OVERALL GAIN OF AN AMPLIFIER; TO MEASURE HUM AND PRACTICALLY ANY NUMBER OF OTHER MEASUREMENTS AND TESTS WHICH ARE USEFUL TO THE RADIO TECHNICIAN.

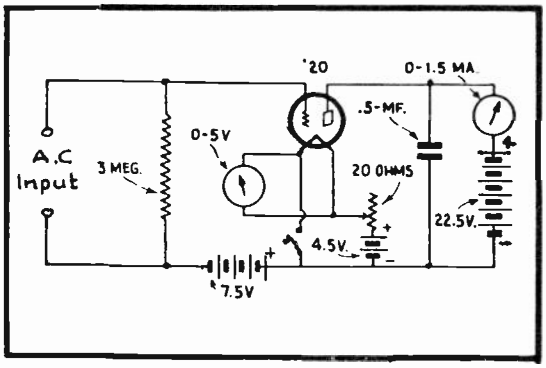

FIG. 2

Circuit of the V. T. Voltmeter.

IN SPITE OF ITS UNIVERSAL APPLICATION, IT IS REALLY QUITE SIMPLE IN CONSTRUCTION, AS WELL AS BEING EASY TO USE.

THE CIRCUIT DIAGRAM OF A SIMPLE BUT PRACTICAL V.T. VOLTMETER IS SHOWN YOU IN FIG. 2. THE FUNDAMENTAL OPERATING PRINCIPLES OF THIS INSTRUMENT ARE IDENTICAL TO THOSE OF A GRID BIAS OR POWER TYPE DETECTOR WITH WHICH YOU ARE ALREADY FAMILIAR. THAT IS, WITH NO A.C. VOLTAGES APPLIED TO THE GRID CIRCUIT WHICH IS USED IN THE V.T. VOLTMETER, THE PLATE CURRENT AS INDICATED BY THE MILLIAMMETER WILL BE PRACTICALLY ZERO.

AS A.C. VOLTAGES ARE IMPRESSED UPON THE INPUT TERMINALS OF THE V.T. VOLTMETER, A DEFINITE PLATE CURRENT FLOW WILL BE INDICATED BY THE MILLIAMMETER. THE VALUE OF THIS PLATE CURRENT WILL DEPEND UPON THE MAGNITUDE OF THE A.C. VOLTAGE APPLIED TO THE TUBE'S GRID, THAT IS, THE GREATER THE APPLIED A.C. VOLTAGE, THE GREATER WILL BE THE FLOW OF PLATE CURRENT AND VICE VERSA.

SINCE THERE IS A DEFINITE RELATION BETWEEN THE A.C. VOLTAGE AND THE RESULTING PLATE CURRENT, THE INSTRUMENT CAN BE CALIBRATED SO THAT PLATE CURRENT READINGS AS INDICATED BY THE MILLIAMMETER CAN BE INTERPRETED AS A.C. VOLTAGE. WE SHALL GO INTO THE CALIBRATION OF V.T. VOLTMETERS A LITTLE LATER IN THIS LESSON. FOR THE PRESENT, WE SHALL GO INTO THE CONSTRUCTIONAL FEATURES OF DIFFERENT DESIGNS MORE THOROUGHLY.

AN A.C. — OPERATED V.T. VOLTMETER

IN FIG. 3 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF A V.T. VOLTMETER WHICH IS A.C. OPERATED AND THEREFORE REQUIRES NO BATTERY UP-KEEP. THE

POWER PACK FOR THIS INSTRUMENT MAY BE THE SAME AS THAT EMPLOYED IN AN ORDINARY RECEIVER, EMPLOYING A BH GASEOUS RECTIFIER AS HERE ILLUSTRATED OR ELSE AN -80 OR -82 FILAMENT TYPE RECTIFIER, PROVIDED THAT THE CIRCUIT BE ALTERED CORRESPONDINGLY.

THE TUBE AS USED IN THE INDICATING SYSTEM OF THIS INSTRUMENT, YOU WILL NOTICE, IS A TYPE -30 BATTERY TUBE WHICH IS RATHER UNUSUAL IN A CIRCUIT DEPENDING UPON AN A.C. POWER SUPPLY. UPON CLOSER INSPECTION OF FIG. 3, HOWEVER, YOU WILL OBSERVE THAT THE CIRCUIT ARRANGEMENT IS SUCH THAT THE FILAMENT OF THE -30 TUBE IS BEING SUPPLIED WITH D.C. WHICH IS RECEIVED FROM THE "B" CIRCUIT OF THE POWER SUPPLY THROUGH ADEQUATE RESISTANCE. SINCE THE FILAMENT CURRENT REQUIREMENTS OF THE 30 TUBE ARE COMPARATIVELY LOW THIS DOESN'T PLACE AN ABNORMAL LOAD UPON THE "B" SYSTEM OF THE POWER PACK. THE -30 TUBE HAS EXCELLENT CHARACTERISTICS FOR THIS WORK. ALSO NOTICE THAT A SINGLE 30 HENRY CHOKE, TOGETHER WITH A 4 MFD. CONDENSER, OFFERS ADEQUATE FILTERING FOR THE "B" SUPPLY.

IN ORDER TO MAINTAIN THE PROPER VOLTAGE ON THE CIRCUIT, A 0-3 VOLT D.C. VOLTMETER IS CONNECTED ACROSS THE -30 TUBE'S FILAMENT. WITH THIS

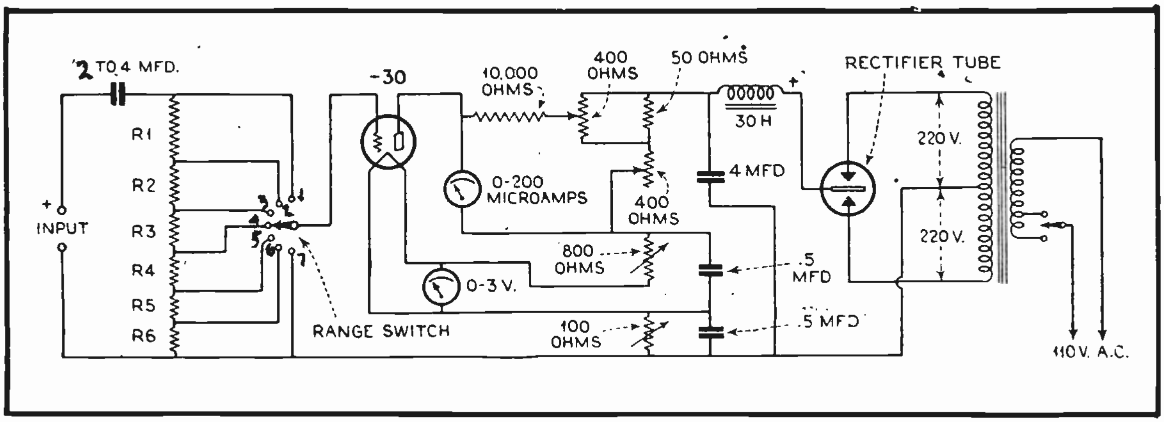

FIG. 3
Circuit of the A.C. Operated V.T. Voltmeter.

METHOD OF INDICATION, A CONSTANT CURRENT CAN BE MAINTAINED IN THE DIVIDER RESISTORS, WITH THE RESULT THAT IDENTICAL VOLTAGES ARE ALWAYS APPLIED TO THE TUBE WHEN IN OPERATION.

IT IS WELL TO BEAR IN MIND THAT THE TUBE SELECTED FOR THE METER BE ONE THAT HAS BEEN USED FOR A PERIOD OF 40 OR 50 HOURS. IN THIS WAY, CERTAIN IRREGULARITIES WILL BE ELIMINATED WHICH ARE DUE TO CHANGE THE TUBE'S CHARACTERISTICS AFTER SOME USE.

THE RESISTORS WHICH ARE USED IN THE VOLTAGE DIVIDER NET-WORK SHOULD BE OF A HIGH QUALITY WIRE-WOUND TYPE. THE 100 AND 800 OHM RESISTORS, WHICH HAVE AN ARROW DRAWN THROUGH THEM IN THE DIAGRAM OF FIG. 3, SHOULD BE OF THE SEMI-VARIABLE TYPE, THAT IS WIRE-WOUND, WITH SLIDING ADJUSTING CLAMPS AS USED ON CONVENTIONAL VARIABLE VOLTAGE DIVIDER RESISTORS.

IN THE VOLTAGE DIVIDER, TWO 400 OHM, WIRE-WOUND POTENTIOMETERS ARE EMPLOYED, ONE OF THESE IS USED AS A RHEOSTAT IN THE PLATE CIRCUIT WHILE THE OTHER IS USED AS A POTENTIOMETER AND CONNECTED ACROSS THE 50 OHM RESISTOR. THE ARM OF THIS LATTER POTENTIOMETER IS CONNECTED TO THE PLATE SIDE OF THE MICROAMMETER THROUGH A 10,000 OHM PROTECTIVE RESISTOR. THE purpose of this potentiometer can best be explained in the followingmann-er:

With the primary winding of the power transformer connected to the 110 volt A.C. circuit and the 400 ohm rheostat adjusted so that the fila-ment voltage becomes 1.7 volts, which is desirable for operating the 30 tube in this meter, some plate current will be indicated by the microamm-eter. This is known as the RESIDUAL plate current and its value will be affected considerably by the setting of the 400 ohm potentiometer.Now then, with no A.C. signal voltage applied to the grid circuit of the tube, it is desirable that the microammeter indicate zero so as to simplify the read-ings. The circuit arrangement is such that a small "bucking" voltagefeeds from the 400 ohm potentiometer through the 10,000 ohm resistor and to the plate side of the microammeter and by careful adjustment, a position on the potentiometer can be found at which a bucking voltage of the proper magnitude can be obtained in order to cause the microammeter to read zero. This is the setting which is employed when the instrument is in use so that the meter needle will move across its scale with the zero mark as a starting point while A.C. voltages of various values are impressed across its input circuit. The .5 mfd. condensers as placed in this circuit are used for bypassing purposes only.

The input to the vacuum tube voltmeter (grid to filament) is shunted with a series combination of precision resistors which serve the purpose of a divider network in order to secure various ranges of the meter. This network must be reasonably high in value so that the power consumed by the by the instrument shall be of negligible quantity. The network consists of six individual precision resistors, each of such a value so as to give a suitable multiplying factor to increase the range of the instrument. The value of these resistors is given in Fig. 4. The total resistance of this input network thus becomes equal to 1,000,000 ohms and a selector switch is provided by means of which various meter ranges can be obtained.

Resistor	Value in Ohms
R_1	500,000
R_2	300,000
R_3	100,000
R_4	80,000
R_5	10,000
R_6	10,000

FIG. 4
Resistor Table for the V.T. Voltmeter.

By closer inspection of the circuit in Fig. 3, you will observe that the voltage divider pro-vides a permanent path for the bias voltage, and the A.C. voltages which are to be measured are applied across the input divider through a 2 or 4 mfd. condenser. This condenser should be of a high quality paper dielect-ric type.

The entire unit can be housed in a compact cabinet or handy carry-ing case and with its panel lay-out arranged as shown in Fig. 5.

When placing the range selector switch in Fig. 3 in the "straight-up" position or position #1, an A.C. input voltage of approximately 2 volts will offer full-scale deflection on the microammeter and no multip-lying factor will be required to interpret the meter reading.

With this point in mind, let us now see how such an instrument is calibrated.

CALIBRATING THE METER

The first step is to connect the tester to the 110 volt A.C. line

AND ADJUST THE 400 OHM RHEOSTAT SO THAT THE FILAMENT VOLTAGE FOR THE -30 TUBE BECOMES 1.7 VOLTS AS ALREADY SPECIFIED. PERMIT THE TUBE TO "HEAT UP" TO NORMAL TEMPERATURE AND THEN ADJUST THE 800 AND 100 OHM RESISTORS SO THAT THE PLATE VOLTAGE OF THE -30 TUBE BECOMES 48V. AND THE BIAS VOLTAGE 5.8V. OBSERVE THE RESIDUAL PLATE CURRENT AS INDICATED BY THE MICROAMMETER. NOW ADJUST THE 400 OHM POTENTIOMETER VERY SLOWLY UNTIL THE MICROAMMETER OFFERS A ZERO READING. THE INSTRUMENT IS NOW PREPARED FOR CALIBRATION.

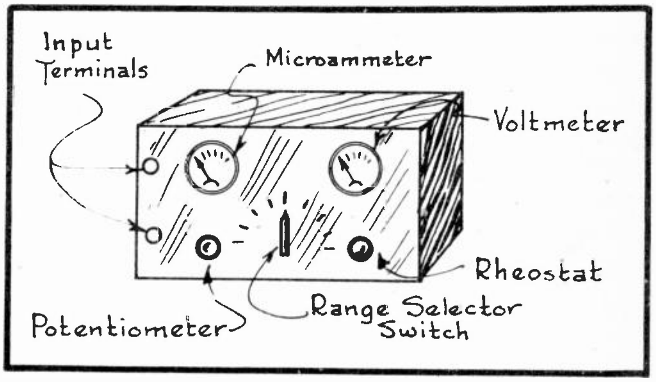

FIG. 5
The Assembled V. T. Voltmeter.

THE SET-UP FOR CALIBRATING THE V.T. VOLTMETER IS CLEARLY ILLUSTRATED IN FIG. 6. HERE YOU WILL OBSERVE THAT WE HAVE FIRST A TRANSFORMER. THIS MAY BE AN ORDINARY POWER TRANSFORMER HAVING A 110 VOLT PRIMARY WINDING AND A SECONDARY WINDING RATED ANYWHERES FROM 2.5 UP TO 10 VOLTS. A 400 OHM WIRE-WOUND POTENTIOMETER IS CONNECTED ACROSS THE SECONDARY AND TO THE INPUT TERMINALS OF THE V.T. VOLTMETER AS HERE SHOWN. BY MEANS OF THIS POTENTIOMETER, VARIOUS CONTROLLED VALUES OF A.C. VOLTAGES CAN BE APPLIED ACROSS THE INPUT TERMINALS.

THIS VOLTAGE INPUT TO THE V.T. VOLTMETER SHOULD BE MEASURED CAREFULLY WITH A PRECISION TYPE LOW-RANGE A.C. VOLTMETER OF KNOWN ACCURACY WHICH IS CONNECTED ACROSS THE INPUT TERMINALS OF THE V.T. VOLTMETER AS SHOWN IN FIG. 6.

IN CONDUCTING THIS CALIBRATION TEST, THE CALIBRATING POTENTIOMETER IS ADJUSTED FIRST FOR A VERY LOW A.C. VOLTAGE AS SHOWN BY THE A.C. VOLTMETER, FOR EXAMPLE .1 VOLT, AND THE CORRESPONDING READING ON THE MICROAMMETER NOTED WHILE THE RANGE SELECTOR SWITCH IS IN POSITION #1. THE CALIBRATING POTENTIOMETER IS THEN ADJUSTED FOR A SLIGHTLY HIGHER READING ON THE A.C. VOLTMETER AS .2 VOLTS, FOR INSTANCE, AND AGAIN THE CORRESPONDING READING ON THE MICROAMMETER IS OBSERVED. THIS PROCEDURE IS CONTINUED IN THIS MANNER BY GRADUALLY USING LARGER A.C. INPUT VOLTAGES AS DETERMINED BY THE CALIBRATING POTENTIOMETER AND INDICATED ON THE A.C. VOLTMETER. THE CORRESPONDING PLATE CURRENT IS READ FOR EACH VOLTAGE STEP UNTIL A MAXIMUM A.C. INPUT VOLTAGE OF 2 VOLTS IS ATTAINED. YOU WILL FIND THAT AS THE A.C. INPUT VOLTAGE IS INCREASED, THE PLATE CURRENT AS INDICATED BY THE MICROAMMETER WILL ALSO INCREASE CORRESPONDINGLY.

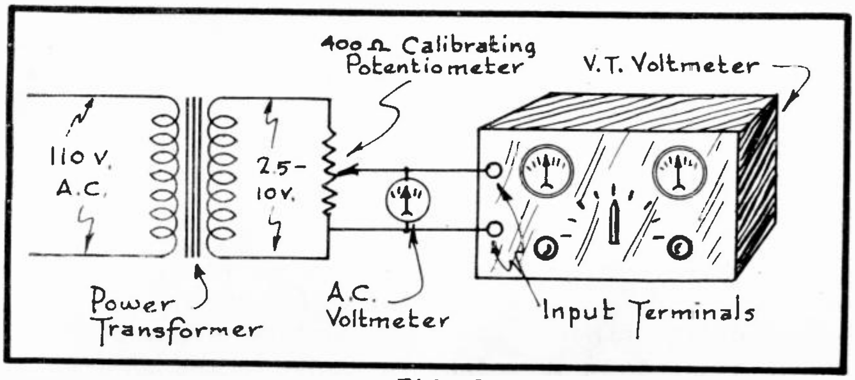

FIG. 6
The Calibration Set-Up

AFTER YOU

HAVE OBTAINED ABOUT TWELVE DIFFERENT VOLTAGE INPUT READINGS, TOGETHER WITH THEIR CORRESPONDING MICROAMMETER READINGS, YOU CAN PLOT ON A GRAPH EACH OF THE MICROAMMETER READINGS AGAINST THE CORRESPONDING A.C. INPUT VOLTAGE READINGS AS SHOWN IN FIG. 7. THEN BY DRAWING A CONTINUOUS LINE THROUGH THE POINTS THUS PLOTTED, YOU WILL OBTAIN THE RESULTING CALIBRATION CURVE APPEARING IN FIG. 7.

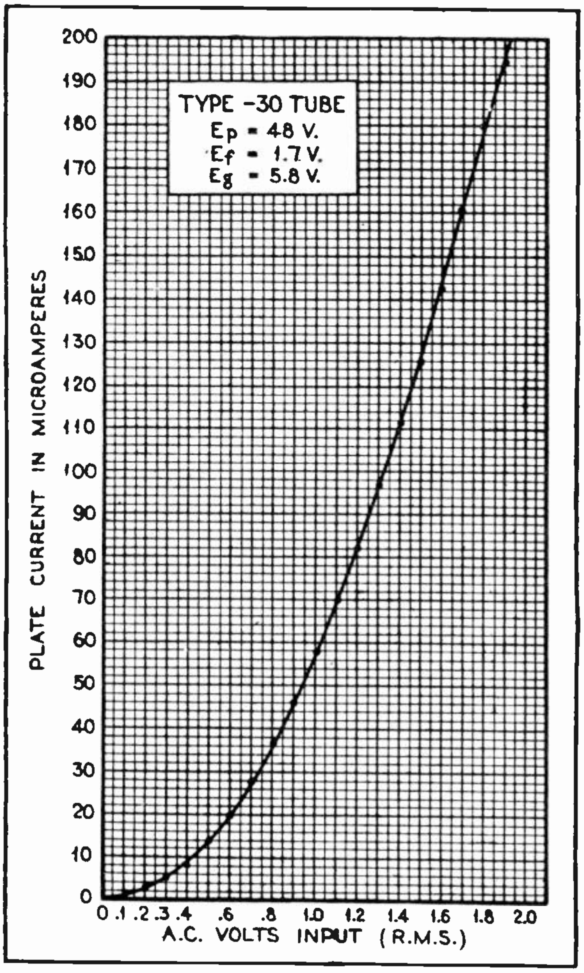

FIG. 7
The Calibration Curve.

SINCE THE A.C. METER WAS USED DURING THE CALIBRATION PROCESS AND INDICATED EFFECTIVE VOLTS, IT IS CLEAR THAT THE V.T. METER HAS BEEN CALIBRATED FOR A.C. VOLTS INPUT EXPRESSED IN EFFECTIVE OR R.M.S. VALUES.

WITH THE JOB OF CALIBRATION THUS COMPLETED, ANY UNKNOWN A.C. VOLTAGE, NOT GREATER THAN 2 VOLTS, CAN BE IMPRESSED ACROSS THE INPUT TERMINALS OF THE V.T. VOLTMETER WITH THE RANGE SELECTOR SWITCH IN THE LOWEST OR FIRST POSITION AND THE MICROAMMETER READING NOTED. FOR INSTANCE, IF THE MICROAMMETER READING HAPPENS TO BE 20 MICROAMPERES DURING THIS TEST, WE SIMPLY REFER TO THE PLATE CURRENT LINE MARKED "20" AT THE LEFT OF THE GRAPH IN FIG. 7 AND FOLLOW THIS LINE TOWARDS THE RIGHT UNTIL WE COME TO THE POINT WHERE IT INTERSECTS THE CALIBRATION CURVE. FROM HERE, WE FOLLOW THE VERTICAL INTERSECTION LINE STRAIGHT DOWNWARD AND NOTE THE CORRESPONDING A.C. INPUT VOLTAGE WHICH IN THIS PARTICULAR CASE HAPPENS TO BE .6 VOLT EFFECTIVE. IN LIKE MANNER, ANY OTHER UNKNOWN A.C. INPUT VOLTAGE WITHIN THE RANGE OF THE INSTRUMENT CAN BE APPLIED TO THE INPUT TERMINALS OF THE V.T. VOLTMETER, THE PLATE CURRENT NOTED AND THE VALUE OF THE A.C. VOLTAGE DETERMINED BY REFERENCE TO THE CALIBRATION CURVE AS ALREADY DESCRIBED.

BEAR IN MIND, THAT BEFORE USING THE V.T. VOLTMETER, IT IS ALWAYS NECESSARY THAT ITS FILAMENT, PLATE AND GRID BIAS VOLTAGE BE THE SAME VALUES AS THEY WERE DURING CALIBRATION AND THAT THE INSTRUMENT BE BALANCED FOR A ZERO READING ON THE MICROAMMETER WHEN NO A.C. VOLTAGE IS APPLIED ACROSS ITS INPUT TERMINALS.

THE DESIGN OF THE INSTRUMENT ILLUSTRATED IN FIG. 3 IS SUCH THAT THE SAME CALIBRATION CURVE CAN BE USED FOR ANY OF THE SIX RANGES WHICH THE INSTRUMENT OFFERS. WHEN USING ANY RANGE OTHER THAN THE LOWEST ONE (POSITION #1 OF THE RANGE SWITCH), IT IS ONLY NECESSARY TO REFER TO THE CALIBRATION CHART AS USUAL BUT THE A.C. VOLTAGE VALUE DETERMINED IN THIS WAY MUST BE MULTIPLIED BY THE MULTIPLYING FACTOR SPECIFIED IN FIG. 8. IN OTHER WORDS,

WITH THE RANGE SELECTOR SWITCH IN POSITION #1, THE MAXIMUM A.C. VOLTAGE IS 2 VOLTS AND THE VOLTAGE VALUES ARE DETERMINED DIRECTLY FROM THE CALIBRATION CURVE. IF THE RANGE SELECTOR SWITCH IS PLACED IN POSITION #2, THEN A RANGE OF 2 TO 4 VOLTS IS COVERED AND THE VOLTAGE VALUE AS DETERMINED FROM THE CALIBRATION CURVE WILL HAVE TO BE MULTIPLIED BY 2 IN ORDER TO OBTAIN THE CORRECT VOLTAGE ETC. FROM THIS DESCRIPTION, FIG. 8 WILL BE SELF-EXPLANATORY.

POSITION OF RANGE SWITCH	RANGE COVERED	MULTIPLYING FACTOR
1	0 - 2 V	DIRECT READING
2	2 - 4 V	2
3	4 - 10 V	5
4	10 - 20 V	10
5	20 - 100 V	50
6	100 - 200 V	100

FIG. 8
Meter Ranges and Multiplying Factors.

SHOULD PEAK VOLTAGE READINGS BE DESIRED INSTEAD OF EFFECTIVE VOLTAGE, THEN THIS CAN BE ACCOMPLISHED IN EITHER OF TWO WAYS. ONE METHOD IS TO DETERMINE THE EFFECTIVE VOLTAGE VALUE FROM THE CALIBRATION CHART AND THEN CALCULATE THE PEAK VOLTAGE FROM THE RELATION THAT THE PEAK VALUE IS EQUAL TO 1.41 TIMES THE EFFECTIVE VALUE. A MORE CONVENIENT METHOD IS TO MAKE A SEPARATE CALIBRATION CURVE FOR PEAK VOLTAGES BY CONVERTING THE EFFECTIVE VOLTS INTO PEAK VOLTS BY CALCULATION DURING THE CALIBRATION PROCESS AND THEN PLOTTING THESE PEAK VOLTAGE VALUES AGAINST THE PLATE CURRENT READINGS AND DRAWING THE CURVE. IN THIS WAY, PEAK VOLTAGES CAN BE DETERMINED DIRECTLY FROM THE GRAPH AND FURTHERMORE, YOU THEN HAVE TWO HANDY CALIBRATION CHARTS FOR QUICK REFERENCE -- ONE FOR EFFECTIVE OR R.M.S. VOLTAGES AND THE OTHER FOR PEAK VALUES.

APPLICATION OF THE V.T. VOLTMETER

NOW THAT YOU ARE FAMILIAR WITH THE CONSTRUCTION AND METHOD OF READING A V.T. VOLTMETER, LET US CONTINUE WITH DIFFERENT APPLICATIONS OF THIS INSTRUMENT TO PRACTICAL TESTING JOBS.

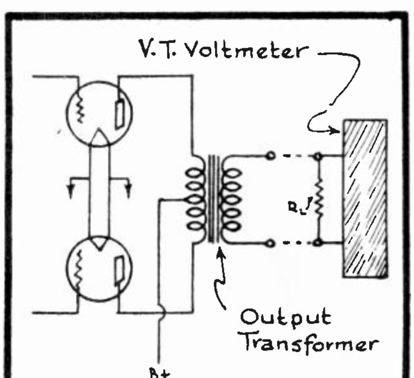

FIG. 9
Measuring Power Output.

MEASURING POWER OUTPUT

IN FIG. 9 YOU ARE SHOWN THE SET-UP FOR MEASURING THE POWER OUTPUT OF A RECEIVER OR AMPLIFIER. TO MAKE THIS TEST, THE SPEAKER VOICE COIL IS DISCONNECTED FROM THE SECONDARY WINDING OF THE OUTPUT TRANSFORMER AND RESISTOR R_L IS CONNECTED IN ITS PLACE. THE RESISTANCE VALUE OF R_L SHOULD BE EQUAL TO THE IMPEDANCE RATING OF THE SPEAKER VOICE COIL TO WHICH THE SECONDARY WINDING OF THE OUTPUT TRANSFORMER IS MATCHED.

THE INPUT TERMINALS OF THE V.T. VOLTMETER ARE CONNECTED ACROSS R_L. AN AUDIO SIGNAL OF ABOUT 400 CYCLES IS THEN FED INTO THE INPUT END OF THE AMPLIFIER. THIS SIGNAL MAY BE FURNISHED BY AN A.F. OSCILLATOR OR IF IT IS DESIRED TO PASS IT THROUGH THE ENTIRE RECEIVER, AN R.F. OSCILLATOR MODULATED AT THIS FREQUENCY MAY BE COUPLED TO THE INPUT END OF THE RECEIVER.

As the signal current flows through R_L, the resulting voltage drop across R_L is measured by the V.T. voltmeter. This voltage should be expressed in an effective value and the power output can then be determined by using the formula $W = \frac{E^2}{R}$, where W = power output in watts; E = effective voltage across R_L as determined by measurement and R = resistance value of resistor R_L expressed in ohms.

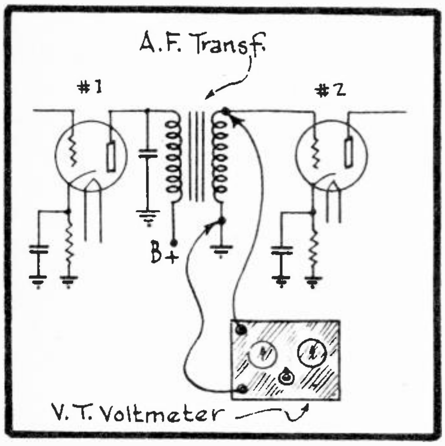

FIG. 10
Signal Voltage Measurement.

HUM MEASUREMENT

To measure the hum output of a receiver or amplifier, you can use the same set-up as illustrated in Fig. 9 only that the voltage reading across R_L is taken without any signal input into the amplifier or receiver. The resulting reading will then be in terms of "hum voltage".

MEASURING A.F. SIGNAL VOLTAGE

Fig. 10 shows you the set-up for measuring the signal voltage across the grid circuit of a tube. Here, for instance, the V.T. voltmeter is connected across the secondary winding of the A.F. transformer and will therefore measure the A.C. signal voltage which is developed across this winding. In this manner, one can determine whether or not the signal voltage across the grid circuit of tube #2 exceeds the D.C. bias voltage which is applied to this same tube. As you will recall, the bias voltage should exceed the peak A.C. signal voltage in order to prevent distortion.

CONSTRUCTION OF AN A.F. OSCILLATOR

When testing and shooting trouble in A.F. amplifiers, an A.F. oscillator will be found to be very handy. The circuit diagram of such an oscillator, which can be built at low cost, is illustrated for you in Fig. 11.

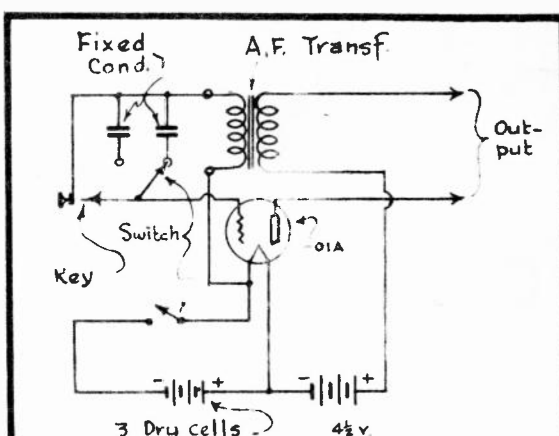

FIG. 11
A Simple but Effective A.F. Oscillator Circuit.

