RADIO - TELEVISION

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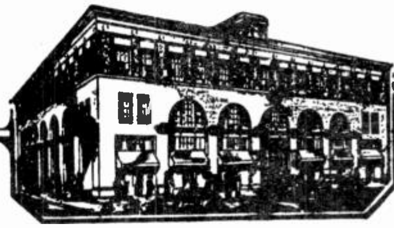

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LESSON NO. 31

• AUTOMATIC VOLUME CONTROL •

IF YOU HAVE LISTENED TO RADIO RECEIVERS A GOOD DEAL IN WHICH AN AUTOMATIC VOLUME CONTROL SYSTEM WAS NOT EMPLOYED, YOU HAVE NO DOUBT NOTICED THAT IT IS A COMMON OCCURRENCE TO BE LISTENING TO A PROGRAM, WHEN ALL AT ONCE, THE VOLUME SUDDENLY INCREASES TO A BLARE OR ELSE DECREASES TO SUCH AN EXTENT THAT THE SPEAKER SOUNDS ARE HARDLY AUDIBLE. THIS CONDITION IS ESPECIALLY PRONOUNCED DURING THE RECEPTION OF DISTANT PROGRAMS AND IT IS REALLY ANNOYING, FOR IT MAKES IT NECESSARY FOR THE OPERATOR TO EITHER TURN UP THE VOLUME CONTROL OR ELSE TURN IT DOWN, SO AS TO KEEP THE VOLUME AT A PLEASING LEVEL. WE CANNOT REALLY BLAME THIS SO CALLED "FADING" PROBLEM TO FAULTY RECEIVER OPERATION BECAUSE THE TROUBLE IS CAUSED BY TRICKS OF NATURE SOMEWHERES OUT IN THE SPACE BETWEEN THE TRANSMITTER AND THE RECEIVER. THE RECEIVER IS SIMPLY AMPLIFYING WHATEVER SIGNAL ENERGY REACHES IT AND CONSEQUENTLY, IF CONDITIONS ARE SUCH THAT A GREATER PERCENTAGE OF THE TRANSMITTED WAVE ACTS UPON THE RECEIVER'S ANTENNA AT SOME PARTICULAR INSTANT, IT IS NO MORE BUT NATURAL THAT THE SPEAKER VOLUME SHOULD INCREASE BECAUSE MORE SIGNAL ENERGY IS AT THIS TIME AVAILABLE FOR AMPLIFICATION.

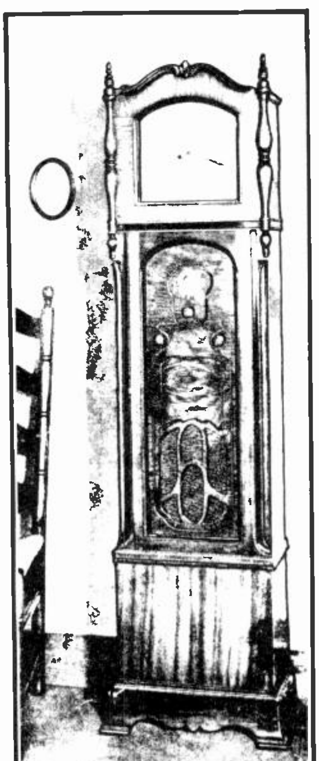

FIG. 1
A Modern Radio-clock Combination.

THEN ON THE OTHER HAND, IF ATMOSPHERIC CONDITIONS SUDDENLY CHANGE SO THAT THE TRANSMITTED WAVE HAS ITS COURSE OF TRAVEL TEMPORARILY ALTERED, SO TO SPEAK AND SO THAT VERY LITTLE OF THE RADIATED ENERGY STRIKES THE RECEIVER ANTENNA, THEN OF COURSE, VERY LITTLE ENERGY IS AVAILABLE AT THE RECEIVER FOR AMPLIFICATION AND CONSEQUENTLY THE VOLUME SUFFERS.

AUTOMATIC VOLUME CONTROL

SINCE IT IS IMPOSSIBLE TO CONTROL THE AMOUNT OF SIGNAL ENERGY REACHING THE MILLIONS OF LISTENERS AT ALL DIFFERENT POINTS OF THE GLOBE, THE LOGICAL STEP FOR US TO TAKE IN