The key is not altogether necessary but frequently is of use to cause signal interruption while making tests. The fixed condensers, with the accompanying switch, which are connected across the primary of the audio transformer, are used to alter the frequency being generated. The choice of their capacity depends upon the constructor, they may be a .002 mfd. and a 0.025 mfd. or even more such condensers can be used. The condenser switch can then be set to the position offering the desired tone.

THE SIGNAL CAN BE HEARD BY CONNECTING A PAIR OF HEADPHONES ACROSS THE OUTPUT AND IN THIS MANNER CAN BE USED IN CONJUNCTION WITH THE KEY AS A CODE PRACTICE SET IF SO DESIRED.

APPLICATION OF THE A.F. OSCILLATOR

A SERVICE USE OF THIS OSCILLATOR IS ILLUSTRATED IN FIG. 12. HERE THE OUTPUT OF THE OSCILLATOR IS CONNECTED ACROSS THE GRID CIRCUIT OF A RECEIVER A.F. AMPLIFIER STAGE. THUS AUDIO FREQUENCIES CAN BE IMPRESSED UPON THE RECEIVER'S AUDIO AMPLIFIER AND BE REPRODUCED BY THE SPEAKER. IN THIS WAY, THE AMPLIFIER CAN BE CHECKED FOR ITS FAITHFULNESS IN REPRODUCING VARIOUS FREQUENCIES OR ELSE THIS SIGNAL CAN BE USED AS AN AID IN LOCATING CIRCUIT TROUBLE IN THE AMPLIFIER.

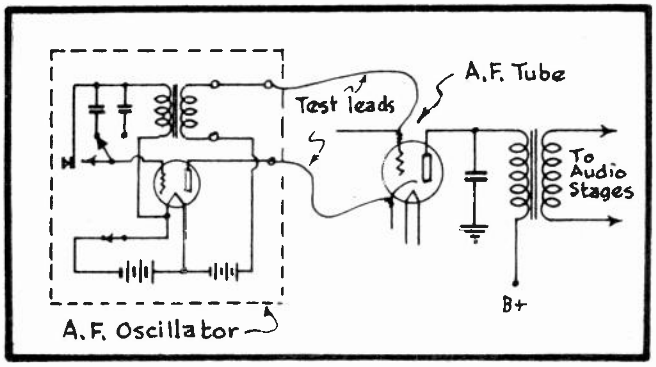

FIG. 12
Testing With A.F. Oscillator.

IT IS NOT ALWAYS NECESSARY TO CONNECT THE OSCILLATOR TO THE CIRCUIT AS SHOWN IN FIG. 12 BUT ANY CONNECTION SUITABLE FOR A PHONOGRAPH PICK-UP INSTALLATION CAN ALSO BE USED WITH THIS OSCILLATOR. BY HAVING A VARIETY OF BY-PASS CONDENSERS CONNECTED IN PARALLEL WITH THE PRIMARY OF THE OSCILLATOR'S TRANSFORMER, A CONSIDERABLE RANGE OF TEST FREQUENCIES IS AVAILABLE.

THE GRID-DIP OSCILLATOR

IN FIG. 13 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF A BATTERY OPERATED GRID-DIP TYPE SERVICE OSCILLATOR. WHEN USING THIS OSCILLATOR FOR ALIGNING THE TUNING CIRCUITS OF RECEIVERS ETC., THE NEEDLE OF THE MILLIAMMETER, WHICH IS CONNECTED IN THE GRID CIRCUIT OF THE OSCILLATOR, WILL UNDERGO A "DIPPING" ACTION WHENEVER THE RECEIVER CIRCUIT UNDER TEST IS TUNED TO RESONANCE WITH THE FREQUENCY GENERATED BY THE OSCILLATOR. HENCE THE APPROPRIATE NAME "GRID-DIP OSCILLATOR".

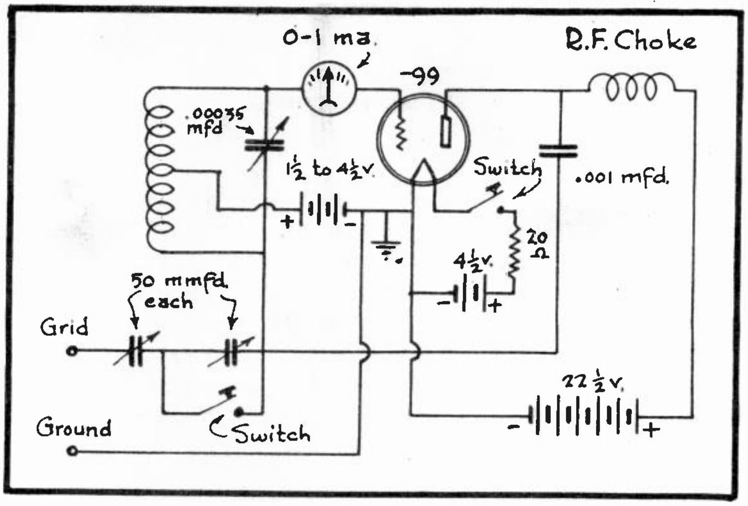

FIG. 13
Grid-Dip Oscillator Circuit for Battery Operation.

THE VALUES OF MOST OF THE PARTS USED IN THE CONSTRUCTION OF THIS OSCILLATOR ARE GIVEN DIRECTLY IN THE DIAGRAM OF FIG. 13. THE TUNED WINDING SHOULD CONSIST OF 120 TURNS OF #28 B&S ENAMELED WIRE WOUND ON A TUBULAR FORM HAVING A 2" DIAMETER. THE ADJACENT TURNS ARE WOUND SIDE BY SIDE WITHOUT SPACING AND THE WINDING IS CENTER-TAPPED. THE ENTIRE UNIT IS HOUSED IN A METAL CONTAINER WHICH

SERVES AS A SHIELDING AND THE METER, TUNING DIAL, SWITCHES AND CONTROL KNOBS FOR THE 50 MMFD. VARIABLE CONDENSERS, AS WELL AS THE TERMINALS FOR THE EXTERNAL CIRCUIT CONNECTIONS ARE MOUNTED ON A CONTROL PANEL OF THE BOX.

THE CIRCUIT FOR THE SAME OSCILLATOR AS ADAPTED FOR OPERATION ON A 110 VOLT A.C. LIGHTING CIRCUIT IS ILLUSTRATED FOR YOU IN FIG. 14. THE POWER TRANSFORMER, WHICH IS USED FOR THIS PURPOSE, CONSISTS OF A PRIMARY WINDING DESIGNED FOR 110 VOLTS AND A SINGLE SECONDARY WINDING DESIGNED FOR 25 OR 30 VOLTS. THE TRANSFORMER AS USED IN SOME MODELS OF TRICKLE CHARGERS WILL SERVE THIS PURPOSE.

THE TWO 50 MMFD. CONDENSERS ARE COUPLING CONDENSERS BY MEANS OF WHICH LOOSE COUPLING CAN BE OBTAINED BETWEEN THE OSCILLATOR AND THE SET UNDER TEST AT THE HIGH FREQUENCIES AND CLOSE COUPLING AT THE LOW FREQUENCIES. A SWITCH IS PROVIDED FOR SHORTING ONE OF THESE CONDENSERS WHEN CLOSE COUPLING IS DESIRED AND BRINGS IT BACK INTO EFFECT WHEN LOOSE COUPLING IS DESIRED.

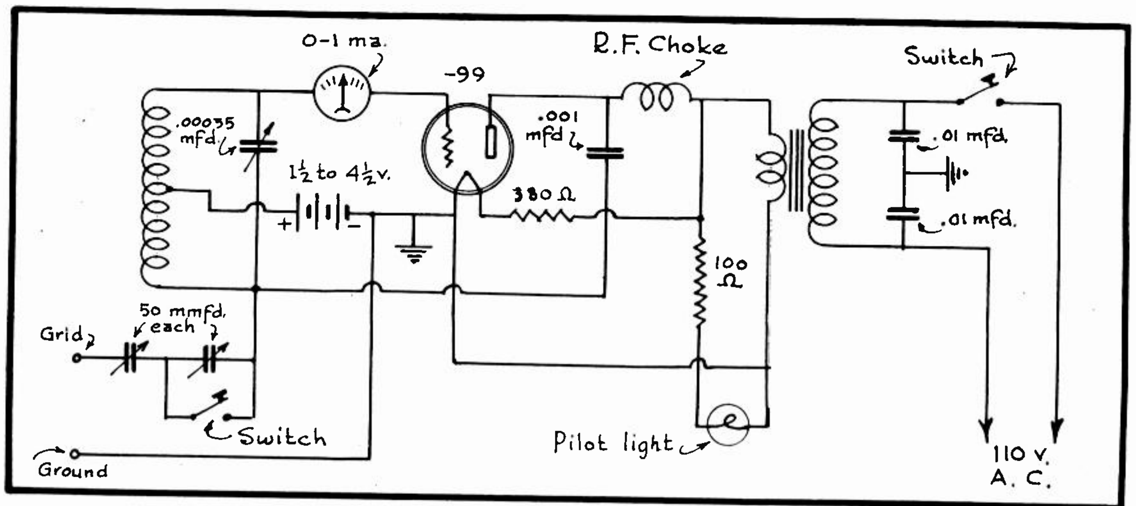

FIG. 14

The A.C. Operated Grid-Dip Oscillator.

THE COUPLING IS ADJUSTED SO THAT THE MILLIAMMETER NEEDLE DROPS GRADUALLY TO A MINIMUM VALUE AS THE CIRCUIT UNDER TEST IS BROUGHT INTO RESONANCE AND COMES UP AGAIN GRADUALLY AS THE RESONANCE POINT IS PASSED. TOO CLOSE COUPLING WILL CAUSE A METER DEFLECTION WHICH IS TOO ABRUPT FOR ACCURACY.

IN ORDER TO BALANCE THE TUNING CIRCUITS OF A RECEIVER'S R.F. AMPLIFIER WITH THIS OSCILLATOR, THE RECEIVER'S POWER SWITCH IS LEFT IN THE "OFF" POSITION. THE GROUND TERMINAL OF THE OSCILLATOR IS THEN CONNECTED TO THE GROUND TERMINAL OF THE RECEIVER AND THE GRID TERMINAL OF THE OSCILLATOR TO THE CONTROL GRID OF THE FIRST R.F. TUBE. THE OSCILLATOR IS THEN PUT INTO OPERATION AND ADJUSTED FOR A FREQUENCY OF ABOUT 1400 KC. THE TRIMMER CONDENSER FOR THIS PARTICULAR TUNING CIRCUIT IN THE RECEIVER IS THEN ADJUSTED SLOWLY UNTIL THE MILLIAMMETER NEEDLE DIPS TO A MINIMUM POSITION, AT WHICH TIME THE RECEIVER'S TUNED CIRCUIT WILL BE AT RESONANCE WITH THE OSCILLATOR FREQUENCY.

THIS SAME PROCESS IS REPEATED FOR EACH OF THE RECEIVER'S TUNING CIRCUITS IN THE SAME MANNER. WHEN ALL OF ITS STAGES HAVE BEEN RESONATED TO

THIS FREQUENCY, THE SET CAN AGAIN BE CHECKED FOR ALIGNMENT AT AN OSCILLATOR FREQUENCY CORRESPONDING TO THE CENTER OF THE BROADCAST BAND AND AGAIN AT A LOW BROADCAST FREQUENCY.

AS YOU CONTINUE WITH YOUR STUDIES, YOU WILL RECEIVE ADDITIONAL INSTRUCTION REGARDING THE USE OF THE TESTING DEVICES WHICH ARE DESCRIBED IN THIS LESSON.

IN THE NEXT LESSON, THE DESIGN AND CONSTRUCTION OF POWER TRANSFORMERS IS GOING TO BE EXPLAINED TO YOU IN DETAIL AND WITHOUT A DOUBT, YOU ARE GOING TO FIND IT TO BE ESPECIALLY INTERESTING AND INSTRUCTIVE. THE LESSON IS PRACTICAL BUT SPECIFIC REGARDING ALL POINTS ASSOCIATED WITH POWER TRANSFORMER DESIGNING PRACTICE.

YOU NO DOUBT REALIZE BY THIS TIME THAT NOTHING IS BEING OVERLOOKED IN THE WAY OF PREPARING THIS COURSE OF INSTRUCTION SO THAT YOU MAY RECEIVE THE COMPLETE TRAINING YOU NEED IN ORDER TO ATTAIN SUCCESS IN THE RADIO PROFESSION.

BEAR IN MIND, THAT THERE IS ALWAYS A GOOD POSITION OPEN IN THE RADIO INDUSTRY FOR THE MAN WHO IS FULLY QUALIFIED AND THE COMPLICATIONS IN THE DESIGN OF MODERN EQUIPMENT IS RAPIDLY WEEDING OUT THE SO-CALLED PRACTICAL MECHANICS AND ELECTRICIANS WHO THROUGH LACK OF TRAINING CANNOT KEEP UP WITH THE RAPID PROGRESS MADE BY THE INDUSTRY. THIS CONDITION IS IDEAL FOR THE TRAINED MAN IN THAT IT OFFERS HIM STILL GREATER OPPORTUNITIES AND PLACES THE ENTIRE RADIO INDUSTRY ON A HIGHER PAYING BASIS.

THE TECHNICIAN POSSESSING OUTSTANDING SKILL AND ABILITY CAN DEMAND A HIGH SALARY WHILE A MAN WITH LITTLE OR NO TECHNICAL TRAINING HAS TO BE CONTENT WITH WHATEVER COMPENSATION HE CAN GET.

NATIONAL'S INTENTIONS ALWAYS HAS AND ALWAYS WILL BE TO PREPARE ITS STUDENTS FOR THE BETTER JOBS IN THE INDUSTRY.

Examination Questions

Ans Mar 11, 41

LESSON NO. 58

"Success without difficulty, or achievement without effort, is robbed of most of its triumph".

1. – Explain the basic constructional and operating principles of the vacuum tube voltmeter.

2. – What are some of the chief advantages which the V.T. voltmeter has to offer?

3. – What provision is generally made in the circuits of a V.T. voltmeter so that the meter in its plate circuit will offer a zero reading when no A.C. signal voltage is applied across its input terminals?

4. – Explain how you would calibrate a V.T. voltmeter for A.C. voltages expressed in effective values.

5. – How would you calibrate a V.T. voltmeter for A.C. voltages expressed in peak values?

6. – Mention some of the tests to which a V.T. voltmeter may be applied.

7. – What is the essential difference between an A.F. oscillator and a modulated R.F. test oscillator?

8. – Of what particular value is an A.F. oscillator in radio service work?

9. – Describe a grid-dip oscillator.

10. – How would you employ a grid-dip oscillator in order to align the tuning circuits of a T.R.F radio receiver?

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LESSON NO. 59

DESIGN AND CONSTRUCTION OF POWER TRANSFORMERS

THE DESIGN AND CONSTRUCTION OF POWER TRANSFORMERS FOR RADIO PURPOSES HAS ALWAYS AROUSED WIDE-SPREAD INTEREST AMONG RADIO SERVICE MEN AND EXPERIMENTERS. WE REALIZE THAT YOU TOO ARE NOW ANXIOUS TO ACQUIRE THE "INSIDE INFORMATION" CONCERNING THIS INTERESTING SUBJECT.

IT IS OF COURSE TRUE THAT IN THE GENERAL PROCEDURE OF RADIO SERVICE WORK, IT IS THE CUSTOMARY PRACTICE TO REPLACE A BURNED OUT POWER TRANSFORMER WITH A NEW ONE, WHICH AS A RULE CAN BE READILY OBTAINED FROM ANY RADIO SUPPLY STORE. NEVERTHELESS, ONE IS FREQUENTLY FACED WITH THE PROBLEM OF NOT BEING ABLE TO PURCHASE THE PARTICULAR TYPE OF POWER TRANSFORMER NEEDED AND UNDER SUCH CIRCUMSTANCES, THE ONLY SOLUTION IS TO DESIGN AND CONSTRUCT SUCH A UNIT TO FULFILL THE REQUIRED SPECIFICATIONS. FURTHERMORE, IN ORDER FOR YOUR RADIO TRAINING TO BE COMPLETE, YOU SHOULD HAVE AN UNDERSTANDING OF THIS SUBJECT.

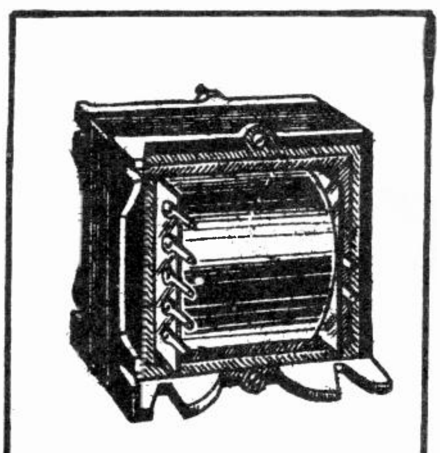

FIG. 1
A Typical Power Transformer.

THIS TYPE OF WORK IS NOT DIFFICULT, PROVIDED THAT ONE HAS THE NECESSARY KNOWLEDGE TO WORK OUT THE DESIGN IN A SYSTEMATIC MANNER.

A GREAT DEAL HAS BEEN PUBLISHED IN THE PAST AS REGARDS POWER TRANSFORMER DESIGN BUT IN MANY CASES, THIS INFORMATION HAS BEEN PRESENTED IN SUCH A MANNER SO AS TO CONFUSE THE READER RATHER THAN TO ASSIST HIM IN GAINING A CLEAR CONCEPTION OF HOW PROBLEMS OF THIS NATURE SHOULD BE TREATED.

IN THE PREPARATION OF THIS LESSON, WE HAVE MADE A SPECIAL EFFORT TO PRESENT YOU WITH THE MOST PRACTICAL AND EASILY APPLIED METHODS SO FAR DEVISED FOR TRANSFORMER DESIGNING PRACTICE AND WE ARE CERTAIN THAT YOU ARE GOING TO FIND THIS INFORMATION VERY VALUABLE, AS WELL AS BEING EASY TO UNDER

STAND. THE SPECIAL FORMULAS, WHICH WE ARE GIVING YOU IN THIS LESSON, ARE SIMPLE IN THEIR APPLICATION BUT AT THE SAME TIME SUFFICIENTLY ACCURATE AS TO THE RESULTS OBTAINED THROUGH THEIR USE FOR ALL PRACTICAL PURPOSES.

ADAPTING A POWER TRANSFORMER TO A GIVEN CIRCUIT

THE FIRST THING TO CONSIDER IS THE CIRCUIT IN WHICH THE POWER TRANSFORMER IS TO BE USED. TO ILLUSTRATE THIS POINT, LET US CONSIDER THE CIRCUIT OF FIG. 2, WHERE WE HAVE A CONVENTIONAL FORM OF SEVEN-TUBE, A.C. OPERATED RECEIVER.

BY INSPECTING THIS CIRCUIT DIAGRAM, WE IMMEDIATELY NOTICE THAT THIS RECEIVER EMPLOYS TWO TYPE -35 "VARIABLE-MU" TUBES, A -24 POWER DETECTOR, A -27 AUDIO TUBE, TWO TYPE -45'S IN A PUSH-PULL POWER STAGE AND A TYPE -80 FULL-WAVE RECTIFIER. WITH ONLY THIS AMOUNT OF INFORMATION AVAILABLE, WE ARE

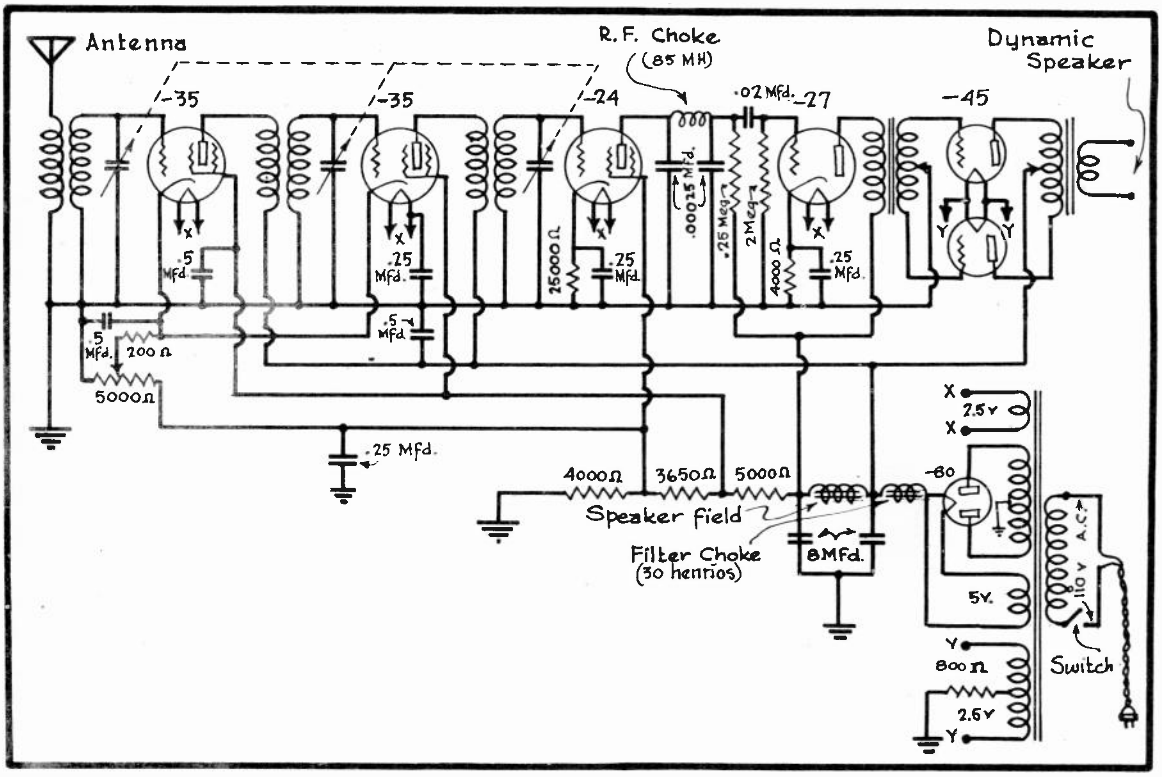

FIG. 2

A Seven-Tube A.C. Operated Receiver.

IN A POSITION TO DETERMINE THE POWER WHICH IS GOING TO BE REQUIRED FROM THE POWER TRANSFORMER, WHICH WE ARE CALLED UPON TO DESIGN FOR THIS PARTICULAR RECEIVER.

FILAMENT CURRENT DEMANDS

WE COMMENCE BY CALCULATING THE CURRENT WHICH IS TO BE CONSUMED BY THE VARIOUS FILAMENT CIRCUITS. FOR EXAMPLE, THE FILAMENTS FOR EACH OF THE -35, -24 AND -27 TUBES ARE TO BE OPERATED AT A VOLTAGE OF 2.5 VOLTS AND UNDER SUCH CONDITIONS WILL DRAW 1.75 AMPERES OF FILAMENT CURRENT. (THIS INFORMATION IS OBTAINED FROM A TABLE OF TUBE CHARACTERISTICS, SUCH AS YOU HAVE ALREADY RECEIVED AMONG YOUR LESSONS). THE FILAMENTS OF THESE AFORE-

MENTIONED TUBES ARE ALL TO BE CONNECTED IN PARALLEL AND TOGETHER CONNECTED ACROSS THE 2.5 VOLT SECONDARY WINDING, WHOSE EXTREMETIES ARE MARKED "X" IN FIG. 2. THEREFORE, THE TOTAL CURRENT WHICH IS TO BE DELIVERED BY THIS SECONDARY WINDING WILL BE 4 X 1.75 OR 7 AMPERES.

THE FILAMENTS OF THE TWO TYPE -45 POWER TUBES ARE TO BE CONNECTED TOGETHER IN PARALLEL AND ACROSS A DIFFERENT 2.5 VOLT SECONDARY WINDING, WHOSE EXTREMETIES ARE MARKED AS "Y" IN FIG. 2. EACH OF THESE -45 TUBES WILL DRAW A FILAMENT CURRENT OF 1.5 AMP. AND SO TOGETHER, THEY WILL DRAW 2X1.5 OR 3 AMPS. FROM THE SECONDARY "Y".

THE -80 RECTIFIER TUBE HAS ITS INDIVIDUAL 5 VOLT SECONDARY WINDING, FROM WHICH IT WILL DRAW A FILAMENT CURRENT OF 2 AMPERES.

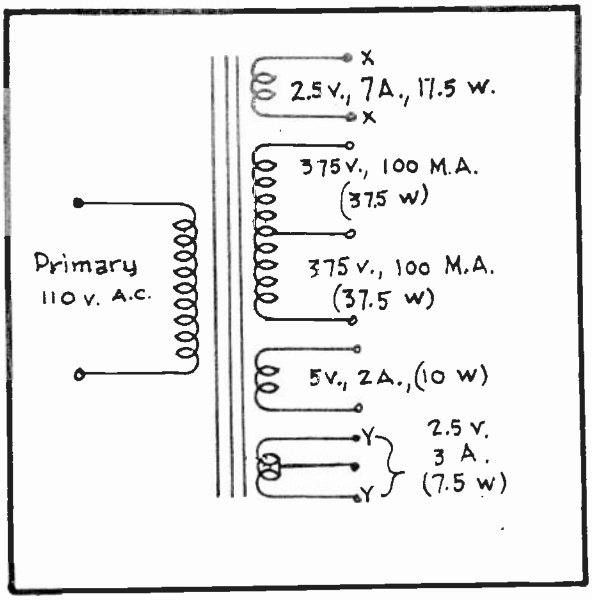

FIG. 3

Lay-out of the Transformer.

"B" CIRCUIT REQUIREMENTS

WE CONTINUE OUR ESTIMATE OF POWER CONSUMPTION BY NEXT CONSIDERING THE CURRENT WHICH IS REQUIRED BY THE "B" SUPPLY. TO BEGIN WITH, EACH OF THE TYPE -35 TUBES WILL DRAW A PLATE CURRENT OF ABOUT 6.5 MA., IN ADDITION TO A SCREEN-GRID CURRENT OF SLIGHTLY LESS THAN 1/3 THIS AMOUNT OR VERY NEARLY 2 MA. THE TOTAL "B" CURRENT DRAWN BY EACH OF THESE TUBES CAN THUS BE CONSERVATIVELY ESTIMATED AS BEING 6.5+2. OR 8.5 MA. BOTH OF THESE -35 TUBES TOGETHER WILL DRAW VERY NEARLY 2 X 8.5 = 17 MA.

THE -27 A.F. AMPLIFIER TUBE WILL DRAW A PLATE CURRENT OF APPROXIMATELY 5 MA., WHILE THE TWO -45 POWER TUBES WILL TOGETHER DRAW 64 MA. (32 MA. PER TUBE). THE POWER DETECTOR DRAWS VERY LITTLE "B" CURRENT, AT THE MOST, NOT EXCEEDING .5 MA. ALTOGETHER, THE "B" DEMAND FROM THE ENTIRE TUBE ASSEMBLY BECOMES 17+5+64+.5 = 86.5 MA.

IN ORDER TO AVOID "MOTOR BOATING" (A PUTT-PUTT SOUND SIMILAR TO THE NOISE PRODUCED BY THE EXHAUST OF A MOTOR BOAT), A BLEEDER CURRENT OF AT LEAST 6 TO 12 MA. SHOULD BE ALLOWED FOR THE "B" SUPPLY OF THE POWER PACK. THIS BLEEDER CURRENT WILL BE GOVERNED BY THE VALUE OF THE RESISTOR WHICH IS CONNECTED BETWEEN B- AND THE LOWEST B+ POTENTIAL USED IN THE CIRCUIT (THE 4000 OHM RESISTOR IN THE CASE OF FIG. 2). ADDING AN ALLOWABLE BLEEDER CURRENT OF 12 MA. TO OUR "B" CURRENT DRAWN BY ALL TUBES, WE FIND THE TOTAL "B" CURRENT DRAWN TO BE 86.5+12=98.5 MA.

TO SIMPLIFY MATTERS, WE WILL ASSUME A VALUE OF 100 MA. AS BEING THE TOTAL DIRECT CURRENT WHICH IS TO BE DRAWN FROM THE "B" SUPPLY OF THE POWER PACK. REMEMBER, THAT IT IS A GOOD PRACTICE TO ASSUME ALL LOAD REQUIREMENTS SOMEWHAT HIGH RATHER THAN LOW. THIS IS TRUE IN RESPECT TO ALL TRANSFORMER CALCULATIONS.

WE CAN NOW LAY OUT OUR TRANSFORMER IN THE DIAGRAM FORM AS SHOWN YOU

IN FIG. 3. OBSERVE THAT ON THIS DIAGRAM WE ARE INDICATING THE VOLTAGE AND CURRENT TO BE SUPPLIED BY EACH OF THE SECONDARY WINDINGS ACCORDING TO THE CALCULATIONS WHICH WE HAVE JUST COMPLETED. THE HIGH VOLTAGE WINDING, YOU WILL NOTE, IS BEING CONSIDERED AS DEVELOPING 375 VOLTS ACROSS EACH HALF, OR 750 VOLTS ACROSS THE ENTIRE WINDING.

WATTAGE REQUIREMENTS

OUR NEXT STEP IS TO CALCULATE THE WATTAGE OR POWER WHICH IS TO BE CONSUMED BY EACH OF THESE SECONDARY WINDINGS. BY APPLYING THE FORMULA "WATTS=VOLTS X AMPERES", WE FIND THE WATTAGE OF THE 2.5 VOLT SECONDARY, MARKED "X" IN FIG. 3, AS BEING 2.5 X 7=17.5 WATTS.

NOW IN THE CASE OF THE HIGH VOLTAGE SECONDARY, WHEN USED WITH FULL-WAVE RECTIFICATION, WE FIND THAT ONLY ONE-HALF OF THIS WINDING WILL DRAW CURRENT DURING EACH HALF OF THE A.C. CYCLE. THEREFORE, THE POWER CONSUMED BY EACH HALF OF THIS WINDING BECOMES 375 X .1=37.5 WATTS (100 MA=.1 AMP.). FURTHERMORE, SINCE ONLY HALF OF THIS WINDING DRAWS CURRENT DURING EACH HALF OF THE A.C. CYCLE, THE HIGH VOLTAGE SECONDARY WINDING, AS A WHOLE, WILL ONLY BE RATED AS HAVING A 37.5 WATT POWER CONSUMPTION OR THE SAME AS ONLY HALF OF THIS SAME WINDING.

THE 5 VOLT SECONDARY WINDING DRAWING 2 AMPERES, HAS A POWER CONSUMPTION OF 5 X 2=10 WATTS, WHILE THE 2.5 VOLT SECONDARY WINDING "Y" WILL REQUIRE 2.5 X 3=7.5 WATTS.

THE PRIMARY WATTAGE

WE ARE NOW READY TO CALCULATE THE WATTAGE OF THE POWER TRANSFORMER'S PRIMARY WINDING AND IN DOING THIS, WE MUST TAKE INTO CONSIDERATION A SLIGHT LOSS WHICH IS ENCOUNTERED BY THE TRANSFER OF ENERGY THROUGH THE CORE. THIS LOSS IS KNOWN AS THE "CORE LOSS" AND IS DISSIPATED IN THE FORM OF HEAT. FOR TRANSFORMERS HAVING A POWER RATING OF 500 TO 1500 WATTS, AN EFFICIENCY OF 95% CAN BE EXPECTED (THIS MEANS A 5% LOSS). FOR 100 TO 500 WATTS, THE EFFICIENCY DROPS TO ABOUT 90% (A 10% LOSS); WHILE IN SMALLER TRANSFORMERS, THE EFFICIENCY WILL PROBABLY BE IN THE NEIGHBORHOOD OF 85% (A 15% LOSS).

IN ORDER TO DETERMINE THE PRIMARY WATTAGE, WE HAVE A CONVENIENT FORMULA WHICH IS AS FOLLOWS:

PRIMARY WATTAGE=TOTAL SECONDARY WATTAGE÷EFFICIENCY EXPRESSED AS A DECIMAL FRACTION.

BY ADDING TOGETHER THE WATTAGES DEMANDED BY THE VARIOUS SECONDARY WINDINGS OF OUR TRANSFORMER WE HAVE: 17.5+37.5+10+7.5=72.5 WATTS. THIS VALUE CORRESPONDS TO THE "TOTAL SECONDARY WATTAGE", AS EXPRESSED IN THE ABOVE FORMULA. WE CAN NOW SEE AHEAD THAT OUR PARTICULAR TRANSFORMER IS GOING TO HAVE A RATING OF LESS THAN 100 WATTS, THEREFORE WE SHALL ASSUME AN EFFICIENCY OF 85% FOR THE UNIT, WHICH IS EQUIVALENT TO A LOSS OF 15%.

WE ARE NOW IN A POSITION TO SUBSTITUTE THESE VALUES IN OUR FORMULA IN THE FOLLOWING MANNER:

PRIMARY WATTAGE=72.5 ÷ .85=85.3 WATTS (NOTE THAT IN ORDER TO CONVERT

PERCENTAGE TO A DECIMAL FRACTION, IT IS ONLY NECESSARY TO DROP THE PERCENT SIGN AND MOVE THE DECIMAL POINT TWO PLACES TOWARDS THE LEFT. HENCE 85% BECOMES .85). FOR THE SAKE OF SIMPLICITY, WE WILL CONSIDER THE PRIMARY WATTAGE AS 85 WATTS.

CALCULATING THE TURNS PER VOLT

THE NEXT STEP IS TO DETERMINE THE "TURNS PER VOLT" FOR THE VARIOUS WINDINGS AND TO ASSIST US IN THIS WORK, WE HAVE A SERIES OF VERY HANDY FORMULAS AVAILABLE. HERE THEY ARE: IF THE TRANSFORMER CORE IS TO BE OF THE "CORE TYPE" AND THE UNIT IS TO BE OPERATED FROM A 60 CYCLE A.C. SUPPLY, THEN THE TURNS PER VOLT $= \dfrac{41}{\sqrt{\text{PRIMARY WATTAGE}}}$. IF THE TRANSFORMER CORE IS TO BE OF THE "CORE TYPE" AND THE UNIT IS TO BE OPERATED FROM A 25 CYCLE A.C. SUPPLY, THEN THE TURNS PER VOLT $= \dfrac{97}{\sqrt{\text{PRIMARY WATTAGE}}}$.

ON THE OTHER HAND, IF THE TRANSFORMER CORE IS TO BE OF THE "SHELL TYPE" AND THE UNIT IS TO BE OPERATED FROM A 60 CYCLE A.C. SUPPLY, THEN THE TURNS PER VOLT $= \dfrac{32}{\sqrt{\text{PRIMARY WATTAGE}}}$.

FINALLY, IF THE TRANSFORMER CORE IS TO BE OF THE "SHELL TYPE" AND THE UNIT IS TO BE OPERATED FROM A 25 CYCLE A.C. SUPPLY, THEN THE TURNS PER VOLT $= \dfrac{77}{\sqrt{\text{PRIMARY WATTAGE}}}$.

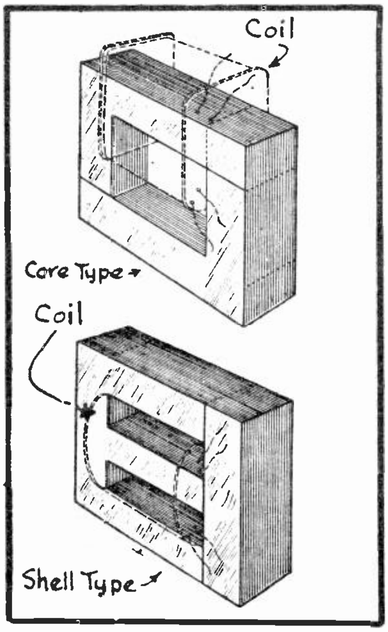

FIG. 4
The Transformer Cores.

FIG. 4 CLEARLY ILLUSTRATES THE DIFFERENCE BETWEEN A "CORE TYPE" AND "SHELL TYPE" TRANSFORMER CORE. AS YOU WILL OBSERVE FROM THIS ILLUSTRATION, THE WINDINGS ARE ALL WOUND ON ONE SIDE OR "LEG" OF THE CORE, IN THE CASE OF THE CORE TYPE ASSEMBLY, WHEREAS ON THE "SHELL TYPE" UNIT, THE WINDINGS ARE ALL PLACED ON A SPECIAL LEG AT THE CENTER OF THE ASSEMBLY. THE "CORE TYPE" UNIT IS EASIER TO CONSTRUCT BUT THE "SHELL TYPE" UNIT IS MORE EFFICIENT, THEREFORE, MOST COMMERCIAL TRANSFORMERS ARE OF THE "SHELL TYPE".

YOU WILL ALSO NOTICE THAT THE VARIOUS FORMULAS WHICH WERE GIVEN YOU IN REGARDS TO THE "TURNS PER VOLT," APPLY DIRECTLY ONLY TO THE TWO MOST COMMON A.C. LIGHTING SUPPLY FREQUENCIES OF 25 AND 60 CYCLES. HOWEVER, A TRANSFORMER DESIGNED FOR ONE PARTICULAR FREQUENCY CAN ALWAYS BE USED ON A SLIGHTLY HIGHER FREQUENCY THAN THAT FOR WHICH IT IS DESIGNED. THAT IS TO SAY, WE MAY USE A 25 CYCLE DESIGN FOR ANY FREQUENCY SLIGHTLY GREATER THAN 25 CYCLES AND A 60 CYCLE DESIGN FOR A FREQUENCY SLIGHTLY HIGHER THAN 60 CYCLES WITH OF COURSE, SOME LOSS OF POWER WHICH IS DISSIPATED IN THE FORM OF HEAT. THE 60 CYCLE TRANSFORMER WILL ALSO OPERATE SATISFACTORILY ON A 50 CYCLE LINE.

LET US ASSUME THAT THE SEVEN-TUBE RECEIVER, FOR WHICH WE ARE DESIGNING THE POWER TRANSFORMER, IS TO BE OPERATED FROM A 60 CYCLE A.C. 110 VOLT LIGHTING CIRCUIT AND THAT THE POWER TRANSFORMER IS TO BE OF THE "SHELL TYPE". THIS BEING THE CASE, WE DETERMINE THE TURNS PER VOLT BY USING THE

FORMULA: TURNS PER VOLT $= \dfrac{32}{\sqrt{\text{PRIMARY WATTAGE.}}}$

SINCE WE HAVE ALREADY CALCULATED OUR PRIMARY WATTAGE AS BEING 85 WATTS, THE TURNS PER VOLT FOR THIS PARTICULAR TRANSFORMER WILL WORK OUT AS FOLLOWS: TURNS PER VOLT $= \dfrac{32}{\sqrt{85}} = \dfrac{32}{9.2} = 3.48.$

IN ACTUAL PRACTICE, IT IS ADVISABLE TO SET THE TURNS PER VOLT FACTOR SLIGHTLY HIGHER RATHER THAN LOWER THAN THE VALUE FOUND BY CALCULATION. THAT IS TO SAY, IN ORDER TO AVOID FRACTIONAL TURNS SO AS TO SIMPLIFY WINDING, WE WILL SET OUR TURNS PER VOLT FACTOR TO THE NEXT WHOLE NUMBER OR 4. THIS MEANS THAT WE SHALL CONSTRUCT THE WINDINGS OF OUR TRANSFORMER ON THE BASIS OF 4 TURNS PER VOLT. ALTHOUGH THIS IS SLIGHTLY HIGHER THAN THE CALCULATED VALUE, IT IS SUFFICIENTLY CLOSE FOR PRACTICAL PURPOSES, WHILE AT THE SAME SIMPLIFYING THE DESIGN CONSIDERABLY AS WELL AS TO IMPROVE THE PERFORMANCE OF THE TRANSFORMER TO WHAT IT WOULD BE WITH A REDUCED TURNS PER VOLT FACTOR.

TABLE I

WIRE TABLE FOR POWER TRANSF. DESIGN

Size	Diameter		Area	Turns per In.	
B & S	Enameled	Double Cotton	Circ. Mils.	Enameled	Double Cotton
8	.1307	.1413	16510.	7.7	7.0
9	.1166	.1252	13090.	8.6	7.9
10	.1041	.1118	10380.	9.6	8.9
11	.0927	.1006	8234.	10.8	9.9
12	.0828	.0902	6530.	12.1	11.0
13	.0740	.0812	5178.	13.6	12.1
14	.0659	.0733	4107.	15.2	13.6
15	.0589	.0655	3257.	17.0	15.1
16	.0526	.0592	2583.	19.1	16.7
17	.0469	.0536	2048.	21.5	18.2
18	.0419	.0487	1624.	23.9	20.2
19	.0373	.0446	1288.	26.8	22.2
20	.0334	.0408	1022.	30.1	24.3
21	.0297	.0368	810.1	33.7	26.7
22	.0265	.0335	642.4	37.7	29.2
23	.0238	.0308	509.5	42.3	31.6
24	.0213	.0283	404.0	47.1	34.4
25	.0191	.0261	320.4	52.9	37.2
26	.0170	.0240	254.1	59.1	40.1
27	.0153	.0219	201.5	66.2	43.1
28	.0135	.0205	159.8	74.1	46.2
29	.0122	.0192	126.7	83.3	49.2
30	.0108	.0179	100.5	92.2	52.5
31	.0097	.0168	79.70	103.4	55.8
32	.0087	.0158	63.21	115.6	58.9
33	.0077	.0150	50.13	129.3	62.1
34	.0069	.0143	39.75	144.9	65.3
35	.0062	.0136	31.52	162.3	68.4
36	.0055	.0130	25.00	181.8	71.4
37	.0049	.0124	19.83	202.4	74.3
38	.0044	.0119	15.72	227.7	77.1
39	.0039	.0115	12.47	252.5	79.8
40	.0034	.0112	9.888	280.1	82.3

WE CAN NOW PROCEED BY CALCULATING THE EXACT NUMBER OF TURNS TO EMPLOY ON EACH OF THE WINDINGS, SIMPLY BY MULTIPLYING THE VOLTAGE AT WHICH EACH OF THE TRANSFORMER WINDINGS IS TO BE OPERATED BY THIS FACTOR OF 4.

THE TURNS REQUIRED FOR EACH WINDING

FOR EXAMPLE, SINCE THE VOLTAGE ACROSS THE PRIMARY WINDING IS TO BE 110 VOLTS, THE NUMBER OF TURNS TO BE USED IN THIS PARTICULAR WINDING WILL BE 110 X 4=440 TURNS. FOR THE 5 VOLT SECONDARY WINDING, WE WILL USE 5 X 4=20 TURNS AND FOR EACH OF THE 2.5 VOLT SECONDARY WINDINGS 2.5 X 4 =10 TURNS.

ACCORDING TO THIS SAME METHOD OF CALCULATION, EACH HALF OF THE HIGH VOLTAGE SECONDARY WINDING MUST CONSIST OF 375 X 4=1500 TURNS. IN ADDITION, HOWEVER, WE MUST CONSIDER "REGULATION" IN RESPECT TO THIS WINDING. THAT IS, WHILE THE RECEIVER IS OPERATING, THE "B" CURRENT DRAWN BY IT AND THROUGH THE HIGH VOLTAGE SECONDARY VARIES CONSIDERABLY WHILE HANDLING SIGNAL VOLTAGES OF DIFFERENT INTENSITIES AND THIS IN TURN WILL AFFECT THE VOLTAGE AVAILABLE FROM OUR GIVEN HIGH VOLTAGE SECONDARY WINDING OF THE POWER TRANS-

FORMER. SO TO TAKE THIS CONDITION INTO ACCOUNT, WE ADD 5% OF THE NUMBER OF THE HIGH VOLTAGE WINDING TURNS TO THE VALUE OBTAINED THROUGH OUR PREVIOUS CALCULATION. THIS 5% IS AN AVERAGE VALUE, WHICH CAN BE EMPLOYED IN THE GENERAL TYPES OF POWER TRANSFORMERS USUALLY ENCOUNTERED IN PRACTICE.

WE THUS FIND THAT EACH HALF OF THE HIGH VOLTAGE SECONDARY WINDING FOR THE PARTICULAR TRANSFORMER UNDER OUR PRESENT CONSIDERATION SHOULD CONSIST OF 1500 TURNS + 1500 X .05 = 1575 TURNS. THE ENTIRE HIGH VOLTAGE SECONDARY WINDING WILL THEREFORE CONSIST OF 2 X 1575 OR 3150 TURNS.

WIRE SIZES NEEDED

WE CAN NOW PROCEED BY DETERMINING THE SIZE OF WIRE TO BE EMPLOYED FOR EACH OF THESE INDIVIDUAL WINDINGS. THE SIZE OF WIRE TO USE FOR ANY GIVEN WINDING WILL DEPEND ENTIRELY UPON THE AMOUNT OF CURRENT WHICH THE PARTICULAR WINDING IN QUESTION IS TO CARRY DURING THE COURSE OF NORMAL OPERATION. NATURALLY, IN ORDER TO AVOID AN EXCESSIVE GENERATION OF HEAT, WE MUST CHOOSE A WIRE SIZE SUFFICIENTLY LARGE SO AS TO CARRY THE REQUIRED CURRENT WITHOUT BECOMING TOO HOT. YET AT THE SAME TIME, WE MUST REMEMBER THAT THE LARGER THE WIRE-SIZE USED, THE GREATER WILL BE THE SPACE REQUIRED IN WHICH TO WIND A GIVEN NUMBER OF TURNS. WE MUST THEREFORE CHOOSE A WIRE SIZE WHICH IS MOST PRACTICAL FROM ALL POINTS OF VIEW AND PREVIOUS EXPERIENCE HAS PROVEN THAT SATISFACTORY RESULTS ARE OBTAINED FOR ALL PURPOSES, BY ALLOWING 1000 CIRCULAR MILS OF CONDUCTOR CROSS-SECTION FOR EACH AMPERE OF CURRENT TO BE CARRIED BY IT. THIS IS THE SAME AS SAYING THAT FOR EACH MILLIAMPERE OF CURRENT, A CONDUCTOR CROSS-SECTION OF 1 CIRCULAR-MIL SHOULD BE AVAILABLE.

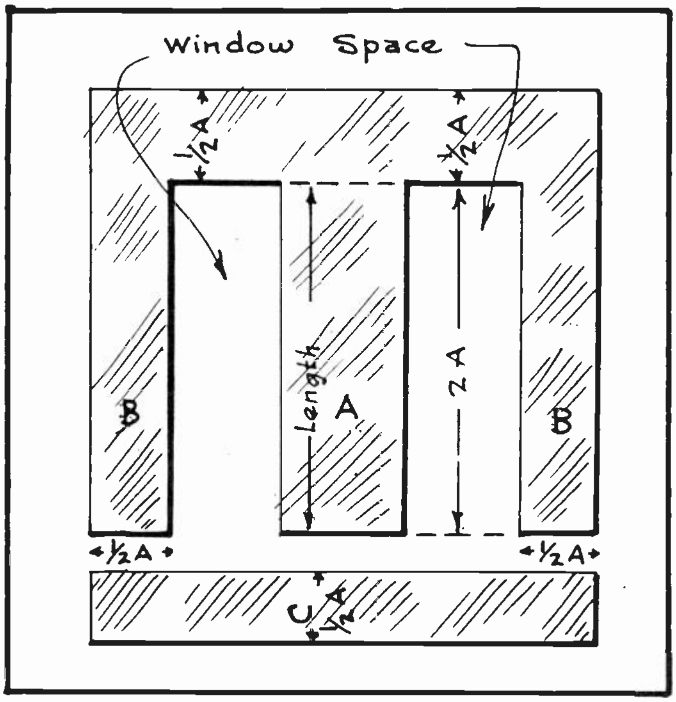

FIG. 5
The Core Laminations.

WITH THIS SIMPLE RULE IN MIND, WE FIND THAT FOR THE 2.5 VOLT SECONDARY WINDING "X" OF OUR TRANSFORMER AND WHICH IS TO CARRY 7 AMPS., WE MUST USE A WIRE-SIZE HAVING A CROSS-SECTIONAL AREA OF 7 X 1000 = 7000 CIRCULAR MILS. BY LOOKING IN THE COLUMN HEADED "AREA-CIRCULAR MILS" IN THE HANDY WIRE TABLE WHICH IS GIVEN YOU IN TABLE 1 OF THIS LESSON, YOU WILL FIND THAT A WIRE CORRESPONDING TO A CROSS-SECTIONAL AREA OF 7000 CIRCULAR MILS WILL BE BETWEEN A #11 AND #12 B&S GAUGE WIRE. WE THEREFORE, CHOOSE A STANDARD WIRE SIZE, WHICH IS THE FIRST SIZE LARGER IN RESPECT TO THE CROSS-SECTIONAL AREA WE WANT. IN OTHER WORDS, FOR THIS SECONDARY WINDING "X", WE WILL USE A #11 B&S SIZE COPPER WIRE.

IN LIKE MANNER, WE FIND THAT THE 2.5 VOLT SECONDARY WINDING "Y", WHICH

IS TO CARRY 3 AMPERES, MUST CONSIST OF A WIRE-SIZE OFFERING A CROSS-SECTIONAL AREA OF 3 X 1000 = 3000 CIRCULAR MILS. ACCORDING TO TABLE I, WE FIND THAT THE CLOSEST STANDARD WIRE-SIZE CORRESPONDING TO THIS VALUE IS A #15 B&S SIZE, SO THIS IS THE WIRE-SIZE WHICH WE WILL USE FOR THIS WINDING.

THE 5 VOLT SECONDARY WINDING WILL BE REQUIRED TO CARRY 2 AMPS. AND SO THE WIRE SIZE NEEDED IN THIS CASE WILL CORRESPOND TO A CROSS-SECTIONAL AREA OF 2 X 1000 = 2000 CIRCULAR-MILS. ACCORDING TO TABLE I, WE THUS CHOOSE THE NEAREST STANDARD SIZE OR A #17 B&S GAUGE.

EACH HALF OF THE HIGH VOLTAGE SECONDARY IS TO CARRY 100 MILLIAMPERES, THEREFORE, THE CROSS-SECTIONAL AREA FOR THE WIRE USED FOR THIS WINDING SHOULD BE 100 MA X 1 CIRCULAR-MIL = 100 CIRCULAR MILS AND SO FROM TABLE I, WE WILL CHOOSE A #30 B&S GAUGE WIRE FOR THIS WINDING. IF DESIRED, ONE COULD CHOOSE THE NEXT SIZE LARGER IN THIS CASE, IN ORDER TO ALLOW FOR A SLIGHT OVER-LOAD. THAT IS, A #29 B&S GAUGE WIRE COULD BE EMPLOYED IF PREFERRED.

OUR FINAL STEP IN REGARDS TO DETERMINING WIRE SIZES WILL BE TO FIND OUT THE SIZE NEEDED FOR THE PRIMARY WINDING, BUT IN ORDER TO BE ABLE TO DO THIS, WE MUST FIRST DO A LITTLE ADDITIONAL CALCULATION. TO BEGIN WITH, WE MUST CALCULATE THE CURRENT WHICH IS TO BE CARRIED BY THIS WINDING AND WE CAN DO THIS VERY READILY BY EMPLOYING "WATT'S LAW" IN THE FORM $\text{CURRENT} = \frac{\text{WATTS}}{\text{VOLTS}}$. IN OTHER WORDS, SINCE THE PRIMARY WATTAGE OF OUR TRANSFORMER HAS ALREADY BEEN DETERMINED AS BEING 85.3 WATTS AND THE PRIMARY WINDING IS TO BE CONNECTED TO A 110 VOLT LIGHTING CIRCUIT, THEN THE APPROXIMATE CURRENT TO BE CARRIED BY THE PRIMARY WINDING UNDER NORMAL CONDITIONS WILL BE $\frac{85.3}{110} = 0.775$ AMPERE.

THE CROSS-SECTION FOR THE WIRE TO BE USED FOR THE PRIMARY WINDING WILL THEREFORE BE 0.775 X 1000 OR 775 CIRCULAR-MILS. ACCORDING TO TABLE I, WE WILL THUS CHOOSE A CONDUCTOR OF A #21 B&S GAUGE.

CALCULATING THE REQUIRED CORE AREA

OUR FOLLOWING STEP WILL BE TO FIGURE OUT THE SIZE OF CORE TO USE FOR THE TRANSFORMER AND FOR THIS WE HAVE TWO HANDY AND EASILY APPLIED FORMULAR. HERE THEY ARE:

WHEN THE A.C. LIGHTING CIRCUIT IS OF THE 60 CYCLE TYPE, THEN THE CROSS SECTIONAL AREA OF THE CORE EXPRESSED IN SQUARE INCHES = VOLTS PER TURN X 7.5.

IF ON THE OTHER HAND, THE FREQUENCY OF THE A.C. LIGHTING CIRCUIT, ACROSS WHICH THE PRIMARY WINDING OF THE TRANSFORMER IS TO BE CONNECTED, IS OF THE 25 CYCLE TYPE, THEN THE CROSS-SECTIONAL AREA OF THE CORE EXPRESSED IN SQUARE INCHES = VOLTS PER TURN X 18.

THIS BRINGS US UP TO THE POINT WHERE WE MUST DETERMINE THE EXACT MEANING OF THE EXPRESSION "VOLTS PER TURN", AS USED IN THESE FORMULAS, AND THE RELATION WHICH THIS SAME EXPRESSION BEARS TO THE TERM "TURNS PER VOLT" WHICH WE HAVE ALREADY USED IN OUR PREVIOUS TRANSFORMER CALCULATIONS. FORTUNATELY, THIS HAPPENS TO BE A VERY SIMPLE MATTER BECAUSE THE "VOLTS PER TURN" IS MERELY EQUAL TO "ONE" DIVIDED BY THE "TURNS PER VOLT". FOR EXAMPLE, IF THE TURNS PER VOLT OF A CERTAIN TRANSFORMER IS 3, THEN THE VOLTS

PER TURN OF THIS SAME TRANSFORMER IS EQUAL TO 1/3.

NOW THEN, FOR THE PARTICULAR TRANSFORMER WHICH WE ARE DESIGNING, WE HAVE ALREADY FOUND THE TURNS PER VOLT TO BE 4. THEREFORE, THE VOLTS PER TURN IN THIS CASE WILL BE 1/4. THIS IS THE SAME AS SAYING 1 DIVIDED BY 4 AND SO BY COMPLETING THIS MATHEMATICAL PROCESS, WE FIND THE VOLTS PER TURN FOR OUR PRESENT USE TO BE 0.25.

WE ARE NOW READY TO CALCULATE THE CROSS-SECTIONAL AREA OF THE CORE FOR OUR TRANSFORMER AND SINCE THE UNIT IS TO BE OPERATED ON A 60 CYCLE A.C. SUPPLY, WE WILL USE THE FORMULA: AREA OF CROSS-SECTION = VOLTS PER TURN X 7.5. SUBSTITUTING OUR VALUE OF .25 FOR THE VOLTS PER TURN IN THIS FORMULA WE HAVE: AREA OF CROSSECTION = .25 X 7.5 = 1.875 SQUARE INCHES.

OUR COMPLETE DATA

WITH THIS CALCULATION FOR THE CORE TAKEN CARE OF, WE HAVE NOW CALCULATED THE BASIC DATA FOR THE CONSTRUCTION OF OUR POWER TRANSFORMER. ARRANGING THIS DATA IN TABULAR FORM FOR HANDY REFERENCE, WE HAVE:

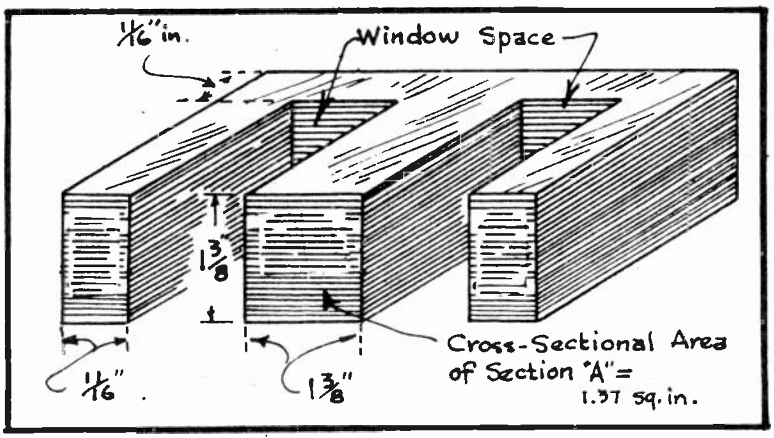

FIG. 6
Stack of E-Shaped Laminations.

CROSS-SECTIONAL AREA OF CORE = 1.875 SQUARE INCHES. PRIMARY WINDING = 440 TURNS OF #21 B&S WIRE. SECONDARY WINDING "X" = 10 TURNS OF #11 B&S WIRE. SECONDARY WINDING "Y" = 10 TURNS OF #15 B&S WIRE. THE 5-VOLT SECONDARY WINDING = 20 TURNS OF #17 B&S WIRE. HIGH VOLTAGE SECONDARY = 3150 TURNS (CENTER-TAPPED) OF #30 B&S WIRE.

PLANNING THE CORE CONSTRUCTION

FOR THE CONSTRUCTIONAL PART OF OUR WORK, WE SHALL BEGIN WITH THE LAYOUT OF THE CORE. SINCE THE CORE IS TO BE OF THE "SHELL-TYPE", WE WILL HAVE TO HAVE ONE GROUP OF "E" SHAPED STEEL LAMINATIONS AND A GROUP OF AN EQUAL NUMBER OF "I"-SHAPED STEEL LAMINATIONS AS SHOWN YOU IN FIG. 5.

TO FULFILL OUR DESIGN REQUIREMENTS UP TO THIS POINT, THE CENTER-LEG OR SECTION "A" OF OUR CORE MUST HAVE A CROSSECTIONAL AREA OF 1.875 SQUARE INCHES. THIS MEANS THAT IF WE DESIRE, WE CAN MAKE THE DIMENSION "A" IN FIG. 5 EQUAL TO $\sqrt{1.875}$ OR 1.37" IN THIS CASE AND USE A SUFFICIENT NUMBER OF LAMINATIONS SO THAT WHEN STACKED UP, THE PILE WILL BE 1.37" THICK. IN THIS WAY, WE WILL OBTAIN A SQUARE CROSS-SECTION AT "A" BEING 1.37" ON A SIDE AND HAVING A CROSS-SECTIONAL AREA OF 1.37 X 1.37 = 1.875 (APPROX.) SQUARE INCHES AS SHOWN IN FIG. 6. A DIMENSION OF 1.37" IS APPROXIMATELY EQUAL TO 1-3/8".

NOW IT IS NOT ALTOGETHER NECESSARY THAT THE CROSS-SECTION OF "A" BE SQUARE-SHAPED. FOR EXAMPLE, YOU CAN ALSO OBTAIN A CROSS-SECTIONAL AREA OF

1.875 SQUARE INCHES AT THIS POINT IF SECTION "A" IS 1" WIDE AND 1.875" THICK. THE RELATION BETWEEN THESE TWO DIMENSIONS REMAINS AS A CHOICE FOR THE DESIGNER, BEING PRIMARILY AFFECTED BY THE DESIRED OVERALL-SIZE AND GENERAL SHAPE OF THE COMPLETED TRANSFORMER, SO THAT IT WILL FIT INTO THE SPACE AVAILABLE ON THE CHASSIS. NEVERTHELESS, A SQUARE CROSS-SECTION IS MOST USED.

IT IS GENERALLY THE PRACTICE TO MAKE THE DIMENSION "B" AND "C" OF FIG. 5 ONE HALF THAT OF THE DIMENSION "A". IN OTHER WORDS, IF "A" IS CHOSEN AS $1\frac{3}{8}$", THEN DIMENSIONS "B" AND "C" WILL BE $\frac{11}{16}$".

FIGURING THE WINDOW-SPACE

THE AMOUNT OF ROOM ALLOTED FOR THE WINDOW-SPACE IN WHICH THE WINDINGS ARE TO BE INSTALLED WILL DEPEND ENTIRELY UPON THE AMOUNT AND SIZE OF THE WIRE AND INSULATION WHICH IT WILL BE NECESSARY TO PUT IN THIS SPACE FOR ANY GIVEN TRANSFORMER. THE SIMPLEST WAY IN WHICH TO FIGURE HOW MUCH SPACE IS NEEDED FOR THIS PURPOSE IS TO DRAW THE TRANSFORMER TO ACTUAL SIZE ON A PIECE OF PAPER AS THE DIMENSIONS DEVELOPE FROM THE SERIES OF CALCULATIONS WHICH ARE NOW GOING TO BE DESCRIBED.

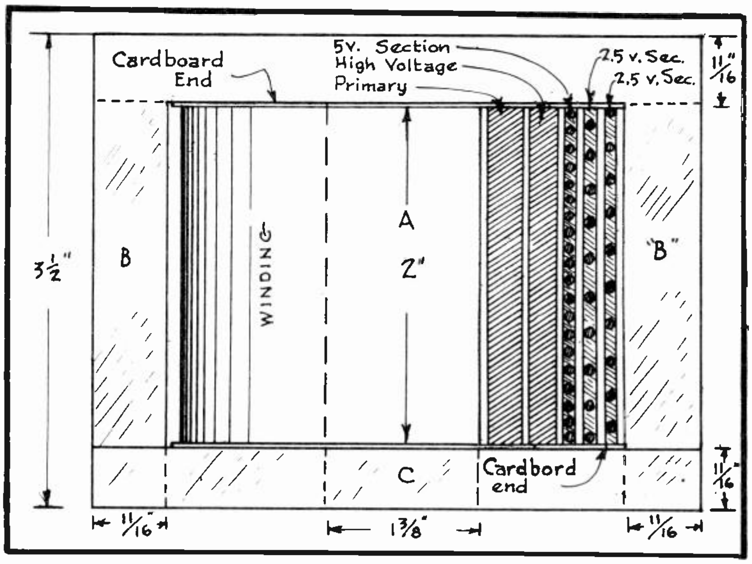

FIG. 7

Figuring the Remaining Core Dimensions.

FOR EXAMPLE, LET US SUPPOSE THAT WE HAVE DECIDED TO MAKE OUR TRANSFORMER $3\frac{1}{2}$" WIDE. THIS HAPPENS TO BE A POPULAR DIMENSIONS AMONG FACTORY BUILT UNITS OF THIS POWER RATING. NOW THEN, IF THIS PARTICULAR DIMENSION IS CHOSEN, IT IS PERFECTLY CLEAR ACCORDING TO FIG. 7 THAT THE MAXIMUM LENGTH FOR SECTION "A" WILL BE $3\frac{1}{2}" - (11/16" + \frac{11}{16}") = 3\frac{1}{2}" - 1\frac{3}{8}" = 2\frac{1}{8}"$. HOWEVER, THIS ENTIRE LENGTH CANNOT BE UTILIZED FOR WINDING PURPOSES DUE TO THE FACT THAT WE ARE GOING TO PROVIDE A CARDBOARD OR FIBER END WASHER AT EACH END OF THE WINDING. ASSUME EACH OF THESE WASHERS TO BE $\frac{1}{16}$" THICK, THE TWO TOGETHER WILL OCCUPY $\frac{1}{8}$" OF WINDING SPACE, THEREBY LEAVING US BUT $2\frac{1}{8}" - \frac{1}{8}" = 2"$ FOR ACTUAL WINDING PURPOSES ALONG THE LENGTH OF THE CORE'S CENTER LEG. THIS DIMENSION IS CLEARLY SPECIFIED IN FIG. 7.

ANOTHER HANDY RULE WITH WHICH TO DETERMINE THE LENGTH OF THE WINDOW-SPACE IS TO MAKE IT EQUAL TO $1\frac{1}{2}$ TO 2 TIMES THE DIMENSION "A" AS ILLUSTRATED BY THE DIMENSION 2A IN FIG. 5. THE WINDING LENGTH IS THEN MADE SLIGHTLY LESS THAN THIS DISTANCE (APPROXIMATELY $\frac{1}{8}$" LESS) IN ORDER TO PERMIT THE FINISHED COIL WITH ITS END WASHERS TO FIT INTO THIS SPACE.

THE NEXT STEP WILL BE TO DETERMINE HOW MUCH SPACE IS NEEDED BETWEEN CENTER LEG "A" AND THE TWO OUTER LEGS OF OUR CORE "B", SO THAT ALL OF THE WINDINGS CAN BE ACCOMMODATED BY THIS WINDOW SPACE. IN FIGURING THIS DIMENSION, IT IS ONLY NECESSARY TO FIGURE IT FOR THE WINDOW SPACE ON ONE SIDE AS THE OTHER SIDE WILL BE EQUAL TO IT.

TO BEGIN WITH, WE MUST FIRST ALLOW FOR SOME INSULATION BETWEEN THE CENTER LEG OF THE CORE "A" AND THE PRIMARY WINDING. SINCE CARDBOARD AND TAPE ARE TO BE USED FORTHE THE INSULATION AT THIS POINT, WE WILL ALLOW A THICKNESS OF 1/8" FOR THIS PURPOSE.

THE NEXT STEP WILL BE TO FIGURE THE THICKNESS OF THE PRIMARY WINDING. WE ARE GOING TO USE 440 TURNS OF #21 B&S DOUBLE- COTTON COVERED WIRE FOR THIS PURPOSE AND ACCORDING TO TABLE I OF THIS LESSON, WE FIND THAT THIS PARTICULAR WIRE CAN BE WOUND 26.7 TURNS TO THE INCH. SINCE WE HAVE 2" AVAILABLE ON OUR CORE CONSTRUCTION FOR EACH LAYER OF WIRE, WE WILL BE ABLE TO GET (26.7 X 2) TURNS OF THIS WIRE PER LAYER. THUS WE HAVE 26.7 X 2=53.4 BUT WE WILL ESTIMATE THIS AT 53 TURNS PER LAYER.

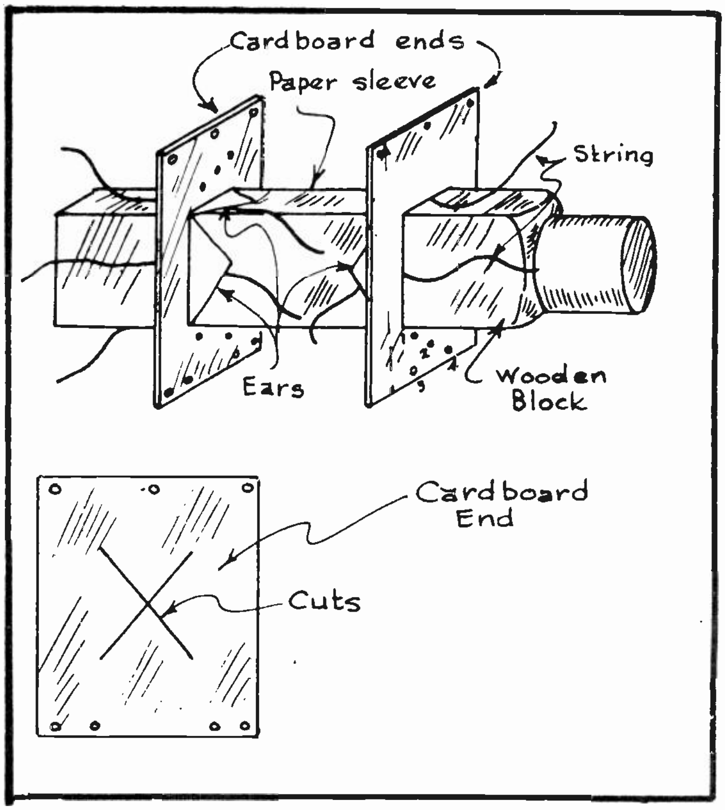

FIG. 8
The Winding Form.

THE TOTAL NUMBER OF PRIMARY TURNS REQUIRED, HOWEVER, IS 440 AND SINCE 53 TURNS CAN BE WOUND ON ONE LAYER, THE TOTAL NUMBER OF LAYERS NEEDED FOR THIS WINDING WILL BE 440 DIVIDED BY 53 OR 8.5 LAYERS. WE WILL ESTIMATE THIS VALUE AT 9 LAYERS.

NOW BY AGAIN CONSULTING TABLE I OF THIS LESSON, WE FIND THAT THE DIAMETER OF DOUBLE COTTON COVERED #21 B&S WIRE IS .0368". NINE LAYERS OF THIS WIRE WILL THEREFORE BE 9 X .0368" OR APPROXIMATELY .33 INCHES THICK.

THE HIGH VOLTAGE SECONDARY WINDING IS TO BE WOUND OVER THE PRIMARY BUT INSULATIVE TAPE WOUND 1/8" THICK SHOULD BE PROVIDED BETWEEN THESE TWO WINDINGS. FOR ALL SECONDARY WINDINGS, PLAIN ENAMELED COPPER WIRE MAY BE USED AND THE THICKNESS OF EACH WINDING MAY BE CALCULATED BY THE METHOD ALREADY DESCRIBED REGARDING THE PRIMARY WINDING. ALLOW A TOTAL OF 1/8" FOR INSULATIVE PAPER WHICH IS TO BE USED BETWEEN EACH LAYER OF THE HIGH-VOLTAGE SECONDARY WINDINGS.

ALTHOUGH WE HAVE SPECIFIED DOUBLE COTTON-COVERED WIRE FOR THE PRIMARY WINDING IN THIS PARTICULAR EXAMPLE, YET PLAIN ENAMELED WIRE CAN ALSO BE USED FOR THIS PURPOSE BUT UNDER SUCH CONDITIONS, INSULATIVE PAPER SHOULD BE PROVIDED BETWEEN EACH LAYER OF TURNS MAKING UP THIS WINDING.

AFTER YOU HAVE ADDED TOGETHER THE THICKNESS OF ALL THE WINDINGS, INCLUDING ALL INSULATION, YOU WILL HAVE THE DIMENSION FOR THE WINDOW SPACE BETWEEN THE CENTER CORE-LEG "A" AND THE TWO END-LEGS "B". IT IS BETTER TO ESTIMATE THE REQUIRED WINDOW SPACE TOO LARGE RATHER THAN TOO SMALL BECAUSE IF IT IS TOO LARGE, YOU CAN FILL IT WITH INSULATIVE TAPE WHILE ON THE OTHER HAND, IF THE WINDOW SPACE IS TOO SMALL, IT WILL BE IMPOSSIBLE TO ASSEMBLE THE CORE AFTER THE ENTIRE WINDING PROCESS HAS BEEN COMPLETED.

HAVING DETERMINED THIS WINDOW SPACE DIMENSION, IT IS A SIMPLE MATTER TO CALCULATE THE TOTAL LENGTH OF THE CORE'S "E" AND "I" SECTIONS. TO DO THIS, IT IS ONLY NECESSARY TO MULTIPLY THE WINDOW SPACE DIMENSION JUST DETERMINED BY 2 IN ORDER TO ALLOW FOR THE WINDOW SPACE ON BOTH SIDES OF THE CORE'S CENTER SECTION "A". TO THIS VALUE ADD THE DIMENSION "A" OF FIG. 5 AND TWICE THE DIMENSION "B". THIS ANSWER WILL BE THE OVER-ALL LENGTH OF THE CORE'S "I" AND "E" SECTIONS. THUS ALL DIMENSIONS FOR CUTTING THE STEEL LAMINATIONS TO THE PROPER SIZE HAVE BEEN DETERMINED.

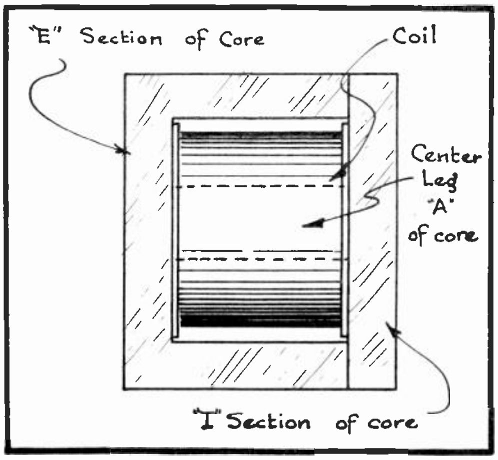

FIG. 9
Assembling the Core.

POSSIBLE CHANGES TO BE CONSIDERED

SHOULD AT ANY TIME THE LENGTH OF THE TRANSFORMER FIGURE OUT TO BE TOO GREAT IN PROPORTION TO ITS WIDTH SO AS TO BE IMPRACTICAL REGARDING ITS GENERAL SHAPE, THEN YOU CAN FIGURE ON USING A GREATER DIMENSION FOR THE WIDTH, OR ELSE TO MAKE DIMENSION "A" SMALLER AND INCREASING THE THICKNESS OF THE CORE ACCORDINGLY OR ELSE A COMBINATION OF BOTH THESE METHODS. BY DOING ALL OF THIS FIGURING ON PAPER BEFORE-HAND, YOU WILL BE ABLE TO FORESEE THE ACTUAL SHAPE AND SIZE OF THE COMPLETED TRANSFORMER AND THUS SAVE YOURSELF CONSIDERABLE TIME IN THE EVENT THAT ANY CHANGES IN THE ORIGINALLY CHOSEN DIMENSIONS ARE FOUND NECESSARY.

THE CORE LAMINATIONS

THE NUMBER OF LAMINATIONS WHICH ARE TO BE CUT FOR BOTH THE "E" AND "I" SECTIONS OF THE TRANSFORMER CORE WILL BE APPROXIMATELY EQUAL TO THE THICKNESS OF THE CORE DIVIDED BY THE THICKNESS OF THE LAMINATION STOCK (SHEETS) USED. FOR 60 CYCLE TRANSFORMERS, CORE MATERIAL .014" THICK IS USUALLY CONSIDERED BEST, WHEREAS SLIGHTLY THICKER CORE MATERIAL MAY BE USED FOR A 25-CYCLE TRANSFORMER. FOR HOME CONSTRUCTION, HOWEVER, IT WILL BE BEST TO USE CORE MATERIAL OF THE SAME THICKNESS FOR A 25 CYCLE TRANSFORMER AS WAS SPECIFIED FOR A 60 CYCLE UNIT. THIS CORE MATERIAL SHOULD PREFERABLY BE TRANSFORMER STEEL WHICH IS CAPABLE OF HANDLING A FLUX DENSITY OF APPROXIMATELY 50,000 LINES OF FORCE PER SQUARE INCH.

CONSTRUCTING THE TRANSFORMER

WITH ALL OF OUR CALCULATIONS COMPLETE, WE ARE NOW READY TO ACTUALLY PROCEED WITH THE CONSTRUCTIONAL WORK ON OUR TRANSFORMER. THE FIRST THING TO DO IN THIS RESPECT IS TO CONSTRUCT A FORM ON WHICH THE WINDINGS ARE TO BE PLACED. THE SIMPLEST METHOD OF DOING THIS IS TO SHAPE A PIECE OF WOOD SO THAT ITS CROSS-SECTION WILL CORRESPOND TO THE CROSS-SECTION OF THE TRANSFORMER CORE'S CENTER-LEG "A".

BUILDING A FORM

WRAP ONE LAYER OF ORDINARY THIN STRING AROUND THIS PIECE OF WOOD AND THEN WRAP A PIECE OF GOOD STIFF PAPER OVER THE STRING. (INSULATIVE PAPER, KNOWN TO THE INDUSTRY AS "FISH-PAPER", IS EXCELLENT FOR THIS PURPOSE). LEAVE THE ENDS OF THE STRING PROJECT OUT THROUGH THE EDGES OF THIS CARDBOARD SLEEVE, SO THAT THE STRING CAN BE EASILY RIPPED OUT AFTER THE WINDING IS COMPLETED IN ORDER TO ENABLE THE ENTIRE WINDING FORM TO BE EASILY REMOVED FROM THE WOOD BLOCK.

THE NEXT STEP IS TO MOUNT THE CARDBOARD OR FIBER ENDS ON THE WINDING FORM. THE SIZE OF THESE ENDS WILL BE GOVERENED BY THE SIZE OF THE CORE-SECTION AND WINDOW SPACE, WHEREAS THE DISTANCE BETWEEN THEM WILL BE GOVERNED BY THE DIMENSION NOTED AS 2" IN FIG. 7. CUT THESE AT THEIR CENTER SO THAT THEY CAN BE SLIPPED ONTO THE ENDS OF THE PAPER SLEEVE AS ILLUSTRATED IN FIG. 8, PROVIDING THE "EARS" AS SHOWN, SO THAT THEY WILL OVERLAP THE PAPER SLEEVE. INSULATION TAPE SHOULD THEN BE WRAPPED OVER THE PAPER SLEEVE IN TWO OR THREE LAYERS, FROM ONE CARDBOARD END TO ANOTHER.

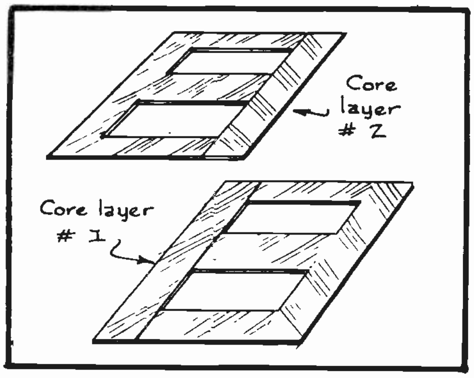

FIG. 10

Alternating Core Placement for Successive Layers.

WINDING THE PRIMARY

YOU CAN NOW PROCEED BY WINDING THE PRIMARY WINDING UPON THE FORM. THIS WINDING SHOULD BE WOUND EVENLY WITH ALL TURNS SIDE BY SIDE (THAT IS, NOT SPACE WOUND). IF THE WINDING IS DONE BY HAND, THE TASK WILL BE A TEDIOUS ONE BECAUSE IN ADDITION TO NEATLY WINDING THE COIL, IT IS ALSO NECESSARY TO KEEP AN ACCURATE COUNT OF THE NUMBER OF TURNS APPLIED. HOWEVER, THE WORK CAN BE SIMPLIFIED BY MOUNTING THE WOODEN FORM BLOCK IN A LATHE TO BE ROTATED AND SO THAT THE OPERATOR NEED ONLY FEED THE WIRE ONTO THE FORM AND KEEP TRACK OF THE NUMBER OF TURNS. TURN INDICATORS ARE ALSO AVAILABLE WHICH CAN BE ATTACHED TO INDICATE THE NUMBER OF REVOLUTIONS COMPLETED BY THE WINDING FORM SO THAT THE OPERATOR CAN TELL AT A GLANCE THE NUMBER OF TURNS BEING APPLIED.

FOR THIS WINDING WORK, ONE CAN ALSO CONSTRUCT A HAND WINDING - JIG ALONG THE SAME LINES AS PRESCRIBED FOR WINDING R.F. TRANSFORMERS IN ONE OF YOUR PREVIOUS LESSONS, ONLY THAT IN THIS PARTICULAR CASE, THE ARRANGEMENT WILL HAVE TO BE SUCH AS TO PERMIT THE ENTIRE WINDING FORM TO BE ROTATED.

REMEMBER, THAT IF PLAIN ENAMEL COVERED WIRE IS USED FOR THE PRIMARY

WINDING, THEN A LAYER OF THIN INSULATION PAPER WILL HAVE TO BE PROVIDED BETWEEN EACH LAYER OF WINDING COMPRISING THE PRIMARY COIL. IF COTTON COVERED ENAMEL WIRE IS USED, THEN THIS ADDITIONAL INSULATION IS NOT NECESSARY.

AFTER COMPLETING THE PRIMARY WINDING, A LAYER OF "EMPIRE CLOTH" SHOULD BE WRAPPED OVER IT. EMPIRE CLOTH IS A SPECIAL TYPE OF TREATED INSULATION CLOTH, WHICH IS AN EXCELLENT INSULATOR AND CAPABLE OF WITHSTANDING CONSIDERABLE VOLTAGE.

THE "STATIC-SHIELD"

TO AVOID THE TRANSFER OF STATIC AND POWER LINE NOISES FROM THE LIGHTING CIRCUIT INTO THE RECEIVER, IT IS ADVISABLE TO SURROUND THE PRIMARY WINDING WITH A "STATIC SHIELD". THIS STATIC SHIELD CONSISTS MERELY OF A THIN SHEET OF COPPER, WHOSE WIDTH IS EQUAL TO THE LENGTH OF THE WINDING FORM. THIS COPPER SHEET SHOULD BE WRAPPED OVER THE INSULATED PRIMARY WINDING AND CUT TO SUCH A LENGTH THAT ITS ENDS WILL NOT MEET OR TOUCH. SOLDER A WIRE TO THIS COPPER SHEET, LEAVING ITS END FREE SO THAT IT CAN LATER BE GROUNDED TO THE TRANSFORMER CORE.

WINDING THE HIGH-VOLTAGE SECONDARY

PLACE ANOTHER LAYER OF EMPIRE CLOTH OVER THIS STATIC SHIELD AND THEN APPLY THE SECONDARY WINDING. BE SURE TO INSULATE EACH LAYER OF SECONDARY WINDING WITH EMPIRE CLOTH OR A THIN PIECE OF INSULATION PAPER AND DON'T FORGET TO PROVIDE A LEAD FOR THE CENTER TAP OF THIS WINDING. FOR ALL WINDINGS, LEAVE THE THE END LEADS OF SUFFICIENT LENGTH SO THAT THEY CAN LATER BE CONVENIENTLY CONNECTED TO SOLDERING LUGS, AT WHICH TIME THEY CAN BE TRIMMED TO THE PROPER LENGTH. ALSO SLIP A SLEEVE OF SPAGHETTI TUBING OVER THE LENGTH OF EACH OF THE PRIMARY AND HIGH VOLTAGE LEADS WHICH ARE TO BE USED ON THE FINISHED TRANSFORMER.

AFTER THE HIGH VOLTAGE SECONDARY WINDING IS APPLIED, WRAP ANOTHER LAYER OF EMPIRE CLOTH OVER IT AND THEN WIND EACH OF THE LOW VOLTAGE WINDINGS IN TURN OVER THE HIGH VOLTAGE SECONDARY, USING EMPIRE CLOTH INSULATION BETWEEN EACH OF THE WINDINGS.

THE OUTER SURFACE OF THE COIL CAN BE TAPED RIGIDLY SO AS TO HOLD THE WINDINGS IN PLACE FIRMLY AND THE END LEADS OF THE COIL CAN THEN BE SOLDERED TO TERMINAL LUGS WHICH ARE FASTENED TO THE PAPER OR FIBER END PIECES OF THE COIL IN THE MANNER AS DONE ON THE TRANSFORMER AS ILLUSTRATED IN FIG. 1 OF THIS LESSON.

WITH THE COIL ITSELF THUS COMPLETED, THE STRING CAN BE RIPPED OUT FROM UNDERNEATH THE WINDING FORM, SO THAT THE ENTIRE COIL, TOGETHER WITH ITS FORM, CAN BE PULLED OFF THE WOODEN WINDING BLOCK.

MANUFACTURERS GENERALLY SOAK THE COMPLETED COIL IN HOT INSULATING VARNISH FOR ABOUT 12 HOURS UNTIL THE ENTIRE UNIT IS THOROUGHLY SOAKED. AFTER THIS PROCESS, THE COIL IS BAKED IN AN OVEN AT A LOW TEMPERATURE FOR TWO OR THREE HOURS SO THAT THE VARNISH BECOMES DRY AND HARD.

ASSEMBLING THE CORE

THE NEXT STEP IS TO ASSEMBLE THE CORE AND FIG. 9 SHOWS YOU HOW

THIS IS DONE. NOTICE HERE THAT AN "E"-SHAPED SECTION OF LAMINATION IS SLIPPED THROUGH THE COIL FROM THE LEFT SO THAT THE CENTER LEG OR SECTION "A" OF THIS PIECE OF LAMINATION PASSES THROUGH THE OPENING PROVIDED IN THE CENTER OF THE COIL. AN "I" SECTION OF LAMINATION IS THEN PLACED ON THE RIGHT SIDE OF THE COIL, SO THAT IT TOUCHES THE EXTREMETIES OF THE "E" SECTION.

FOR THE NEXT LAYER OF THE LAMINATED CORE, INSERT THE "E" SECTION THROUGH THE COIL FROM THE RIGHT SIDE AND PLACE THE "I" SECTION AT THE LEFT ETC. CONTINUE BUILDING UP THE CORE IN THIS MANNER, THUS ALTERNATING THE PLACEMENT OF THE CORE SECTIONS UNTIL THE ENTIRE CORE OPENING IN THE COIL IS FILLED UP AND THE REQUIRED CORE THICKNESS IS OBTAINED.

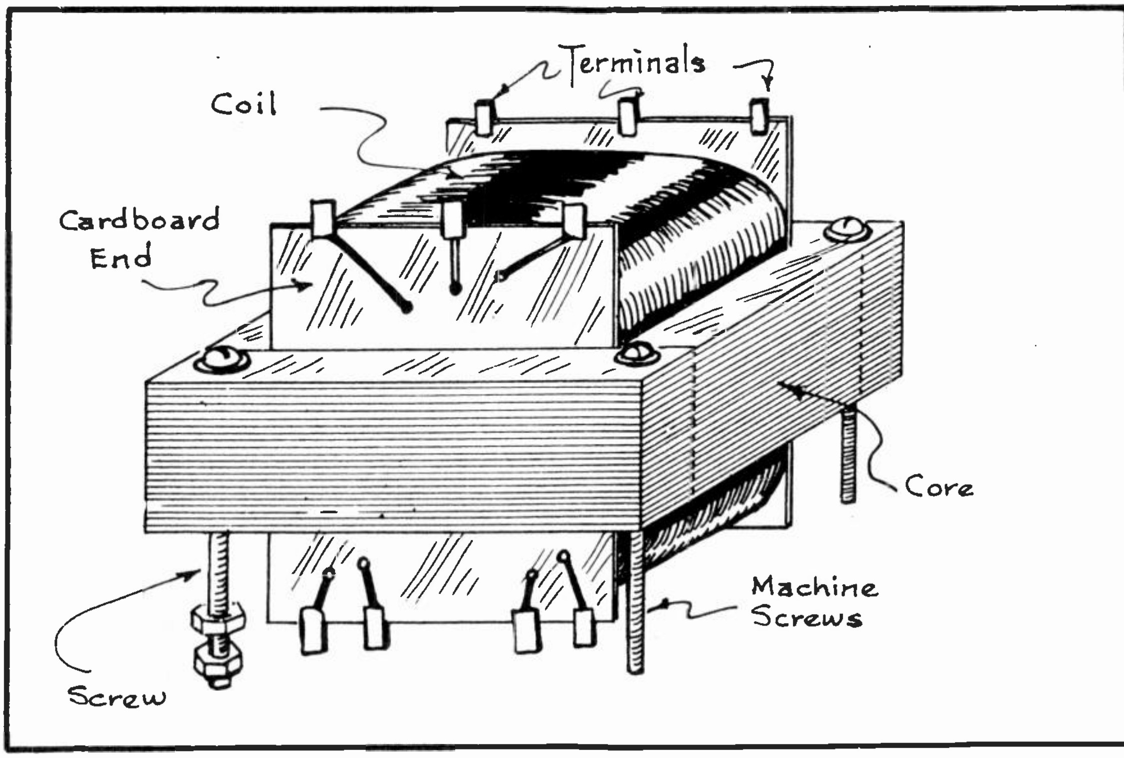

FIG. 11
The Completed Transformer.

FIG. 10 MORE CLEARLY ILLUSTRATES HOW THE POSITION OF THE "E" AND "I" LAMINATION SECTIONS OF THE CORE ARE ALTERNATED FOR EACH LAYER OF THE CORE, AS THE STOCK IS PILED UP. TO SPEED UP THIS PROCESS OF BUILDING UP THE CORE, MOST MANUFACTURES HAVE ADOPTED THE PRACTICE OF INSERTING 4 OR 5 CORE LAMINATIONS OF SIMILAR SECTION AT A TIME FROM EACH SIDE OF THE COIL INSTEAD OF ONLY ONE. IN OTHER WORDS, THE PROCESS OF LAMINATION INSERTION IS ONLY REVERSED AT INTERVALS OF 4 OR 5 LAYERS INSTEAD OF AT EACH SUCCESSIVE LAYER. ALTHOUGH THIS PRACTICE IS NOT THEORITICALLY AS GOOD AS WHEN ALTERNATING THE INSERTIONS FOR EACH SUCCESSIVE LAYER, YET NO NOTICEABLE INEFFICIENCY IS EVIDENT FROM A PRACTICAL STANDPOINT.

THE STATIC SHIELD CAN BE GROUNDED BY LAYING THE FREE END OF ITS LEAD BETWEEN CORE LAMINATIONS SO THAT IT WILL BECOME COMPRESSED BETWEEN THE LAMINATIONS AND THUS BE FIRMLY HELD IN PLACE. IT IS OF COURSE NECESSARY THAT THIS GROUNDING WIRE BE CLEAN AT THE POINT WHERE IT CONTACTS THE

CORE MATERIAL, SO THAT A GOOD GROUND CONNECTION WILL BE OBTAINED.

WHEN ALL OF THE CORE LAMINATIONS HAVE BEEN PLACED INTO POSITION, HOLES CAN BE DRILLED THROUGH THE ENTIRE STACK AT EACH OF THE FOUR CORNERS AND MACHINE SCREWS WITH NUTS CAN BE EMPLOYED FOR FASTENING THE CORE LAMINATIONS INTO ONE RIGID AND COMPACT UNIT. THIS COMPLETED TRANSFORMER IS ILLUSTRATED FOR YOU IN FIG. 11. THE FOUR MACHINE SCREWS ARE GENERALLY CHOSEN OF SUFFICIENT LENGTH SO THAT THEY CAN ALSO BE EMPLOYED FOR MOUNTING THE TRANSFORMER TO A RECEIVER CHASSIS ETC.

SOMETIMES, THE TRANSFORMER IS LEFT IN AN OPEN CONDITION WHILE IN OTHER INSTANCES, IT IS ENCLOSED IN A METAL CONTAINER WITH EXTERNAL LEAD WIRES SOLDERED TO ITS TERMINAL LUGS. THESE DIFFERENT DETAILS OF CONSTRUCTION CAN BE VARIED TO SUIT THE INDIVIDUAL CONSTRUCTOR.

answered March 11, 1941

EXAMINATION QUESTIONS

1. – THE SECONDARY LOAD OF A CERTAIN POWER TRANSFORMER IS AS FOLLOWS: 350 VOLTS AT 95 MA.; 2.5 VOLTS AT 10 AMPS. AND 5 VOLTS AT 2 AMPS. THE TRANSFORMER IS 90% EFFICIENT. HOW MUCH PRIMARY CURRENT WILL BE DRAWN FROM THE A.C. LINE UNDER FULL-LOAD?

2. – IF A CERTAIN POWER TRANSFORMER IS TO HAVE A PRIMARY WATTAGE RATING OF 80 WATTS AND IS TO BE OPERATED OFF A 60 CYCLE 110 VOLT A.C. SUPPLY, THEN HOW MANY TURNS PER VOLTS WOULD YOU USE FOR THE PRIMARY AND LOW VOLTAGE SECONDARY WINDINGS?

3. – WHAT IS THE DIFFERENCE IN THE MEANING BETWEEN THE TWO EXPRESSIONS "TURNS PER VOLT" AND "VOLTS PER TURN"?

4. – IF A CERTAIN SECONDARY WINDING OF A POWER TRANSFORMER IS TO OFFER A VOLTAGE OF 5 VOLTS AND YOU HAVE ALREADY DETERMINED THE "TURNS PER VOLT FACTOR" TO BE 5, THEN HOW MANY TURNS OF WIRE WOULD YOU USE FOR THIS 5 VOLT WINDING?

5. – A CERTAIN TRANSFORMER WINDING IS EXPECTED TO CARRY 80 MA. WHAT SIZE WIRE MAY BE USED FOR THIS WINDING?

6. – DESCRIBE IN DETAIL HOW THE VARIOUS CORE DIMENSIONS OF A POWER TRANSFORMER ARE DETERMINED.

7. – IF YOU HAVE DETERMINED THAT A "TURNS PER VOLT FACTOR" OF 3 IS TO BE USED FOR A GIVEN 60 CYCLE TRANSFORMER, THEN WHAT CROSS-SECTIONAL AREA WOULD YOU USE IN THE CONSTRUCTION OF THE CORE?

8. – WHAT IS A "STATIC-SHIELD" USED FOR IN POWER TRANSFORMER AND HOW IS IT INSTALLED IN THE UNIT?

9. – EXPLAIN BRIEFLY HOW YOU WOULD PROCEED IN THE TASK OF WINDING THE TRANSFORMER COILS.

RADIO - TELEVISION

Practical Training

NATIONAL SCHOOLS

Established 1905

Los Angeles, California

J. A. ROSENKRANZ, Pres.

LESSON NO. 60

• ANTENNA SYSTEMS FOR ALL-WAVE RECEIVERS •

IN ONE OF YOUR PREVIOUS LESSONS DEALING WITH THE PRINCIPLES AND CONSTRUCTIONAL FEATURES OF ALL-WAVE RECEIVERS, YOU WERE TOLD THAT THE ORDINARY TYPE OF ANTENNA WILL NOT ENABLE THE ALL-WAVE RECEIVER TO OPERATE AT ITS BEST DURING THE RECEPTION OF SHORT-WAVE PROGRAMS.

THERE ARE TWO OUTSTANDING REASONS FOR THIS AND THEY ARE AS FOLLOWS:

(1) THE ORDINARY TYPE OF ANTENNA PERMITS TOO MUCH "MAN-MADE" STATIC TO BE DELIVERED TO THE RECEIVER. THEN SINCE SHORT-WAVE RECEIVER CIRCUITS ARE MORE SUSCEPTABLE TO THIS FORM OF STATIC THAN ARE STANDARD WAVE RECEIVER CIRCUITS, THIS EXTRANEOUS NOISE AT TIMES BECOMES UNBEARABLE AND CAUSES WEAK SIGNALS TO BECOME INAUDIBLE.

(2) THE ORDINARY TYPE OF ANTENNA POSSESSES A VERY BROAD TUNING CHARACTERISTIC AND ALTHOUGH IT OFFERS A PICK-UP OF SIGNAL ENERGY ON THE SHORT-WAVE BANDS, IT NEVERTHELESS INTRODUCES CONSIDERABLE LOSS AS COMPARED TO WHAT ITS PERFORMANCE WOULD BE IF IT WERE MORE NEARLY RESONATED TO THE FREQUENCIES BEING RECEIVED.

THE LATEST TYPE OF ALL-WAVE ANTENNA SYSTEMS SOLVE BOTH OF THESE PROBLEMS IN SEVERAL DIFFERENT WAYS. LET US NOW PROCEED AND STUDY EACH OF THESE BASIC DESIGNS IN DETAIL.

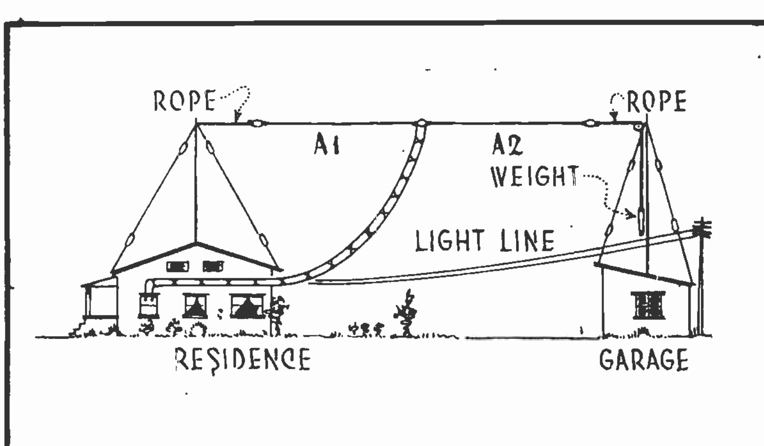

FIG. 1
A Modern Antenna

THE DOUBLET ANTENNA

THE FIRST OF THESE ANTENNA SYSTEMS, WHICH WE SHALL CONSIDER, IS THE DOUBLET WITH THE TRANSPOSED LEAD-IN AND which is illustrated in Fig. 2. You will no doubt remember this as also being the type of antenna as recommended for regular short-wave reception in a previous lesson dealing with this type of receiver. This same antenna is also suitable for all-wave receivers by applying the design constants which are offered in the following explanation.

To begin with, the horizontal portion of the antenna should be erected as high as possible and as far as practical from all surrounding buildings, trees and other objects which tend to absorb radio energy.

For best performance, the two horizontal lengths of the antenna A_1 and A_2 in Fig. 2 should be exactly equal in length and run exactly in the same direction or plane. When erecting this type of antenna, one should also remember that it is highly directional as to its pick up characteristics and receives best from directions at right angles to the direction in which the wire is stretched. That is to say, if the sections A_1 and A_2 of this antenna are run in a straight line north and south, then it will be most responsive to signals coming from the east and west.

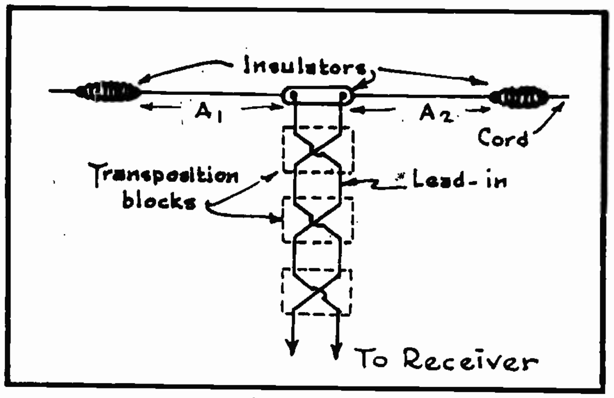

FIG. 2

Doublet With Transposed Lead-in.

The tuning characteristics of the doublet antenna are largely governed by the lengths A_1 and A_2. For best results on a given wavelength, the lengths A_1 and A_2 should each be equal to $\frac{1}{4}$ of the wavelength which one desires to receive best. For instance, if it is desired to resonate the system at 49 meters, around which a number of favorite short-wave broadcast stations operate, then the length of A_1 and A_2 should each be equal to $49 \div 4$ or 12.25 meters.

A simple method of determining these lengths expressed in feet when the resonant frequency is expressed in kilocycles is to divide the constant 492,000 by the desired frequency expressed in kilocycles and multiply the result by 0.95. This will furnish accurate figures on wavelengths of 20 meters and above. The answer which is obtained in this manner will be the total length of the antenna's flat top. This length is then cut in half and a strain insulator is placed at its exact center.

From the explanation as thus far offered, it becomes apparent that in order to realize maximum efficiency on all the different wave-bands, a different antenna-length would be required for each wave-band. This, however, would ordinarily be considered as impractical from a constructional standpoint in that a number of different antennas would have to be used — each of a different length. We must remember, however, that in addition to offering maximum pick-up at the fundamental resonant frequency, the doublet antenna will also be very effective in accepting the energy radiated by transmitters which operate on harmonics of the fundamental frequency for which the antenna is designed.

For example, if the antenna system is designed to resonate at 160 meters or 1875 Kc., then it will also operate with maximum efficiency at the harmonics of this fundamental and which occur respectively at 80 meters --3750 Kc; 40 meters--7500 Kc, and 20 meters--15,000 Kc. In other words, if the antenna system is designed to resonate at one of the longer wavelengths of the short-wave spectrum, it will also operate efficiently at still shorter wavelengths or higher frequencies corresponding to the harmonics. The reverse, however, is not true -- that is, if the antenna is designed to resonate at a fundamental of 40 meters or 7500 Kc., then it will not perform efficiently at 80 meters -- 3750 kc. or any other wavelength greater than 40 meters.

Another point to remember is that although the antenna is resonated to one particular frequency, it will also operate satisfactorily at frequencies which are not too far removed from resonance in either direction.

For maximum efficiency on the amateur bands, the length of the antenna's flat top should be as follows:

For 40 meters -- A_1 and A_2 each 33 ft. 3 inches
For 80 meters -- A_1 and A_2 each 66 ft. 6 inches
For 160 meters -- A_1 and A_2 each 133 ft.

In order to realize maximum efficiency for short-wave broadcast reception, the lengths A_1 and A_2 can each be $38\frac{1}{4}$ ft.

Remember that in all of these cases the rule of harmonics, as already explained, still applies.

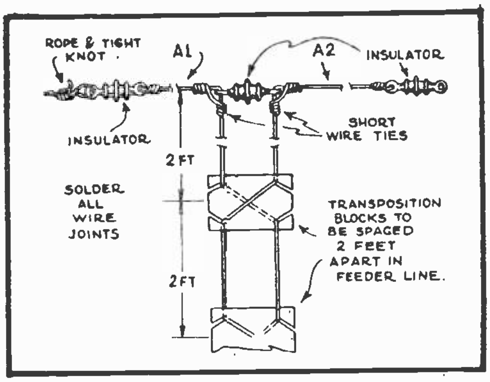

FIG.3
The Lead-in.

It will also no doubt be of interest to you to know that the majority of the short-wave stations broadcasting programs for popular entertainment are concentrated in the 16, 19, 25, 31 and 49 meter bands.

THE LEAD-IN

The constructional details of the transposed lead-in are more clearly illustrated in Fig. 3. Observe that the two lead-in wires are run parallel to eachother and transposed (crossed over) at definite intervals. The permissible distance between transmission blocks is from 15 inches to 2 ft. Enameled copper wire should be used for the lead-in, together with high-quality transposition blocks which can be purchased from any good radio supply house.

For greatest efficiency, the length of each of the lead-in wires should be equal to twice the length of A_1 or A_2 as used with the same antenna system. That is, if A_1 and A_2 are each $38\frac{1}{4}$ ft. long, then each of the lead-in wires should be $76\frac{1}{2}$ ft. long etc.

When using a special coupler between the lead-in and the receiver, you will find that this rule regarding feeder lengths is not strictly adhered to in practice. Quite often, this length is simply made as long as

NECESSARY IN ORDER TO CONNECT THE ANTENNA TO THE RECEIVER. THIS IS PARTLY JUSTIFIED BY THE FACT THAT THE CHIEF PURPOSE FOR TRANSPOSING THE LEAD-IN IS TO PREVENT THE PICK-UP OF INTERFERENCE NOISE AND THE LOCATION FOR THE ELEVATED PORTION OF THE ANTENNA IS ALSO SELECTED WITH THIS POINT IN MIND. THEREFORE, IF NECESSARY, IT IS MORE PRACTICAL TO ERECT THE ANTENNA AT SOME PARTICULAR SITE WHICH IS MOST FREE FROM INTERFERENCE AND SIMPLY RUN THE LEAD-IN IN THE BEST MANNER POSSIBLE TO AVOID ANY ADDITIONAL INTERFERENCE PICK-UP.

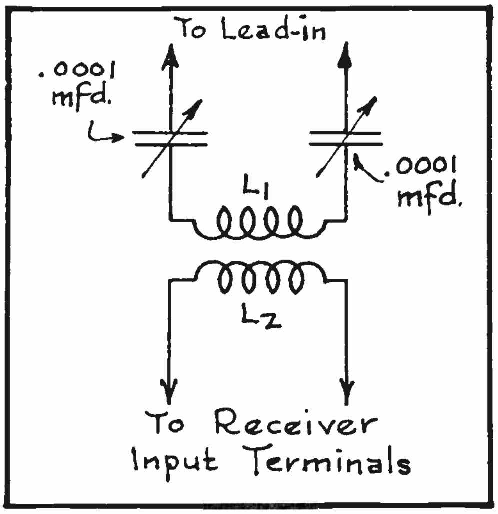

FIG. 4
The Tuned Coupler

THE SAME PRECAUTIONS SHOULD BE TAKEN IN RUNNING THIS LEAD-IN AS ALREADY SUGGESTED FOR THE ORDINARY SINGLE-WIRE LEAD-IN WHICH WAS DESCRIBED IN AN EARLIER LESSON REGARDING ANTENNAS.

THIS BRINGS US UP TO THE POINT OF COUPLING THE TWO-WIRE LEAD-IN TO THE RECEIVER. ALTHOUGH THE SYSTEM WILL OPERATE BY CONNECTING ONE OF THE LEAD-IN WIRES TO THE ANTENNA TERMINAL AND THE OTHER LEAD-IN WIRE TO THE GROUND TERMINAL OF THE RECEIVER, YET FAR BETTER RESULTS WILL BE OBTAINED BY INSTALLING A SUITABLE COUPLING UNIT BETWEEN THE LEAD-IN AND THE RECEIVER.

THE TUNED COUPLER

A TUNED COUPLING WITH IMPEDANCE MATCHING FEATURES IS THE MOST EFFICIENT TYPE. ONE OF THESE IS ILLUSTRATED IN FIG. 4 AND AS YOU WILL OBSERVE, IT CONSISTS OF A WINDING L_1 WHICH IS CONNECTED IN SERIES WITH THE TWO LEAD-IN WIRES THROUGH A PAIR OF MIDGET VARIABLE CONDENSERS, EACH RATED AT .0001 MFD. CAPACITY. THIS PARTICULAR CIRCUIT PERMITS TUNING THE ANTENNA LEAD-IN TO THE FREQUENCY BEING RECEIVED.

COIL L_1 IS INDUCTIVELY COUPLED TO ANOTHER COIL L_2, WHOSE IMPEDANCE SHOULD MATCH AS NEARLY AS POSSIBLE THE IMPEDANCE OF THE RECEIVER'S SHORT-WAVE ANTENNA COIL. COIL L_1 MAY CONSIST OF APPROXIMATELY 16 TURNS OF #22 B&S DOUBLE COTTON COVERED WIRE CLOSE-WOUND ON A TUBULAR COIL FORM OF $1\frac{1}{4}$" DIAMETER. COIL L_2 MAY CONSIST OF ABOUT 10 TURNS OF #30 B&S ENAMELED WIRE CLOSE-WOUND ON THE SAME FORM AND SPACED FROM L_1 BY APPROXIMATELY 1/16". BY MAKING THE COUPLING BETWEEN L_1 AND L_2 VARIABLE, THE PERFORMANCE OF THE COUPLER CAN BE IMPROVED STILL MORE.

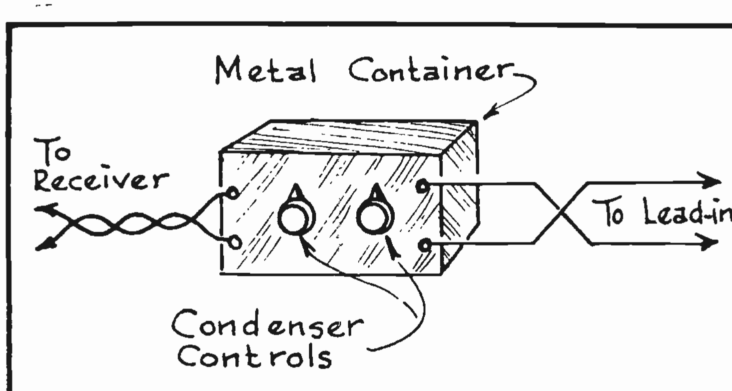

FIG. 5
The Antenna Coupler.

THIS COUPLER CAN BE ENCLOSED AS A UNIT IN A METAL SHIELD CAN, PROVIDED WITH THE NECESSARY TERMINALS FOR MAKING THE LEAD-IN AND RECEIVER CON-

NECTIONS AND CONTROL KNOBS FOR THE CONDENSERS. THE COUPLER IS THEN USED AS AN AUXILIARLY UNIT IN CONJUNCTION WITH THE RECEIVER. THE WIRES BETWEEN THE COUPLER AND THE RECEIVER MAY BE A TWISTED-PAIR FIXTURE WIRE. DURING RECEPTION, THE COUPLER CONTROLS ARE ADJUSTED FOR MAXIMUM SIGNAL INTENSITY.

A UNIVERSAL COUPLER

ALTHOUGH THE TUNED-COUPLER CALLS FOR ADDITIONAL MANIPULATION ON THE PART OF THE OPERATOR, YET IT IS THE MOST EFFICIENT TYPE. FOR THOSE WHO ARE WILLING TO SACRIFICE A CERTAIN AMOUNT OF EFFICIENCY FOR THE SAKE OF MORE SIMPLE OPERATION, THE UNIVERSAL COUPLER NOW TO BE EXPLAINED WILL BE SATISFACTORY.

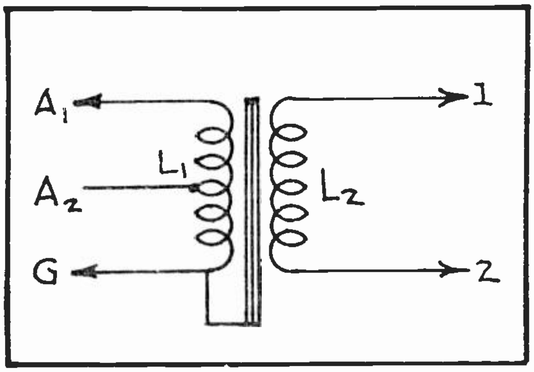

FIG. 6
Universal Coupler.

THE CONSTRUCTION OF THIS UNIVERSAL COUPLER IS SHOWN YOU IN FIG. 6. HERE THE TWO COILS L_1 AND L_2 ARE WOUND ON A TUBULAR FORM OF $1\frac{1}{4}$" DIAMETER IN THE FOLLOWING MANNER: FIRST APPLY L_1 BY WINDING 50 TURNS OF #28 B&S. ENAMELED WIRE CLOSE-WOUND AND CENTER-TAPPED. WIND ONE LAYER OF EMPIRE CLOTH OVER L_1 TO COVER THIS WINDING AND OVER THIS EMPIRE CLOTH WRAP A PIECE OF SHEET BRASS OF 7/8" WIDTH. THIS STRIP OF BRASS, WHICH IS GOING TO SERVE AS AN ELECTROSTATIC SHIELD, SHOULD NOT QUITE COMPLETE A FULL TURN. ATTACH A LEAD-WIRE TO ONE CORNER OF THIS BRASS STRIP SO THAT ITS ELECTRICAL CONNECTION CAN LATER BE AFFECTED.

WRAP ANOTHER LAYER OF EMPIRE CLOTH OVER THE BRASS STRIP AND THEN APPLY L_2 WHICH SHOULD CONSIST OF 10 TURNS OF #26 DOUBLE SILK COVERED WIRE SPACED ONE TURN AND WOUND IN THE SAME DIRECTION AS L_1.

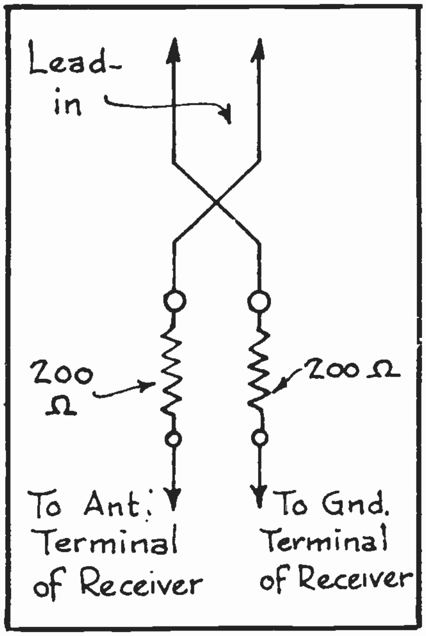

FIG. 7
Resistor Coupler.

THIS COUPLER CAN BE MOUNTED AT THE RECEIVER'S INPUT TERMINALS, WHERE IT NEED NOT BE DISTURBED. TERMINALS 1 AND 2 CAN BE CONNECTED TO THE ANTENNA AND GROUND TERMINALS OF THE RECEIVER. TERMINALS A_1 AND A_2 CAN BE CONNECTED TO THE ANTENNA LEAD-IN WIRES WHILE THE "G" TERMINAL IS CONNECTED TO GROUND. NOTICE THAT THE ELECTROSTATIC SHIELD IS ALSO GROUNDED. THIS COUPLER WILL PROVIDE AVERAGE PERFORMANCE OVER ALL OF THE WAVE-BANDS GENERALLY REQUIRED BY THE CONVENTIONAL TYPE OF ALL-WAVE RECEIVER.

THE RESISTANCE COUPLER

ANOTHER METHOD OF CONNECTING THE DOUBLET ANTENNA TO THE RECEIVER, WITHOUT THE USE OF AN INDUCTIVE TYPE COUPLER, IS TO CONNECT A 200 OHM 1 WATT RESISTOR BETWEEN THE RECEIVER'S ANTENNA TERMINAL AND ONE OF THE LEAD-IN WIRES AND ANOTHER 200 OHM 1 WATT RESISTOR BETWEEN THE RECEIVER'S GROUND TERMINAL AND THE OTHER LEAD-IN WIRE. NO GROUND CONNECTION IS USED. SOMETIMES, THESE RESISTORS ARE HELD IN CLIPS

AND INTERCHANGED WITH A SET HAVING OTHER VALUES DURING THE RECEPTION ON THE VARIOUS WAVE-BANDS.

THIS RESISTOR METHOD OF COUPLING ALTHOUGH BEING VERY SIMPLE, IS NEVERTHELESS NOT AS EFFICIENT AS THE OTHER METHODS SO FAR DESCRIBED.

VARIOUS COMMERCIAL TYPES OF ANTENNA COUPLERS ARE ALSO AVAILABLE ON THE MARKET SO THAT IT IS NOT ALTOGETHER ESSENTIAL FOR ONE TO ACTUALLY CONSTRUCT THE COUPLERS DESCRIBED IN THIS LESSON, UNLESS ONE REALLY CHOOSES TO DO SO.

LEAD-IN CABLE

AS YOU WILL NO DOUBT REALIZE, IT REQUIRES CONSIDERABLE WORK TO INSTALL AN ANTENNA SYSTEM WITH THE LEAD-IN ARRANGEMENTS AS SO FAR DESCRIBED. FOR THOSE WHO WANT TO SIMPLIFY THIS TASK, THE METHOD ILLUSTRATED IN FIG. 8 IS SUGGESTED. HERE THE DOUBLET FEATURES ARE STILL RETAINED BUT THE LEAD-IN IS RUN WITH A SPECIAL LOW-IMPEDANCE, TWIN-CONDUCTOR, R.F. TRANSMISSION CABLE OF THE TRANSPOSITION TYPE.

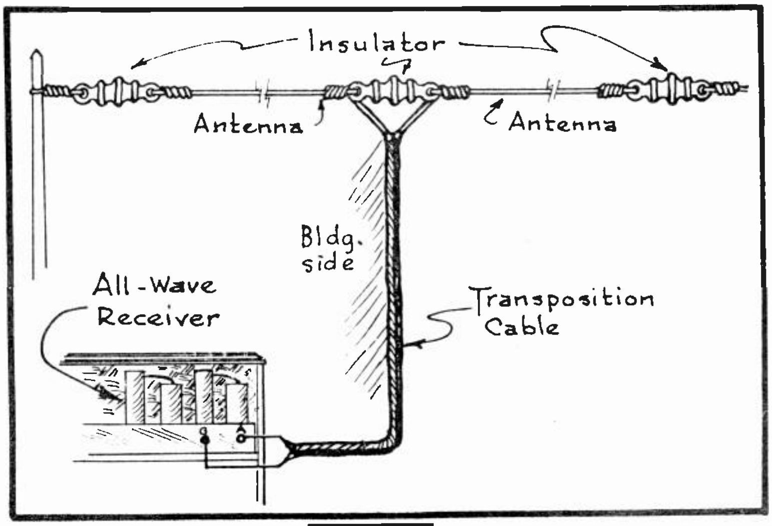

FIG. 8
Applying Transposition Cable

THIS TRANSMISSION CABLE IS AVAILABLE ON THE MARKET FOR THIS PURPOSE. THE TRANSPOSED TWIN CONDUCTORS ARE ALREADY ENCLOSED WITHIN A COMMON INSULATIVE AND WEATHER-PROOF COVERING. IT THUS BECOMES ONLY NECESSARY TO REMOVE A SHORT LENGTH OF THE OUTER COVERING FROM EACH END OF THIS CABLE SO THAT THE ENDS OF THE CONDUCTORS CAN BE CONNECTED TO THE ANTENNA AND RECEIVER AS SHOWN IN FIG. 8. THIS RUN OF CABLE CAN THEN BE SUPPORTED BY MEANS OF PORCELAIN KNOB INSULATORS WHICH ARE FASTENED TO THE BUILDING AT THE MOST LOGICAL POINTS. A PORCELAIN TUBE SHOULD BE USED AT THE POINT WHERE THE CABLE ENTERS THE BUILDING.

ALTHOUGH IN FIG. 8 THE LEAD-IN WIRES ARE SHOWN AS BEING CONNECTED DIRECTLY TO THE ANTENNA AND GROUND TERMINALS OF THE RECEIVER, YET HERE AGAIN THE EFFICIENCY OF THE SYSTEM CAN BE IMPROVED BY USING AN IMPEDANCE MATCHING TRANSFORMER BETWEEN THE LEAD-IN AND THE RECEIVER.

SOMETIMES, YOU WILL FIND DOUBLET ANTENNA INSTALLATIONS WHERE THE LEAD-IN IS RUN WITH A TWISTED-PAIR LAMP CORD BUT THE OTHER METHODS SO FAR DESCRIBED ARE MORE SATISFACTORY.

AS A GENERAL RULE, THE DOUBLET ANTENNA AS DESIGNED PRIMARILY FOR EFFICIENT SHORT-WAVE RECEPTION BECOMES LESS EFFICIENT AT THOSE FREQUENCIES CORRESPONDING TO THE STANDARD BROADCAST WAVE-BAND. THEREFORE, WHEN USED IN

CONJUNCTION WITH AN ALL-WAVE RECEIVER, THE VOLUME CONTROL OF THE RECEIVER WILL HAVE TO BE TUNED FARTHER UP THAN NORMAL DURING THE RECEPTION OF BROADCAST PROGRAMS ON THE STANDARD WAVE BAND.

A COMBINATION ANTENNA

IN FIG. 9 A METHOD IS ILLUSTRATED WHERE THE ANTENNA OPERATES AS A DOUBLET FOR MOST EFFICIENT SHORT-WAVE RECEPTION AND AS A T-TYPE ANTENNA FOR BETTER RECEPTION ON THE STANDARD WAVE-BANDS. A SWITCHING ARRANGEMENT MAKES THIS CHANGE-OVER A SIMPLE TASK.

BY STUDYING FIG. 9, YOU WILL NOTICE THAT THE ELEVATED OR HORIZONTAL PORTION OF THIS ANTENNA, AS WELL AS THE LEAD-IN, ARE ERECTED ACCORDING TO THE CONVENTIONAL DOUBLET METHOD. THE LEAD-IN, HOWEVER, IS CONNECTED TO A DOUBLE-POLE, DOUBLE-THROW SWITCH IN SUCH A MANNER THAT WITH THE SWITCH CLOSED IN THE "DOWN" OR SHORT-WAVE POSITION, THE TWO ENDS OF THE LEAD-IN WILL BE CONNECTED TO THE ANTENNA AND GROUND TERMINALS OF THE RECEIVER. THE ANTENNA WILL THEREFORE NOW FUNCTION AS A DOUBLET.

BY CLOSING THE SWITCH TO THE "UP" OR STANDARD BROADCAST POSITION, THE GROUND TERMINAL OF THE RECEIVER WILL BE GROUNDED AUTOMATICALLY, WHILE AT THE SAME TIME THE TWO LEAD-IN WIRES WILL BE SHORTED TOGETHER AND BOTH CONNECTED TO THE ANTENNA TERMINAL OF THE RECEIVER. THUS THE ANTENNA FUNCTIONS AS A T-TYPE ANTENNA FOR RECEPTION ON THE STANDARD-WAVE BROADCAST BAND.

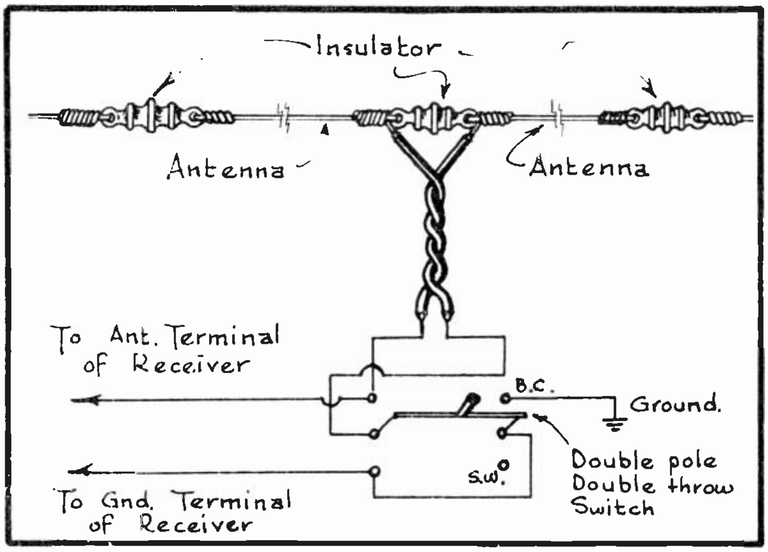

FIG. 9

Application of the Change-Over Switch.

ALL-WAVE ANTENNA KITS

QUITE A NUMBER OF MANUFACTURERS HAVE PLACED UPON THE MARKET ALL-WAVE ANTENNAS IN KIT FORM. IN THESE KITS, ALL OF THE NECESSARY PARTS ARE INCLUDED FOR THE ENTIRE INSTALLATION AND ALL COMPONENTS ARE MATCHED TO EACH OTHER. COMPLETE INSTRUCTIONS ARE ALSO FURNISHED WITH EACH OF THESE KITS SO THAT THE CAREFULLY DESIGNED PARTS WILL BE USED TO THE BEST ADVANTAGE. THE MAJORITY OF THESE KITS ARE DESIGNED TO OFFER SATISFACTORY RESULTS FOR SHORT-WAVE RECEPTION, AS WELL AS FOR RECEPTION ON THE STANDARD-WAVE BROADCAST BAND. THIS IS GENERALL ACCOMPLISHED BY A SWITCHING ARRANGEMENT WHICH IS PROVIDED ON THE COUPLING TRANSFORMER. THESE ALL-WAVE ANTENNA KITS CAN BE PURCHASED FROM MOST OF THE LARGER RADIO SUPPLY COMPANIES.

APPLICATION OF THE PENTAGRID CONVERTER TUBE TO SHORT-WAVE CONVERTERS

YOU ARE ALREADY FAMILIAR WITH THE BASIC CONSTRUCTIONAL FEATURES AND

OPERATING PRINCIPLES OF SHORT-WAVE CONVERTERS, AS WELL AS HAVING A GOOD UNDERSTANDING OF THE PENTAGRID CONVERTER TUBES SUCH AS THE 2A7 AND THE 6A7 WHICH ARE EXTENSIVELY USED IN SUPERHETERODYNE RECEIVERS TO SERVE AS A FIRST DETECTOR AND OSCILLATOR TUBE SIMULTANEOUSLY. SINCE THE CONVENTIONAL TYPE OF SHORT-WAVE CONVERTER ALSO REQUIRES THE USE OF A FIRST DETECTOR OR MIXER TUBE, AS WELL AS AN OSCILLATOR, IT IS NO MORE BUT LOGICAL THAT THE PENTAGRID CONVERTER TUBE CAN ALSO BE USED TO SERVE THIS TWO FOLD PURPOSE TO ADVANTAGE IN SHORT-WAVE CONVERTERS. FIG. 10 SHOWS YOU A TYPICAL EXAMPLE OF HOW THIS CAN BE ACCOMPLISHED.

BY STUDYING THE CIRCUIT DIAGRAM IN FIG. 10 YOU WILL SEE THAT THIS PARTICULAR CONVERTER HAS ITS INDIVIDUAL POWER SUPPLY, CAN BE OPERATED FROM EITHER AN A.C. OR D.C. 110 VOLT LIGHTING CIRCUIT AND USES ONLY TWO TUBES. THE -37 TUBE SERVES AS A RECTIFIER FOR THE "B" SUPPLY AND HAS ITS GRID AND PLATE TERMINALS CONNECTED TOGETHER, WHILE THE 6A7 IS USED AS A COM-

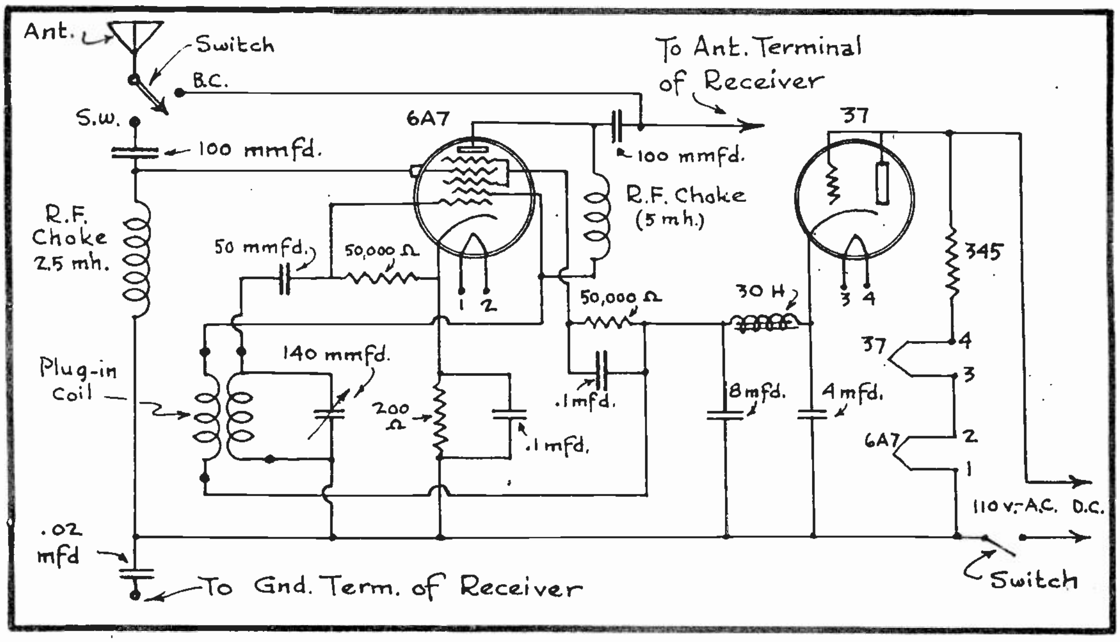

FIG. 10
Pentagrid Converter Tube Used In Short-Wave Converter.

BINATION FIRST DETECTOR AND OSCILLATOR.

THE HEATERS OF THE TWO TUBES ARE CONNECTED IN SERIES AS SHOWN IN THE RIGHT HAND SECTION OF THE DIAGRAM AND TOGETHER CONNECTED ACROSS THE 110 VOLT CIRCUIT THROUGH A 345 OHM, 35 WATT RESISTOR.

A TWO-POSITION SWITCH IS PROVIDED IN THE ANTENNA INPUT CIRCUIT OF THE CONVERTER. WITH THIS SWITCH IN THE B.C. POSITION, THE ANTENNA WILL BE CONNECTED DIRECTLY TO THE ANTENNA TERMINAL OF THE RECEIVER FOR BROADCAST RECEPTION AND THE CONVERTER'S POWER SWITCH IS OF COURSE AT THIS TIME TURNED OFF.

FOR SHORT-WAVE RECEPTION, THE TWO-POSITION SWITCH IS CLOSED IN THE S.W. POSITION WHICH CONNECTS THE ANTENNA IN SERIES WITH THE 100 MMFD. CONDENSER, THE 2.5 MILLIHENRY R.F. CHOKE, THE .02 MFD. CONDENSER AND GROUND.

HENCE THE INCOMING SIGNAL VOLTAGES ARE APPLIED TO THE CONTROL GRID OF THE TUBE.

THIS INPUT CIRCUIT OF THE CONVERTER IS OF THE UNTUNED TYPE, THAT IS, NO WINDING TUNED BY A VARIABLE CONDENSER IS USED IN THIS CIRCUIT. THE OSCILLATOR SECTION OF THE 6A7 TUBE, HOWEVER, IS TUNED BY A SINGLE 140 MMFD. VARIABLE CONDENSER WHICH IS CONNECTED ACROSS THE WINDING OF A PLUG-IN COIL. THE PLUG-IN COILS AS USED FOR THIS PURPOSE CONSIST OF TWO COUPLED WINDINGS, ONE OF WHICH IS TUNED BY THE 140 MMFD. VARIABLE CONDENSER WHILE THE OTHER SERVES AS THE FEED BACK COIL TO PRODUCE OSCILLATION. FROM TWO TO FOUR PLUG-IN COILS CAN BE USED TO COVER THE DESIRED WAVE-BANDS.

WHEN TUNING IN SHORT-WAVE SIGNALS WITH THIS CONVERTER, THE RECEIVER DIAL IS SET TO A POSITION CORRESPONDING TO A FREQUENCY SETTING AROUND 1000 KC. WHERE NO STANDARD BROADCAST SIGNAL COMES THROUGH. THE CONVERTER DIAL IS THEN ADJUSTED UNTIL THE DESIRED SHORT-WAVE SIGNAL IS HEARD. THE 5 MILLIHENRY R.F. CHOKE SERVES AS THE LOAD IN THE PLATE CIRCUIT OF THE 6A7 TUBE WITH WHICH TO FORCE THE SIGNAL THROUGH THE 100 MMFD. CONDENSER AND ON ITS WAY TO THE RECEIVER INPUT. WITH THIS ARRANGEMENT, TRUE SUPERHETERODYNE ACTION IS OBTAINED IN THE CONVERTER ALTHOUGH ONLY A SINGLE TUNING CONDENSER AND CONTROL IS EMPLOYED.

A FOUR-TUBE SHORT-WAVE CONVERTER

THE CIRCUIT DIAGRAM OF ANOTHER GOOD SHORT-WAVE CONVERTER IS ILLUSTRATED FOR YOU IN FIG. 11. HERE, FOUR TUBES ARE USED — A TYPE 77 AS THE FIRST DETECTOR, A 37 AS AN OSCILLATOR, A 78 AS AN I.F. AMPLIFIER AND A 37 AS A RECTIFIER. THIS CONVERTER HAS ITS OWN POWER PACK AND IS DESIGNED TO BE OPERATED FROM A 110 VOLT A.C. CIRCUIT.

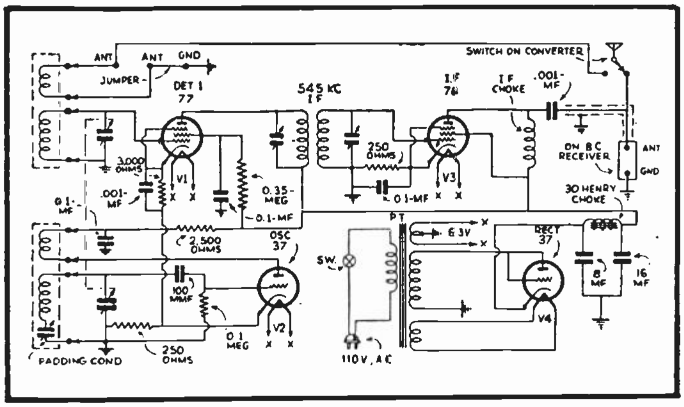

FIG. 11
The Four Tube Converter.

A TUNED INPUT IS FURNISHED FOR THE FIRST DETECTOR TUBE AND THE OSCILLATOR FREQUENCY IS SO ADJUSTED THAT WHEN IT HETERODYNES WITH THE INCOMING SIGNAL, A BEAT FREQUENCY OF 545 KC. WILL BE PRODUCED. THIS BEAT FREQUENCY IS THEN AMPLIFIED BY THE I.F. AMPLIFIER SECTION OF THIS CONVERTER, WHOSE I.F. TRANSFORMER HAS ITS PRIMARY AND SECONDARY WINDINGS BOTH PEAKED TO 545 KC.

THE OUTPUT OF THE 78 I.F. TUBE IS COUPLED TO THE INPUT OF THE STANDARD-WAVE BROADCAST RECEIVER SO THAT THIS AMPLIFIED BEAT FREQUENCY WILL BE TRANSFERRED TO THE RECEIVER FOR FURTHER AMPLIFICATION AND DETECTION. THE RECEIVER WILL OF COURSE ALSO HAVE TO BE TUNED TO A FREQUENCY OF 545 KC. FOR BEST SHORT-WAVE RECEPTION.

A SWITCH IS PROVIDED ON THE CONVERTER SO THAT THE ANTENNA CAN BE CONNECTED TO THE INPUT OF THE CONVERTER FOR SHORT-WAVE RECEPTION OR TO THE INPUT OF THE RECEIVER FOR STANDARD-WAVE BROADCAST RECEPTION WITH A MINI-

MUM OF EFFORT.

A TWO-GANG TUNING CONDENSER IS USED WITH THIS CONVERTER AND A GANG SWITCH IS EMPLOYED FOR COIL CHANGING PURPOSES IN ORDER TO COVER THE VARIOUS SHORT-WAVE BANDS. FOR THE SAKE OF CLARITY, ONLY A SINGLE GROUP OF COILS ARE SHOWN IN THE DIAGRAM. THE OTHER GROUPS ARE EXACTLY LIKE THOSE SHOWN WITH RESPECT TO THE CIRCUIT CONNECTIONS, ONLY THAT THE NUMBER OF TURNS USED VARY AS YOU ALREADY KNOW.

RADIO MANUFACTURER'S (R.M.A.) COLOR CODE FOR RESISTORS

IT IS NOT THE GENERAL PRACTICE AMONG THE MANUFACTURERS OF RESISTORS TO MARK THE OHMIC VALUE UPON THE UNIT. INSTEAD OF THIS, THE OUTER SURFACE OF THE RESISTOR UNIT IS PAINTED IN A COMBINATION OF COLORS AND BY PROPERLY INTERPRETING THIS COLOR-COMBINATION, ONE CAN READILY DETERMINE THE RESISTANCE VALUE OF THE UNIT.

FIG. 12 SHOWS YOU THE CUSTOMARY MANNER IN WHICH FIXED RESISTORS ARE COLORED. AS YOU WILL OBSERVE, THE BODY OF THE RESISTOR IS PAINTED ONE COLOR, THE END OF THE RESISTOR ANOTHER COLOR AND A THIRD COLOR IS ADDED IN THE FORM OF A SPOT OR BAND AT THE CENTER OF THE BODY.

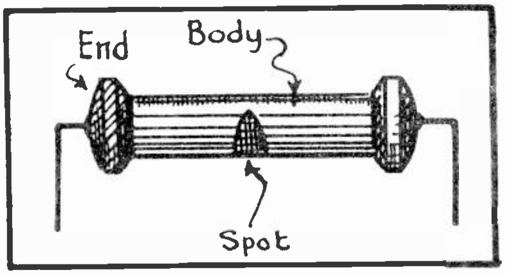

FIG. 12
Resistor Color Combination

THE BODY COLOR OF THE RESISTOR INDICATES THE FIRST SIGNIFICANT FIGURE, THE END COLOR DESIGNATES THE SECOND SIGNIFICANT FIGURE AND THE SPOT OR BAND COLOR DESIGNATES THE THIRD SIGNIFICANT FIGURE OF THE UNIT'S OHMIC VALUE.

THE FOLLOWING TABLE EXPLAINS THE NUMERICAL VALUE FOR THE RESPECTIVE COLORS.

BODY COLOR	END COLOR	SPOT OR BAND COLOR
BROWN...........1	BLACK..........0	BLACK..........0
RED.............2	BROWN..........1	BROWN..........0.
ORANGE..........3	RED............2	RED............00.
YELLOW..........4	ORANGE.........3	ORANGE.........000.
GREEN...........5	YELLOW.........4	YELLOW.........0000.
BLUE............6	GREEN..........5	GREEN..........00000.
VIOLET..........7	BLUE...........6	BLUE...........000000.
GRAY............8	VIOLET.........7	
WHITE...........9	GRAY...........8	
BLACK...........0	WHITE..........9	

EXAMPLE:- A FIXED RESISTOR HAS A RED BODY COLOR, A BLACK END COLOR AND A GREEN SPOT ON ITS BODY. WHAT IS THE RESISTANCE IN OHMS OF THIS UNIT?

ANSWER:- BODY COLOR OF RED DESIGNATES A FIRST SIGNIFICANT FIGURE OF 2; END COLOR OF BLACK DESIGNATES A SECOND SIGNIFICANT FIGURE OF 0, BRINGING THE VALUE SO FAR TO 20; GREEN SPOT ON BODY DESIGNATES A THIRD SIGNIFICANT FIGURE OF 00000; THE RESISTANCE OF THIS PARTICULAR UNIT IS THEREFORE 2,000,000 OHMS OR 2 MEGOHMS.

COLOR-CODED FIXED MICA CONDENSERS

ALTHOUGH SOME MANUFACTURERS OF FIXED MICA CONDENSERS MARK THE CAPACITIVE VALUE DIRECTLY UPON THE UNIT WHILE OTHERS DON'T SUPPLY ANY IDENTIFICATION MARKINGS AT ALL, YET THERE ARE OTHERS WHICH MARK THE RATING OF THE CONDENSER DIRECTLY UPON THE UNIT IN THE FORM OF A COLOR CODE.

IN THE CASE OF COLOR CODING, THREE COLORED DOTS INDICATE ITS CAPACITY AND TWO COLORED DOTS ITS D.C. WORKING VOLTAGE. THE COLORS ARE ASSIGNED AS FOLLOWS: BLACK = 0; BROWN = 1; RED = 2; ORANGE = 3; YELLOW = 4; GREEN = 5; BLUE = 6; PURPLE = 7; GRAY = 8; WHITE = 9.

ON CONDENSERS HAVING THREE DOTS ON ONE SIDE AND TWO ON THE OTHER, THE DESIGNATIONS ARE TO BE READ WITH THE CAPACITY RATING (3 DOTS) AT THE BOTTOM, WHILE ON CONDENSERS HAVING ALL FIVE DOTS ON ONE SIDE, THE DESIGNATIONS ARE TO BE READ WITH THE CAPACITY RATING AT THE TOP.

REFERRING TO THIS CODE, THE FIRST COLOR INDICATES THE FIRST DIGIT OF THE CAPACITY EXPRESSED IN MMFD. THE SECOND COLOR INDICATES THE SECOND DIGIT OF THE CAPACITY ALSO EXPRESSED IN MMFD. THE THIRD COLOR INDICATES THE NUMBER OF CIPHERS FOLLOWING THE SECOND DIGIT OF THE CAPACITY.

TO ILLUSTRATE THIS, LET US CONSIDER AN ACTUAL EXAMPLE: THE CAPACITIVE MARKING OF A CERTAIN MICA CONDENSER APPEARS AS RED, GREEN AND BROWN DOTS ARRANGED IN A ROW AND IN THE ORDER HERE STATED. THE RED DOT INDICATES THE FIRST DIGIT AS BEING 2; THE GREEN DOT INDICATES THE SECOND DIGIT AS BEING 5 AND THE BROWN DOT DESIGNATES THAT ONE CIPHER FOLLOWS THE SECOND DIGIT. THUS THE CAPACITIVE VALUE OF THE CONDENSER IS 250 MMFD.

AS ANOTHER EXAMPLE, THE THREE DOTS ARRANGED IN THE ORDER OF BROWN, BLACK AND RED, WOULD INDICATE THE CONDENSER CAPACITY AS BEING 1000 MMFD.

AS TO THE CODING OF THE D.C. VOLTAGE RATING BY THE TWO DOTS, THE FIRST DOT INDICATES MULTIPLES OF 10 VOLTS. FOR EXAMPLE, THE TWO DOTS ON A CERTAIN CONDENSER ARE RESPECTIVELY COLORED ORANGE AND GREEN. THE D.C. WORKING VOLTAGE OF THE CONDENSER IS THEREFORE 350 VOLTS. SHOULD THE TWO DOTS BE BLUE AND BLACK RESPECTIVELY, THEN THE D.C. VOLTAGE RATING OF THE CONDENSER WOULD BE 600 VOLTS.

Examination Questions

LESSON NO 60

"Success without difficulty, or achievement without effort, is robbed of most of its triumph".

1. - WHAT ARE SOME OF THE CHIEF DISADVANTAGES OF THE ORDINARY TYPE OF ANTENNA SYSTEM WHEN USED FOR SHORT-WAVE RECEPTION?

2. - WHAT ARE SOME OF THE MORE IMPORTANT POINTS TO CONSIDER WHEN ERECTING A DOUBLET ANTENNA?

3. - IF YOU WERE CONTEMPLATING THE CONSTRUCTION OF A DOUBLET ANTENNA AND WISHED TO RESONATE IT AT 6122 KC., HOW LONG WOULD YOU MAKE EACH OF THE TWO SECTIONS A_1 AND A_2, THAT IS, THE TWO HALVES OF THE ANTENNA'S HORIZONTAL OR ELEVATED SECTIONS?

4. - DESCRIBE A TYPICAL TUNED COUPLER WHICH MAY BE USED AS THE CONNECTION BETWEEN THE LEAD-IN WIRES OF A DOUBLET ANTENNA AND A RECEIVER.

5. - DESCRIBE A TYPICAL TRANSPOSITION TYPE LEAD-IN EMPLOYING TRANSPOSITION BLOCKS AND WHICH IS TO BE USED IN CONJUNCTION WITH A DOUBLET ANTENNA.

6. - A CERTAIN RESISTOR HAS A BROWN BODY COLOR, A BLACK END COLOR AND A YELLOW SPOT ON ITS BODY. WHAT IS THE RESISTANCE VALUE OF THIS RESISTOR?

7. - DRAW A DIAGRAM, SHOWING HOW A SWITCH WILL PERMIT AN ANTENNA TO BE USED EITHER AS A DOUBLET OR A T TYPE ANTENNA FOR ALL-WAVE RECEPTION.

8. - WHAT IS THE CHIEF ADVANTAGE OF USING SOME COUPLING DEVICE BETWEEN THE LEAD-IN WIRES OF A DOUBLET ANTENNA AND THE RECEIVER RATHER THAN CONNECTING THE LEAD-IN WIRES DIRECTLY TO THE RECEIVER?

9. - HOW WOULD A DOUBLET ANTENNA ACT IF THE TWO HALVES A_1 AND A_2 OF THE ELEVATED SECTION WERE NOT OF EQUAL LENGTH?

10. - EXPLAIN BRIEFLY WITH THE AID OF A DIAGRAM, SHOWING HOW A PENTAGRID CONVERTER TUBE MAY BE USED IN A SHORT-WAVE CONVERTER.

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LESSON NO. 61

METAL TUBES

FROM YOUR ASSOCIATION WITH RADIO SO FAR, YOU WILL REALIZE WHAT A GREAT MANY REFINEMENTS HAVE BEEN MADE FROM YEAR TO YEAR IN THE DESIGN OF VACUUM TUBES.

THE MOST RECENT REVOLUTIONARY CHANGE WHICH TOOK PLACE CONSISTED OF REPLACING THE CUSTOMARY GLASS BULB OR ENCLOSURE WITH A METAL CONTAINER. TUBES OF THIS LATTER DESIGN ARE KNOWN AS THE METAL TUBES AND THEY ARE BEING USED EXTENSIVELY IN RECEIVERS OF RECENT DESIGN.

IN FIG.1 YOU ARE SHOWN THE CHASSIS OF A MODERN ALL-WAVE RECEIVER WHICH IS EQUIPPED WITH METAL TUBES. BY STUDYING THIS ILLUSTRATION CAREFULLY, YOU WILL OBSERVE HOW TUBES OF THIS TYPE APPEAR WHEN INSTALLED IN A TYPICAL RECEIVER.

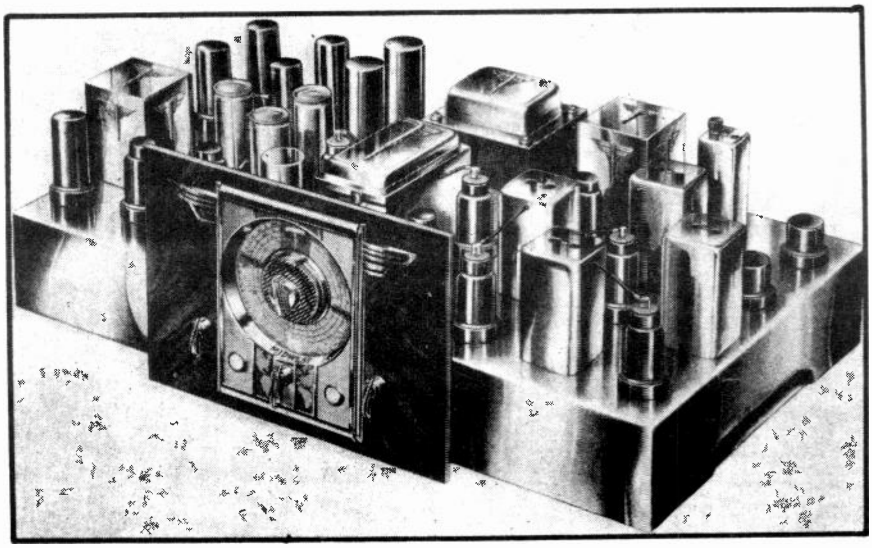


FIG. 1
A Modern All-Wave Metal Tube Receiver.

AT THE LEFT OF FIG. 2 YOU ARE SHOWN A COMPARISON OF SIZE AND APPEARANCE BETWEEN A TYPICAL GLASS AND METAL TUBE, WHILE AT THE

RIGHT OF FIG. 2 ONE TYPE OF METAL TUBE IS SHOWN IN GREATER DETAIL.

ASIDE FROM THE METAL ENCLOSURE, THE MAJORITY OF METAL TUBES ARE SMALLER BOTH IN DIAMETER AND HEIGHT THAN THE CORRESPONDING GLASS TUBE. ANOTHER GREAT DIFFERENCE FROM THE STANDPOINT OF APPEARANCE IS THAT THE METAL TUBES ARE EQUIPPED WITH 8-PRONG BASES WHICH ARE KNOWN AS OCTAL BASES. IN ADDITION, THE OCTAL BASE IS FITTED WITH AN ALIGNING PLUG.

TUBE CONSTRUCTION

YOU WILL ACQUIRE A STILL CLEARER UNDERSTANDING OF THE INTERNAL CONSTRUCTION OF THE ALL-METAL TUBE BY REFERRING TO THE CUT-AWAY SECTION OF THE TUBE WHICH APPEARS IN FIG.3. STUDY THIS ILLUSTRATION CAREFULLY AND NOTE THAT THE INDEX NUMBERS, WHICH APPEAR ON THIS UNIT, CORRESPOND WITH THE PARTS NAMES ALSO APPEARING IN THIS SAME ILLUSTRATION IN TABULAR FORM.

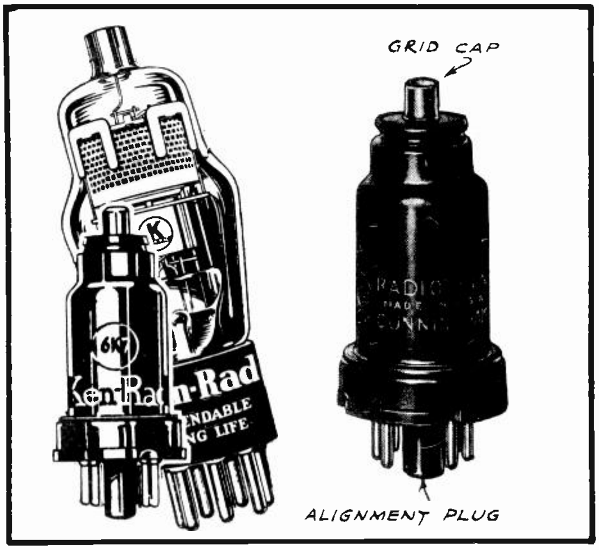


FIG. 2
Tube Comparison

A GROUP OF VARIOUS TYPES OF POPULAR METAL TUBES ARE SHOWN YOU IN FIG.4, WHILE FIG.5 FURNISHES THE OUTLINE DIMENSIONS OF THESE SAME TUBES AS SPECIFIED BY R.C.A. FROM AN EXAMINATION OF THESE TWO ILLUSTRATIONS, YOU WILL ACQUIRE A CLEAR MENTAL PICTURE OF THESE DISTINCTIVE TUBE SHAPES, THEIR PROPORTIONS AS TO SIZE, AND THEIR CORRESPONDING IDENTIFICATION NUMBERS.

THE OCTAL BASE

THE ARRANGEMENT AND DIMENSIONS OF THE SMALL OCTAL 8-PIN BASE, AS USED WITH THESE METAL TUBES, IS ILLUSTRATED IN FIG.6.

YOU WILL OBSERVE FROM THIS ILLUSTRATION THAT WHEN A TOTAL OF EIGHT PRONGS ARE MOUNTED ON THE BASE, THEY ARE SPACED EQUI-DISTANT APART AND NUMBERED AS DESIGNATED IN FIG. 6. THESE PRONGS ARE ALL EQUAL IN DIAMETER AND LENGTH, AND IF THE PARTICULAR TUBE TYPE HAPPENS TO BE SUCH THAT ALL EIGHT PRONGS ARE NOT REQUIRED, THEN THE SURPLUS PRONGS ARE SIMPLY OMITTED FROM THE BASE BY THE MANUFACTURER.

REGARDLESS OF THE NUMBER OF BASE PRONGS USED, HOWEVER, THE SPACING OF THE PRONGS USED STILL REMAINS THE SAME AS THOUGH ALL EIGHT PRONGS WERE INSTALLED. AT THOSE POINTS ON THE BASE WHERE NO PRONGS ARE REQUIRED, THEY ARE OMITTED IN THE ORDER AS SPECIFIED IN THE TABLE IN THE LOWER SECTION OF FIG.6.

WITH A STANDARD BASE ARRANGEMENT AS THIS FOR ALL METAL TUBES, IT IS CLEAR THAT THE SAME SIZE AND TYPE OF SOCKET CAN BE USED FOR ANY OF THESE TUBES, AND CIRCUIT CONNECTIONS ONLY MADE AT THOSE POINTS WHERE NECESSARY.

THE CONSTRUCTIONAL FEATURES OF AN OCTAL TUBE SOCKET ARE SHOWN IN

FIG.7. HERE YOU WILL NOTE THAT EIGHT HOLES ARE ARRANGED IN A CIRCULAR PATH AROUND THE SOCKET TO ACCOMMODATE THE PRONGS OF THE TUBE BASE. A ROUND HOLE IS PROVIDED AT THE CENTER OF THE SOCKET THROUGH WHICH THE ALIGNING PLUG OF THE TUBE BASE CAN BE INSERTED.

A SLOT IN THE ALIGNING HOLE TAKES CARE OF THE KEY PROJECTION ON THE ALIGNING PLUG OF THE TUBE BASE AND THUS PERMITS THE TUBE TO BE INSTALLED INTO THE SOCKET IN ONE POSITION ONLY, IN SPITE OF THE FACT THAT ALL OF THE PRONG HOLES OF THE SOCKETS ARE OF THE SAME SIZE AND EQUALLY SPACED.

THE NUMBERING OF THE BASE PRONGS, AS WILL BE NOTED IN FIG.6, ALWAYS STARTS FROM THE SHELL CONNECTION OF THE TUBE AND WHICH IS THE FIRST PIN TO THE LEFT OF THE LOCATING KEY ON THE ALIGNING PLUG WHEN THE BASE IS VIEWED FROM THE BOTTOM AND WITH THE KEY TOWARD THE OBSERVER. FROM THIS FIRST PIN, THE OTHERS ARE ALL NUMBERED IN A CONSECUTIVE ORDER AND IN A CLOCKWISE DIRECTION.

METAL TUBE CHARACTERISTICS

NOW THAT YOU ARE IN A GENERAL WAY FAMILIAR WITH METAL TUBES, YOUR NEXT STEP WILL BE TO ACQUAINT YOURSELF WITH THE SYMBOLS AND OPERATING CHARACTERISTICS OF EACH OF THESE TUBE TYPES.

IN EACH OF THE SYMBOLS OF THE TUBES WHICH ARE NOW GOING TO BE DESCRIBED TO YOU, THE FOLLOWING ABREVIATIONS ARE USED: S = THE METAL SHELL OF THE TUBE WHICH IS ALWAYS CONNECTED TO PIN #1 OF THE BASE. THIS PIN CONNECTION IS THEN GROUNDED WHEN WIRING THE CIRCUITS AND THE METAL SHELL THEN SERVES AS A SHIELD FOR THE TUBE, THEREBY DOING AWAY WITH THE NEED FOR A SHIELD AS REQUIRED BY GLASS TUBES; H = HEATER CONNECTION; K-K_1 AND K_2 = CATHODE CONNECTIONS; P-P_1 AND P_2 = PLATE OR DIODE PLATE CONNECTIONS; G-G_1 -G_2

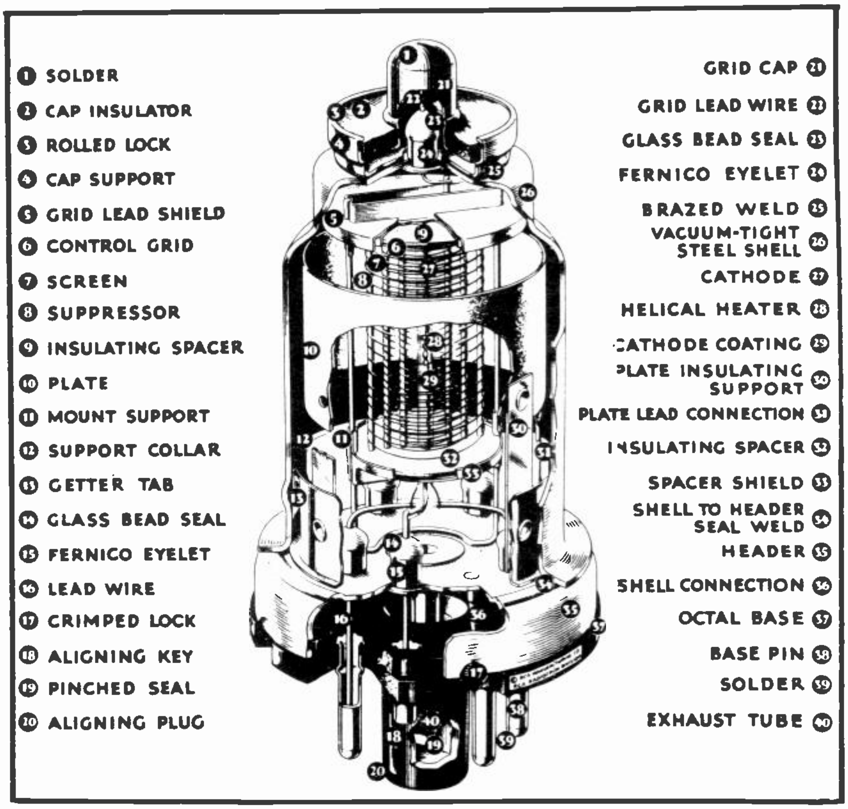


FIG. 3
Internal Structure of an All- Metal Tube.

G_3-G_4 AND G_5 = GRID CONNECTIONS.

THE 5Z4

THE 5Z4 IS A FULL-WAVE, HIGH-VACUUM RECTIFYING TUBE OF THE METAL TYPE INTENDED FOR USE IN D-C POWER-SUPPLY DEVICES WHICH OPERATE FROM THE A-C SUPPLY LINE.

HEATER VOLTAGE	5.0	VOLTS
HEATER CURRENT	2.0	AMPERES
A-C PLATE VOLTAGE PER PLATE (RMS)	400 MAX.	VOLTS
PEAK INVERSE VOLTAGE	1100 MAX.	VOLTS
D-C OUTPUT CURRENT	125 MAX.	MILLIAMPERES
BASE	SMALL OCTAL 5-PIN	

THE BASE PINS OF THE 5Z4 FIT THE FIVE-CONTACT OCTAL-BASE SOCKET FOR THIS PIN ARRANGEMENT (OR THE UNIVERSAL EIGHT-CONTACT SOCKET) WHICH SHOULD BE INSTALLED TO HOLD THE TUBE IN A VERTICAL POSITION WITH THE BASE DOWN. PROVISION SHOULD BE MADE FOR FREE CIRCULATION OF AIR AROUND THE TUBE SINCE IT BECOMES QUITE HOT DURING OPERATION.

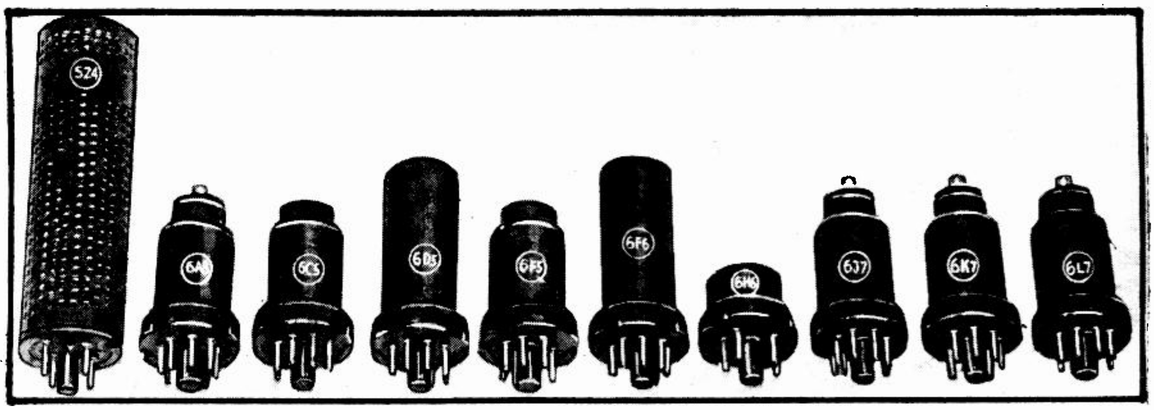


FIG. 4
A Group of Popular Metal Tubes.

THE HEATER OF THE 5Z4 IS DESIGNED TO OPERATE FROM THE A-C LINE THROUGH A STEP-DOWN TRANSFORMER. THE VOLTAGE APPLIED TO THE HEATER SHOULD BE THE RATED VALUE OF 5.0 VOLTS UNDER OPERATING CONDITIONS AND AVERAGE LINE VOLTAGE.

THE 6C5

THE 6C5 IS A THREE-ELECTRODE TUBE OF THE METAL TYPE RECOMMENDED FOR USE AS A DETECTOR, AMPLIFIER, OR OSCILLATOR. THIS TUBE HAS A HIGH MUTUAL CONDUCTANCE TOGETHER WITH A COMPARATIVELY HIGH AMPLIFICATION FACTOR.

HEATER VOLTAGE (A.C. OR D.C.)	6.3	VOLTS
HEATER CURRENT	0.3	AMPERE
PLATE VOLTAGE	250 MAX.	VOLTS
GRID VOLTAGE	-8	VOLTS
PLATE CURRENT	8	MILLIAMPERES
PLATE RESISTANCE	10000	OHMS
AMPLIFICATION FACTOR	20	

MUTUAL CONDUCTANCE	2000	MICROMHOS
GRID-PLATE CAPACITANCE	1.8	MMFD.
GRID-CATHODE CAPACITANCE	4	MMFD.
PLATE-CATHODE CAPACITANCE	13	MMFD.
BASE	SMALL OCTAL 6-PIN	

IF A GRID-COUPLING RESISTOR IS USED, ITS MAXIMUM VALUE SHOULD NOT EXCEED 1.0 MEGOHM.

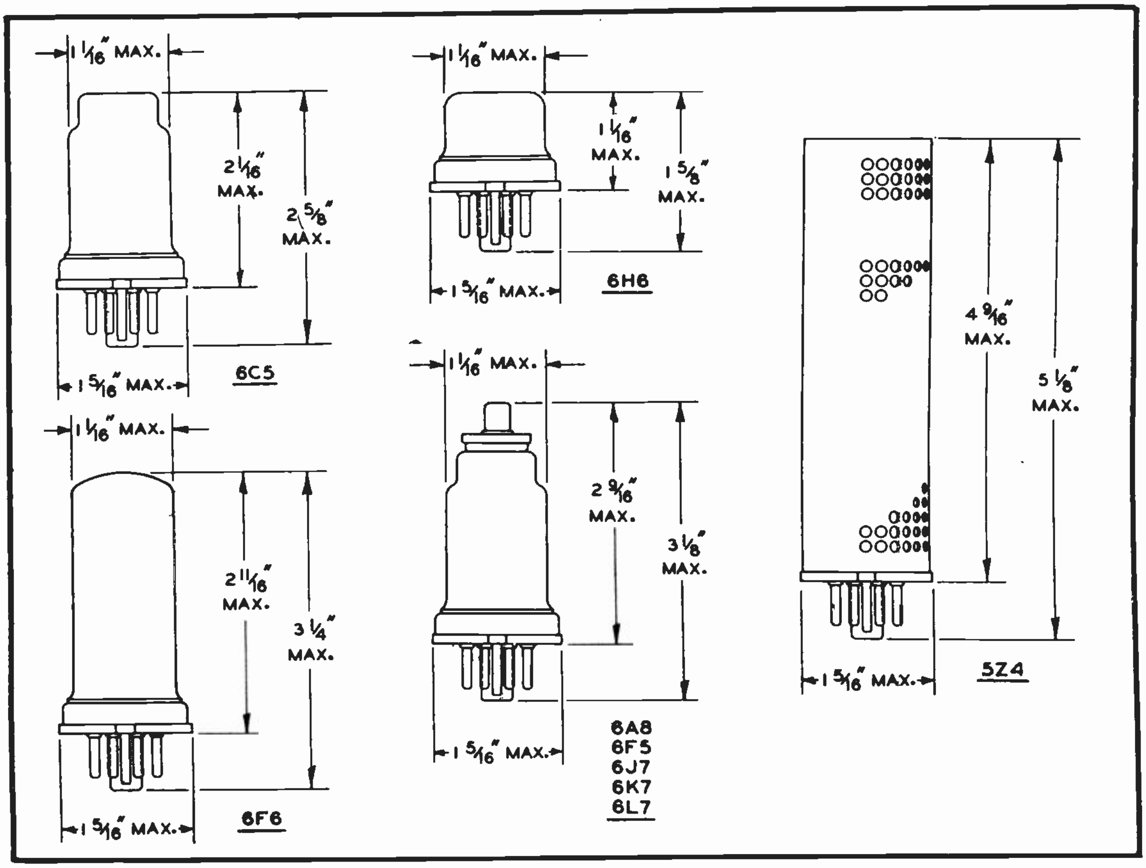


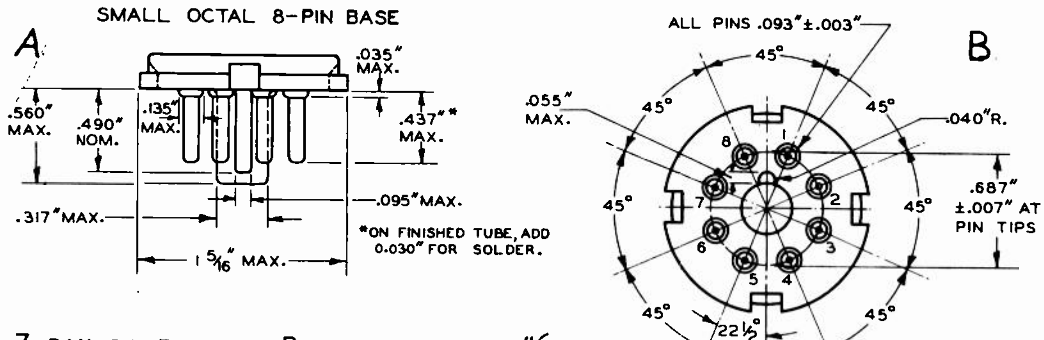
FIG. 5
Dimensions of All-Metal Tubes.

AS AN AMPLIFIER, THE 6C5 IS APPLICABLE TO RADIO FREQUENCY OR AUDIO FREQUENCY CIRCUITS. FOR CIRCUITS UTILIZING RESISTANCE COUPLING, TYPICAL OPERATING CONDITIONS ARE AS FOLLOWS:

PLATE-SUPPLY VOLTAGE	250	VOLTS
GRID-BIAS VOLTAGE (APPROX.)	-5	VOLTS
PLATE LOAD RESISTOR	50000 TO 100000	OHMS
PLATE CURRENT	1 TO 2	MILLIAMPERES
VOLTAGE AMPLIFICATION	14	
VOLTAGE OUTPUT (5% SECOND HARMONIC)	42	VOLTS (RMS)

AS A DETECTOR, THE 6C5 MAY BE OF THE GRID-LEAK AND CONDENSER OR GRID-BIAS TYPE. THE PLATE VOLTAGE FOR THE GRID LEAK AND CONDENSER METHOD SHOULD BE 45 TO 100 VOLTS. A GRID LEAK FROM 0.1 TO 1.0 MEGOHM WITH A

GRID CONDENSER OF 0.00005 TO 0.0005 MFD. IS SATISFACTORY. FOR THE GRID-BIAS METHOD OF DETECTION, A PLATE-SUPPLY VOLTAGE OF 250 VOLTS MAY BE USED TOGETHER WITH A NEGATIVE GRID-BIAS VOLTAGE OF APPROXIMATELY 17 VOLTS. THE PLATE CURRENT SHOULD BE ADJUSTED TO 0.2 MILLIAMPERE WITH NO INPUT SIGNAL VOLTAGE. THE GRID-BIAS VOLTAGE MAY BE SUPPLIED FROM THE VOLTAGE DROP IN A RESISTOR BETWEEN CATHODE AND GROUND.



7-PIN BASE AS AT B, OMITTING PIN #6
6-PIN BASE AS AT B, OMITTING PINS #4&6
5-PIN BASES ARRANGEMENT #1-AS AT B, OMITTING PINS #3,5 & 7
ARRANGEMENT #2-AS AT B, OMITTING PINS #3,5 & 6

FIG. 6
The Small Octal 8-Pin Tube Base.

THE 6F5

THE 6F5 IS A HIGH-MU TRIODE OF THE METAL TYPE. IT IS PARTICULARLY SUITABLE FOR USE IN RESISTANCE-COUPLED AMPLIFIER CIRCUITS.

HEATER VOLTAGE (A.C. OR D.C.)	6.3	VOLTS
HEATER CURRENT	0.3	AMPERE
PLATE VOLTAGE	250 MAX.	VOLTS
GRID VOLTAGE	-2	VOLTS
PLATE CURRENT	0.9	MILLIAMPERE
PLATE RESISTANCE	66000	OHMS
AMPLIFICATION FACTOR	100	
MUTUAL CONDUCTANCE	1500	MICROMHOS
GRID-PLATE CAPACITANCE	2	MMFD.
GRID-CATHODE CAPACITANCE	6	MMFD.
PLATE-CATHODE CAPACITANCE	12	MMFD.
BASE	SMALL OCTAL 5-PIN	

AS AN AMPLIFIER IN RESISTANCE-COUPLED A-F CIRCUITS, THE 6F5 MAY BE OPERATED UNDER THE FOLLOWING CONDITIONS:

PLATE-SUPPLY VOLTAGE	250	250	VOLTS
GRID-BIAS VOLTAGE	-1.3	-1.3	VOLTS
PLATE LOAD RESISTOR	0.25 TO 1.0	0.25 TO 1.0	MEGOHM

GRID RESISTOR * *	0.25	0.5	MEGOHM
PLATE CURRENT	0.2 TO 0.4	0.2 TO 0.4	MILLIAMPERE
VOLTAGE AMPLIFICATION	52 TO 56	51 TO 60	
VOLTAGE OUTPUT	11 TO 20	14.5 TO 25.5	VOLTS (RMS)

* FOR THE FOLLOWING AMPLIFIER TUBE.

WHEN A 6F5 IS USED TO AMPLIFY THE OUTPUT OF THE 6H6 DIODE, IT IS RECOMMENDED THAT FIXED GRID BIAS BE EMPLOYED. DIODE-BIASING OF THE 6F5 IS NOT SUITABLE BECAUSE OF THE PROBABILITY OF PLATE-CURRENT CUT-OFF, EVEN WITH RELATIVELY SMALL SIGNAL VOLTAGES APPLIED TO THE DIODE CIRCUIT.

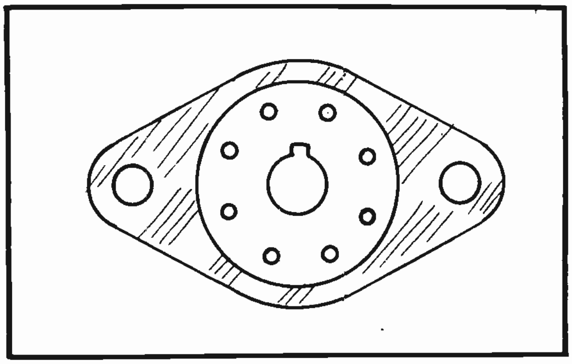


FIG. 7
An Octal Socket.

THE 6F6

THE 6F6 IS A HEATER-CATHODE POWER-AMPLIFIER PENTODE OF THE METAL TYPE FOR USE IN THE AUDIO-OUTPUT STAGE OF A-C RECEIVERS. IT IS CAPABLE OF GIVING LARGE POWER OUTPUT WITH A RELATIVELY SMALL INPUT VOLTAGE. BECAUSE OF THE HEATER-CATHODE CONSTRUCTION, A UNIFORMLY LOW HUM-LEVEL IS ATTAINABLE IN POWER-AMPLIFIER DESIGN.

HEATER VOLTAGE (A.C. OR D.C.)	6.3	VOLTS
HEATER CURRENT	0.7	AMPERE
BASE	SMALL OCTAL 7-PIN	

SINGLE-TUBE CLASS A AMPLIFIER

	PENTODE	CONNECTION	TRIODE (SCREEN TIED TO PLATE)	
PLATE VOLTAGE	250	315 MAX.	250 MAX.	VOLTS
SCREEN VOLTAGE	250	315 MAX.		VOLTS
GRID VOLTAGE	-16.5	-22	-20	VOLTS
PLATE CURRENT	34	42	31	MILLIAMPERES
SCREEN CURRENT	6.5	8		MILLIAMPERES
PLATE RESISTANCE	80000	75000	2600	OHMS
AMPLIFICATION FACTOR	200	200	7	
MUTUAL CONDUCTANCE	2500	2650	2700	MICROMHOS
LOAD RESISTANCE	7000	7000	4000	OHMS
TOTAL HARMONIC DISTORTION	7	7	5	PER CENT
POWER OUTPUT	3	5	0.85	WATTS

UNDER THE ABOVE MAXIMUM VOLTAGE CONDITIONS, TRANSFORMER OR IMPEDANCE INPUT-COUPLING DEVICES ARE RECOMMENDED. IF RESISTANCE-COUPLING IS USED, REFER TO LAST PARAGRAPH OF THIS SECTION.

PUSH-PULL CLASS AB AMPLIFIER (PENTODE CONNECTION)

PLATE VOLTAGE	FIXED-BIAS	SELF-BIAS	
PLATE VOLTAGE	375 MAX.	375 MAX.	VOLTS
SCREEN VOLTAGE	250 MAX.	250 MAX.	VOLTS

GRID VOLTAGE	-26 MIN		VOLTS
SELF-BIAS RESISTOR		340 MIN.	OHMS
ZERO-SIGNAL PLATE CUR. (PER TUBE)	17	27	MA.
ZERO-SIGNAL SCREEN CUR. (PER TUBE)	2.5	4	MA.
LOAD RESISTANCE (PER TUBE)	2500	2500	OHMS
EFFECTIVE LOAD RESISTANCE (PLATE-TO-PLATE)	10000	10000	OHMS
TOTAL HARMONIC DISTORTION	5	5	PER CENT
POWER OUTPUT (2 TUBES)	19 APPROX.*	19 APPROX.#	WATTS

UNDER THE ABOVE MIXUMUM VOLTAGE CONDITIONS, TRANSFORMER OR IMPEDANCE INPUT-COUPLING DEVICES MUST BE USED.

* WITH ONE TRIODE-CONNECTED 6F6 AS DRIVER OPERATED AT PLATE VOLTS OF 250, GRID VOLTS OF -20, AND WITH A MINIMUM PLATE LOAD OF APPROXIMATELY 10000 OHMS: INPUT TRANSFORMER RATIO, PRIMARY TO ONE-HALF SECONDARY, IS 3.32. THE PLATE, SCREEN AND GRID SUPPLY HAVE NEGLIGIBLE RESISTANCE.

\# WITH ONE TRIODE-CONNECTED 6F6 AS DRIVER OPERATED AT PLATE VOLTS OF 250, GRID VOLTS OF -20, AND WITH A MINIMUM PLATE LOAD OF APPROXIMATELY 10000 OHMS: INPUT TRANSFORMER RATIO, PRIMARY TO ONE-HALF SECONDARY IS 2.5. THE PLATE AND SCREEN SUPPLY HAVE NEGLIGIBLE RESISTANCE. THE VALUE GIVEN FOR THE SELF-BIAS RESISTOR IS DETERMINED FOR A MINIMUM GRID BIAS OF -21 VOLTS.

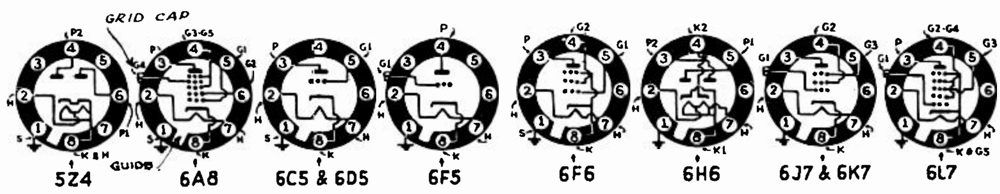


FIG. 8
Symbols and R.M.A. Standard Metal Tube Base Arrangements.

PUSH-PULL CLASS AB AMPLIFIER (TRIODE CONNECTION)

	SCREEN TIED TO PLATE FIXED-BIAS	SELF-BIAS	
PLATE VOLTAGE	350 MAX.	350 MAX.	VOLTS
GRID VOLTAGE	-38		VOLTS
SELF-BIAS RESISTOR		730 MIN.	OHMS
ZERO-SIGNAL PLATE CURRENT (PER TUBE)	22.5	25	MA.
LOAD RESISTANCE (PER TUBE) (PLATE-TO-PLATE)	6000	10000	OHMS
EFFECTIVE LOAD RESISTANCE	1500	2500	OHMS
TOTAL HARMONIC DISTORTION	7	7	PER CENT
POWER OUTPUT (2 TUBES)	18 APPROX	14 APPROX.°	WATTS

UNDER THE ABOVE MAXIMUM VOLTAGE CONDITIONS, TRANSFORMER OR IMPEDANCE INPUT-COUPLING DEVICES MUST BE USED.

WITH ONE TRIODE-CONNECTED 6F6 AS DRIVER OPERATED AT PLATE VOLTS OF 250, GRID VOLTS OF -20, AND WITH A MINIMUM PLATE LOAD OF APPROXIMATELY 10000 OHMS: INPUT TRANSFORMER RATIO, PRIMARY TO ONE-HALF SECONDARY, IS 1.67. THE PLATE AND GRID SUPPLY HAVE NEGLIGIBLE RESISTANCE.

°WITH ONE TRIODE-CONNECTED 6F6 AS DRIVER OPERATED AT PLATE VOLTS OF 250, GRID VOLTS OF -20, AND WITH A MINIMUM PLATE LOAD OF APPROXIMATELY 10000 OHMS: INPUT TRANSFORMER RATIO, PRIMARY TO ONE-HALF SECONDARY, IS 1.29. THE PLATE SUPPLY HAS NEGLIGIBLE RESISTANCE. THE VALUE GIVEN FOR THE SELF-BIAS RESISTOR IS DETERMINED FOR A MINIMUM GRID BIAS OF -36.5 VOLTS.

THE TYPE OF INPUT COUPLING USED FOR CLASS AB POWER-AMPLIFIER TRIODE OR PENTODE SHOULD NOT INTRODUCE TOO MUCH RESISTANCE IN THE GRID CIRCUIT. TRANSFORMER OR IMPEDANCE-COUPLING DEVICES ARE RECOMMENDED. WHEN THE GRID CIRCUIT HAS A RESISTANCE NOT HIGHER THAN 0.05 MEGOHM, FIXED BIAS MAY BE USED; FOR HIGHER VALUES, SELF-BIAS IS REQUIRED. WITH SELF-BIAS, THE GRID CIRCUIT MAY HAVE A RESISTANCE AS HIGH AS, BUT NOT GREATER THAN, 0.5 MEGOHM PROVIDED THE HEATER VOLTAGE IS NOT ALLOWED TO RISE MORE THAN 10% ABOVE RATED VALUE UNDER ANY CONDITION OF OPERATION.

THE 6H6

THE 6H6 IS A HEATER-CATHODE TYPE OF METAL TUBE COMBINING TWO DIODES IN ONE SHELL. EACH DIODE HAS ITS OWN SEPARATE CATHODE AND CORRESPONDING BASE PIN. THIS ARRANGEMENT OFFERS FLEXIBILITY IN THE DESIGN OF CIRCUITS EMPLOYING THE 6H6 FOR DETECTION, FOR LOW-VOLTAGE LOW-CURRENT RECTIFICATION, OR FOR AUTOMATIC VOLUME CONTROL.

HEATER VOLTAGE (A.C. OR D.C.)	6.3	VOLTS
HEATER CURRENT	0.3	AMPERE
PLATE NO. 1 TO PLATE NO.2 CAPACITANCE*	0.02 MAX.	MMFD.
A-C PLATE VOLTAGE PER PLATE (RMS)	100 MAX.	VOLTS
D-C OUTPUT CURRENT	2 MAX.	MILLIAMPERES
BASE	SMALL OCTAL	7-PIN

*WITH SHELL CONNECTED TO CATHODE.

FOR DETECTION, THE DIODES MAY BE UTILIZED IN A FULL-WAVE CIRCUIT OR IN A HALF-WAVE CIRCUIT. IN THE LATTER CASE, ONE PLATE ONLY, OR THE TWO PLATES IN PARALLEL, MAY BE EMPLOYED. THE USE OF THE HALF-WAVE ARRANGEMENT WILL PROVIDE APPROXIMATELY TWICE THE RECTIFIED VOLTAGE AS COMPARED WITH THE FULL-WAVE ARRANGEMENT.

FOR AUTOMATIC-VOLUME CONTROL, THE 6H6 MAY BE USED IN CIRCUITS SIMILAR TO THOSE EMPLOYED FOR ANY OF THE DUPLEX-DIODE TYPES OF TUBES. THE ONLY DIFFERENCE IS THAT THE 6H6 IS MORE ADAPTABLE DUE TO THE FACT THAT EACH DIODE HAS ITS OWN SEPARATE CATHODE.

SINCE THE DIODES BY THEMSELVES DO NOT PROVIDE ANY AMPLIFICATION, IT IS USUALLY NECESSARY TO PROVIDE GAIN BY MEANS OF A SUPPLEMENTARY TUBE. TYPES SUCH AS THE 6C5, 6F5, 6J7, AND 6K7 ARE VERY SUITABLE FOR THIS PUR-

POSE. THEIR USE IN COMBINATION WITH THE 6H6 IS SIMILAR TO THAT OF THE AMPLIFIER SECTIONS OF DUPLEX-DIODE TRIODE OR PENTODE TYPES, SUCH AS THE 76, 75, 6C6, AND 6D6. THE AMPLIFIER SECTIONS OF THESE TYPES HAVE SOMEWHAT THE SAME CHARACTERISTICS AS THE 6C5, 6F5, 6J7, AND 6K7, RESPECTIVELY.

THE 6J7

THE 6J7 IS A TRIPLE-GRID TYPE OF METAL TUBE RECOMMENDED ESPECIALLY FOR SERVICE AS A BIASED DETECTOR IN RADIO RECEIVERS DESIGNED FOR ITS CHARACTERISTICS. IN SUCH SERVICE, THIS TUBE IS CAPABLE OF DELIVERING A LARGE AUDIO-FREQUENCY OUTPUT VOLTAGE WITH RELATIVELY SMALL INPUT VOLTAGE. OTHER APPLICATIONS OF THE 6J7 INCLUDE ITS USE AS A HIGH-GAIN AMPLIFIER TUBE.

HEATER VOLTAGE (A.C. OR D.C.)		6.3	VOLTS
HEATER CURRENT		0.3	AMPERE
PLATE VOLTAGE	100	250 MAX.	VOLTS
SCREEN (GRID No.2) VOLTAGE	100	100**	VOLTS
GRID (GRID No.1) VOLTAGE	-3	-3	VOLTS
SUPPRESSOR (GRID No.3)	CONNECTED TO CATHODE AT SOCKET		
PLATE CURRENT	2	2	MA.
SCREEN CURRENT	0.5	0.5	MA.
PLATE RESISTANCE	1.0	GREATER THAN 1.5	MEGOHMS
AMPLIFICATION FACTOR	1185	GREATER THAN 1500	
MUTUAL CONDUCTANCE	1185	1225	MICROMHOS
GRID VOLTAGE (APPROX.)#	-7	-7	VOLTS
GRID-PLATE CAPACITANCE °		0.005 MAX.	MMFD.
INPUT CAPACITANCE °		7	MMFD.
OUTPUT CAPACITANCE °		12	MMFD.
BASE		SMALL OCTAL 7-PIN	

IF A GRID-COUPLING RESISTOR IS USED, ITS MAXIMUM VALUE SHOULD NOT EXCEED 1.0 MEGOHM.

** MAXIMUM SCREEN VOLTS = 125.
# FOR CATHODE CURRENT CUT-OFF.
° WITH SHELL CONNECTED TO CATHODE.

AS A BIASED DETECTOR, THE 6J7 CAN DELIVER A LARGE AUDIO- FREQUENCY OUTPUT VOLTAGE OF GOOD QUALITY WITH A FAIRLY SMALL RADIO FREQUENCY SIGNAL INPUT. TYPICAL RECOMMENDED CONDITIONS FOR THE 6J7 AS A BIASED DETECTOR ARE AS FOLLOWS:

PLATE SUPPLY *	250	250	250	250	VOLTS
SCREEN VOLTAGE	50	33	100	100	VOLTS
GRID VOLTAGE	-2	-1.7	-3.9	-4.3	VOLTS
CATHODE RESISTOR	3000	8000	4000	10000	OHMS
SUPPRESSOR	CONNECTED TO CATHODE AT SOCKET				
CATHODE CUR.(ZERO SIGNAL)	0.65	0.21	0.97	0.43	MILLIAMPERES
PLATE RESISTOR	0.25	0.50	0.25	0.50	MEGOHM
BLOCKING CONDENSER	0.03	0.03	0.03	0.03	MFD.
GRID RESISTOR#	0.25	0.25	0.25	0.25	MEGOHM
R-F SIGNAL (RMS)**	1.18	1.21	1.38	1.37	VOLTS

* VOLTAGE AT PLATE WILL BE PLATE-SUPPLY VOLTAGE LESS VOLTAGE DROP IN PLAGE RESISTOR CAUSED BY PLATE CURRENT.

FOR THE FOLLOWING AMPLIFIER TUBE.

** WITH THESE SIGNAL VOLTAGES MODULATED 20%, THE VOLTAGE OUTPUT UNDER EACH SET OF OPERATING CONDITIONS IS 17 PEAK VOLTS AT THE GRID OF THE FOLLOWING AMPLIFIER, A VALUE SUFFICIENT TO INSURE FULL AUDIO OUTPUT FROM A TYPE 6F6 AT 250 VOLTS ON PLATE.

THE 6K7

THE 6K7 IS A TRIPLE-GRID SUPER-CONTROL AMPLIFIER TUBE OF THE METAL TYPE RECOMMENDED FOR SERVICE IN THE RADIO-FREQUENCY AND INTERMEDIATE-FREQUENCY STAGES OF RADIO RECEIVERS DESIGNED FOR ITS CHARACTERISTICS. THE ABILITY OF THIS TUBE TO HANDLE UNUSUAL SIGNAL VOLTAGES WITHOUT CROSS-MODULATION AND MODULATION DISTORTION MAKES IT ADAPTABLE TO THE R-F AND I-F STAGES OF RECEIVERS EMPLOYING AUTOMATIC VOLUME CONTROL.

HEATER VOLTAGE (A.C. OR D.C.)				6.3	VOLTS
HEATER CURRENT				0.3	AMPERE
PLATE VOLTAGE	90	180	250 MAX.	250 MAX.	VOLTS
SCREEN (GRID NO.2) VOLTAGE	90	75	100	125 MAX.	VOLTS
GRID (GRID NO.1) VOLT.(MIN.)	-3	-3	-3	-3	VOLTS
SUPPRESSOR (GRID NO.3)	CONNECTED TO CATHODE AT SOCKET				
PLATE CURRENT	5.4	4.0	7.0	10.5	MA.
SCREEN CURRENT	1.3	1.0	1.7	2.6	MA.
PLATE RESISTANCE	0.315	1.0	0.8	0.6	MEGOHM
AMPLIFICATION FACTOR	400	1100	1160	990	
MUTUAL CONDUCTANCE	1275	1100	1450	1650	MICROMHOS
GRID VOLTAGE *	-38.5	-32.5	-42.5	-52.5	VOLTS
GRID-PLATE CAPACITANCE °				0.005 MAX.	MMFD.
INPUT CAPACITANCE °				7	MMFD.
OUTPUT CAPACITANCE °				12	MMFD.
BASE				SMALL OCTAL 7-PIN	

* FOR MUTUAL CONDUCTANCE = 2 MICROMHOS.
° WITH SHELL CONNECTED TO CATHODE.

CONTROL-GRID BIAS VARIATION WILL BE FOUND EFFECTIVE IN CHANGING THE VOLUME OF THE RECEIVER. IN ORDER TO OBTAIN ADEQUATE VOLUME CONTROL, AN AVAILABLE GRID-BIAS VOLTAGE OF APPROXIMATELY 50 VOLTS WILL BE REQUIRED. THE EXACT VALUE WILL DEPEND UPON THE CIRCUIT DESIGN AND OPERATING CONDITIONS. THIS VOLTAGE MAY BE OBTAINED, DEPENDING ON THE RECEIVER REQUIREMENTS, FROM A POTENTIOMETER ACROSS A FIXED SUPPLY VOLTAGE OR BY THE USE OF A VARIABLE SELF-BIAS RESISTOR IN THE CATHODE CIRCUIT.

THE 6L7

THE 6L7 IS A MULTI-ELECTRODE VACUUM TUBE OF THE METAL TYPE DESIGNED WITH TWO SEPARATE CONTROL GRIDS SHIELDED FROM EACH OTHER. THIS DESIGN PERMITS EACH CONTROL GRID TO ACT INDEPENDENTLY ON THE ELECTRON STREAM. THIS TUBE, THEREFORE, IS ESPECIALLY USEFUL AS A MIXER IN SUPERHETERODYNE CIRCUITS HAVING A SEPARATE OSCILLATOR STAGE, AS WELL AS IN OTHER APPLICATIONS WHERE DUAL CONTROL IS DESIRABLE IN A SINGLE STAGE. THE DESIGN OF THE TUBE IS SUCH THAT COUPLING EFFECTS BETWEEN OSCILLATOR AND SIGNAL CIRCUITS ARE MADE VERY SMALL. THIS FEATURE ENABLES THE 6L7 TO GIVE HIGH GAIN IN HIGH-FREQUENCY CIRCUITS.

HEATER VOLTAGE (A.C. OR D.C.)	6.3	VOLTS
HEATER CURRENT	0.3	AMPERE
DIRECT INTERELECTRODE CAPACITANCES:*		
GRID NO. 1 TO GRID NO. 3	0.12	MMFD.
GRID NO. 1 TO PLATE	0.0005 MAX.	MMFD.
GRID NO. 3 TO PLATE	0.25	MMFD.
GRID NO. 1 TO ALL OTHER ELECTRODES	8.5	MMFD.
GRID NO. 3 TO ALL OTHER ELECTRODES	11.5	MMFD.
PLATE TO ALL OTHER ELECTRODES	12.5	MMFD.
BASE	SMALL OCTAL	7-PIN.

TO OPERATE AS A MIXER

PLATE VOLTAGE		250 MAX.	VOLTS
SCREEN (GRIDS NO.2 AND NO.4) VOLTAGE		150 MAX.	VOLTS
TYPICAL OPERATION:			
HEATER VOLTAGE	6.3	6.3	VOLTS
PLATE VOLTAGE	250	250#	VOLTS
SCREEN VOLTAGE	100	150#	VOLTS
SIGNAL-GRID (GRID NO.1) VOLTAGE **	-3	-6 MIN.#	VOLTS
OSCILLATOR-GRID (GRID NO.3) VOLTAGE	-10	-15	VOLTS
PEAK OSCILLATOR VOLTAGE APPLIED TO GRID NO.3 (MINIMUM)	12	18	VOLTS
PLATE CURRENT	2.4	3.3	MA.
SCREEN CURRENT	6.2	8.3	MA.
PLATE RESISTANCE	GREATER THAN 1		MEGOHM
CONVERSION CONDUCTANCE	350	350	MICROMHOS
SIGNAL-GRID (GRID NO. 1) VOLTAGE FOR CONVER. COND. OF 5 MICROMHOS	-30	-45	VOLTS

** THE D-C RESISTANCE IN OSCILLATOR-GRID-NO.3 CIRCUIT SHOULD BE LIMITED TO 50000 OHMS.
# RECOMMENDED VALUES FOR ALL-WAVE RECEIVERS.
* WITH SHELL CONNECTED TO CATHODE.

TO OPERATE AS AN AMPLIFIER

HEATER VOLTAGE	6.3	VOLTS
PLATE VOLTAGE	250 MAX.	VOLTS
SCREEN (GRIDS NO. 2 AND NO. 4) VOLTAGE	100 MAX.	VOLTS
CONTROL GRID (GRID NO.1) VOLTAGE	-3 MIN.	VOLTS
CONTROL GRID (GRID NO.3) VOLTAGE	-3	VOLTS
PLATE CURRENT	5.3	MA.
SCREEN CURRENT	5.5	MA.
PLATE RESISTANCE	0.8	MEGOHM
MUTUAL CONDUCTANCE	1100	MICROMHOS
MUT. COND. {-15 VOLTS BIAS ON GRID NO.1; -15 VOLTS BIAS ON GRID NO.3}	5	MICROMHOS

THE 6A8

THE 6A8 IS A MULTI-ELECTRODE VACUUM TUBE OF THE METAL TYPE DESIGNED TO PERFORM SIMULTANEOUSLY THE FUNCTIONS OF A MIXER (FIRST DETECTOR) TUBE

AND OF AN OSCILLATOR TUBE IN SUPERHETERODYNE CIRCUITS. THROUGH THE USE OF THIS TYPE, THE INDEPENDENT CONTROL OF EACH FUNCTION IS MADE POSSIBLE WITHIN A SINGLE TUBE.

HEATER VOLTAGE (A.C. OR D.C.)	6.3	VOLTS
HEATER CURRENT	0.3	AMPERE
DIRECT INTERELECTRODE CAPACITANCES (APPROX.)*		
GRID NO. 4 TO PLATE	0.03	MMFD.
GRID NO. 4 TO GRID NO. 2	0.1	MMFD.
GRID NO. 4 TO GRID NO. 1	0.09	MMFD.
GRID NO. 1 TO GRID NO. 2	0.8	MMFD.
GRID NO. 4 TO ALL OTHER ELECTRODES (R.F. INPUT)	12.5	MMFD.
GRID NO. 2 TO ALL OTHER ELECTRODES (OSC.OUTPUT)	5	MMFD.
GRID NO. 1 TO ALL OTHER ELECTRODES (OSC. INPUT)	6.5	MMFD.
PLATE TO ALL OTHER ELECTRODES (MIXER OUTPUT)	12.5	MMFD.
BASE	SMALL OCTAL 8-PIN	

* WITH SHELL CONNECTED TO CATHODE.

TO OPERATE AS FREQUENCY CONVERTER

PLATE VOLTAGE		250 MAX.	VOLTS
SCREEN (GRIDS NO.3 AND NO.5) VOLTAGE		100 MAX.	VOLTS
ANODE-GRID (GRID NO.2) VOLTAGE		200 MAX.	VOLTS
ANODE-GRID (GRID NO.2) SUPPLY VOLTAGE **		250 MAX.	VOLTS
CONTROL GRID (GRID NO.4) VOLTAGE		-3 MIN.	VOLTS
TOTAL CATHODE CURRENT		14 MAX.	MA.
TYPICAL OPERATION:			
PLATE VOLTAGE	100	250	VOLTS
SCREEN VOLTAGE	50	100	VOLTS
ANODE-GRID VOLTAGE	100	250#	VOLTS
CONTROL GRID VOLTAGE (MINIMUM)	-1.5	-3	VOLTS
OSCILLATOR GRID (GRID NO.1) RESISTOR	50000	50000	OHMS
PLATE CURRENT	1.2	3.3	MA.
SCREEN CURRENT	1.5	3.2	MA.
ANODE-GRID CURRENT	1.6	4.0	MA.
OSCILLATOR GRID CURRENT	0.25	0.5	MA.

** WHEN THE ANODE-GRID SUPPLY VOLTAGE EXCEEDS 200 VOLTS, IT SHOULD BE APPLIED THROUGH A 20000-OHM VOLTAGE-DROPPING RESISTOR.

CONVERSION CONDUCTANCE	350	500	MICROMHOS
CONTROL GRID VOLTAGE FOR CONVER. COND. OF 2 MICROMHOS (APPROX.)	-20	-45	VOLTS

METAL TUBE CIRCUITS

A CIRCUIT DIAGRAM OF A SIX-TUBE, ALL-WAVE SUPERHETERODYNE IS SHOWN YOU IN FIG. 9. THIS PARTICULAR CIRCUIT MAKES USE OF FIVE POPULAR METAL TUBE TYPES BUT EMPLOYS A GLASS TYPE 80 TUBE AS THE RECTIFIER.

THE BASIC CIRCUIT FEATURES ARE PRACTICALLY IDENTICAL TO THOSE USED IN SIMILAR RECEIVERS WHICH ARE EQUIPPED WITH THE EQUIVALENT GLASS TUBES so that you have nothing new to learn in this respect. It is well, however, to study this diagram carefully, noting in particular how the circuit connections are made to the sockets and elements of the metal tubes.

An eight-tube all-wave receiver, which employs metal tubes throughout, is illustrated for you in Fig. 10. Here a 6K7 is used in the tuned pre-selector stage, a 6A8 as the combination oscillator and first detector, a 6K7 I.F. amplifier, a 6H6 diode detector and A.V.C. tube, a 6C5 A.F. amplifier, followed by two 6F6's in push-pull. A 5Z4 is used as the rectifier.

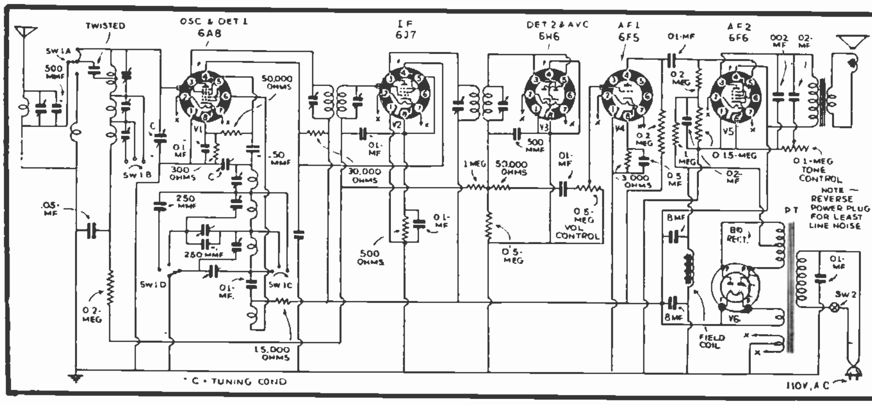


FIG 9

A Six-Tube Superheterodyne

Regardless of whether or not the metal tube symbols as used in a circuit diagram indicate the metal shielding or enclosure of the tube to be grounded, yet this is always the case in actual practice. In other words, base prong #1 is at all times understood to be connected to the ground circuit of the receiver in question.

A.F. AMPLIFIER WITH METAL TUBES

In Fig. 11 you are shown an interesting circuit of an A.F. amplifier which is equipped with seven metal tubes. A single triode — connected 6J7 feeds into a pair of 6C5's connected in push pull and this latter stage operates into a class A prime in which a pair of 6F6's are connected as triodes in a parallel push-pull arrangement.

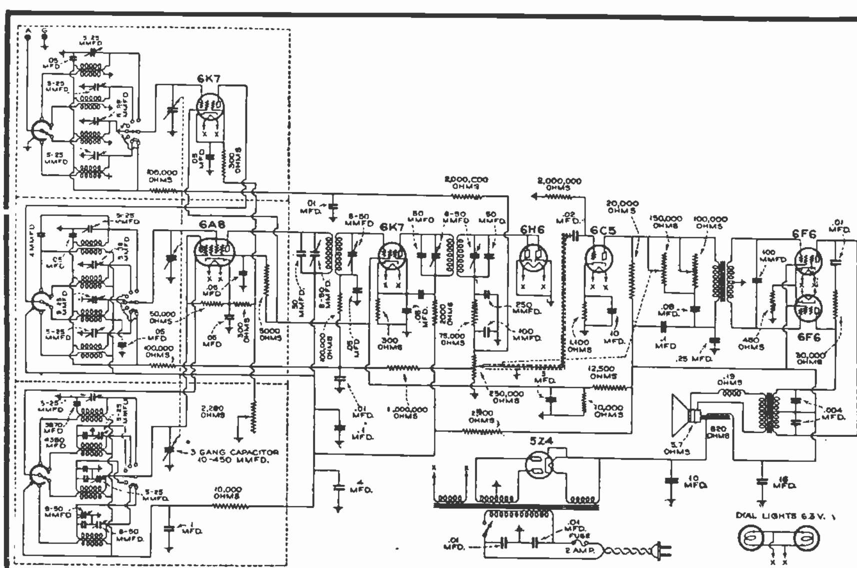


FIG.10

An 8-Metal-Tube Receiver.

This amplifier is capable of furnishing an output of 40 watts but by eliminating two of the 6F6 tubes and thus making the final or output stage straight push-pull, the output power of the amplifier will be reduced to 20 watts. Upon making this change, however, the output transformer must be changed accordingly so that the impedances between the output tubes and transformer will be properly matched.

The power pack, as used with this amplifier, together with its diagram is shown in Fig. 12. To handle the required "B" current, two 5Z4's are connected in parallel, whereas a third 5Z4 is connected in a half-wave rectifying circuit to furnish the bias voltage for the amplifier's output stage.

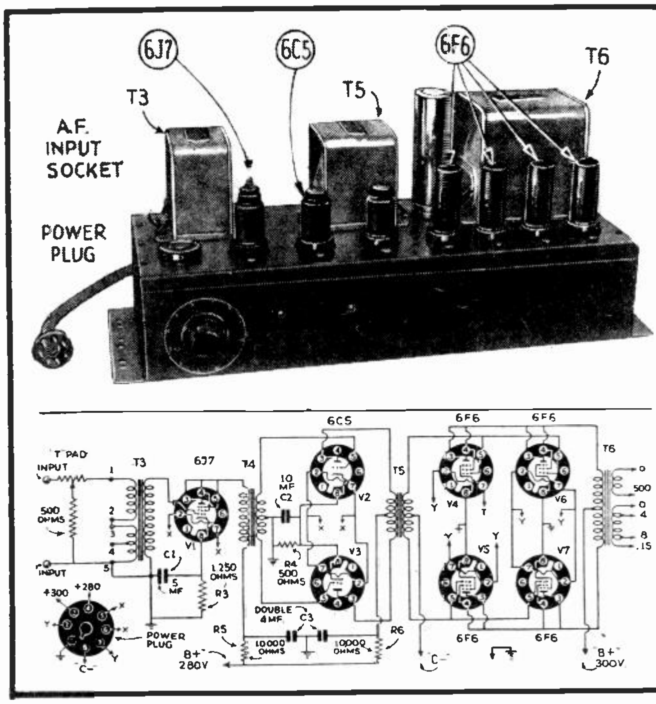


FIG. 11
The Metal-Tube Amplifier

METAL-GLASS TUBES

Besides the all-metal tubes, such as have been described in this lesson, the Triad Manufacturing Co. is making a fully shielded metal tube in which a newly developed glass is used for maintaining the vacuum. Tubes of this type are known as metal-glass tubes and for identification purposes have the letters MG annexed to their type number. Thus: 6A8-MG; 6C5 MG; 6F6 MG; 6H6 MG etc.

These metal-glass tubes are equivalent to the all-metal tubes of corresponding type number and also employ the same octal base arrangement. The outer appearance of these metal-glass tubes are quite similar to that of the all-met-

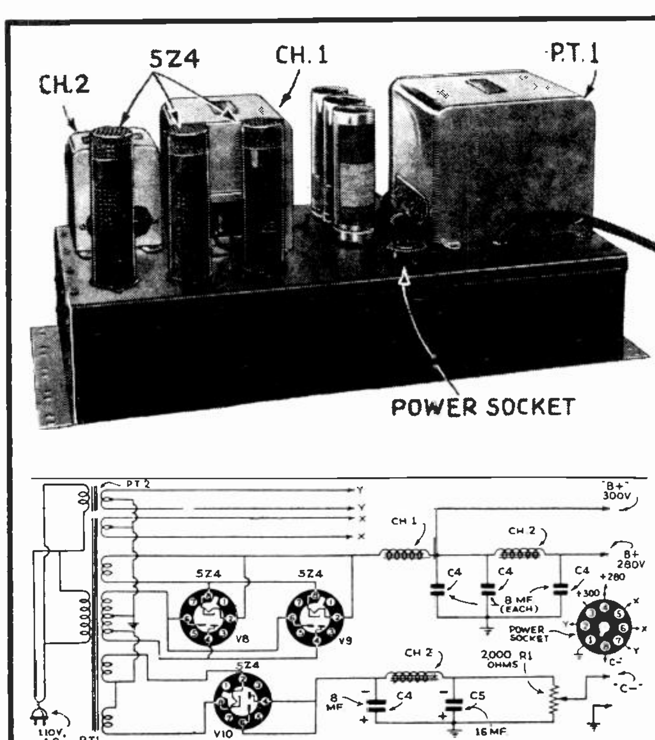


FIG. 12
The Metal-Tube Power Pack.

AL TUBES OF CORRESPONDING TYPE WITH THE EXCEPTION THAT THE METAL-GLASS TUBES ARE GENERALLY SLIGHTLY LARGER IN SIZE.

GLASS-"METAL" TUBES

THE ARCTURUS RADIO TUBE CO. IS MANUFACTURING WHAT ARE KNOWN AS AS GLASS-"METAL" TUBES. THE CHARACTERISTICS OF THESE PARTICULAR TUBES APPROXIMATE THOSE OF THE CORRESPONDING ALL-METAL TUBES, AND THEY EMPLOY THE SAME OCTAL BASE. THESE GLASS-"METAL" TUBES, HOWEVER, EMPLOY A GLASS ENVELOPE AS THE ELEMENT ENCLOSURE AND VACUUM SEAL BUT EMPLOY A SEPARATE EXTERNAL SHIELD OF SPECIAL DESIGN AND WHICH FITS THE CONTOUR OF THE THE GLASS ENVELOPE CLOSELY.

THE TUBES OF THIS TYPE ARE NUMBERED TO CORRESPOND WITH THE EQUIVALENT ALL-METAL TUBES AND ARE IDENTIFIED BY THE SUFFIX LETTER "G", AS 6L7-G ETC.

answered March 3rd, [illegible]

Examination Questions

LESSON NO. 61

1. - DESCRIBE THE CONSTRUCTIONAL FEATURES OF A TYPICAL METAL TUBE.
2. - DESCRIBE THE 6H6 TUBE, METNION ITS OPERATING CHARACTERISTICS AND DRAW A SKETCH WHICH ILLUSTRATES ITS BASE CONNECTIONS.
3. - HOW DO THE SOCKETS FOR THE METAL TUBES COMPARE WITH THE SOCKETS AS USED FOR CONVENTIONAL GLASS TUBES?
4. - DRAW A CIRCUIT DIAGRAM OF A FIVE TUBE T.R.F. RECEIVER AND WHICH IS TO INCLUDE TWO TYPE 6K7 R. F. AMPLIFIERS, ONE 6J7 DETECTOR, A RESISTANCE-CAPACITY COUPLED 6F6 POWER TUBE AND A 5Z4 RECTIFIER.
5. - HOW DOES THE KEY ON THE ALIGNING PLUG OF A METAL TUBE BASE ASSIST ONE IN THE TASK OF IDENTIFYING THE VARIOUS BASE PRONGS OF THE TUBE?
6. - EXPLAIN WHAT SIMILARITIES EXIST BETWEEN METAL TUBES IN GENERAL AND CORRESPONDING GLASS TUBES.
7. - WHAT IS MEANT BY THE EXPRESSION "METAL-GLASS" TUBES AND HOW DO TUBES OF THIS TYPE COMPARE WITH THE METAL TUBES AND GLASS TUBES OF CONVENTIONAL DESIGN?
8. - WHY IS IT CUSTOMARY TO INSTALL AN A.F. AMPLIFIER TUBE AT THE OUTPUT OF A 6H6 TUBE AND PRECEDING THE POWER AMPLIFIER, AS DONE IN FIG.10 OF THIS LESSON?
9. - SPECIFY FOR WHAT PURPOSES EACH OF THE FOLLOWING TUBES ARE BEST ADAPTED: 6A8 - 6K7 - 6H6 - 5Z4 - 6C6 - 6C5 - 6F6.
10. - IN YOUR OPINION, WHAT ADVANTAGES DO THE METAL TUBES HAVE TO OFFER AS COMPARED TO GLASS TUBES OF CORRESPONDING TYPE?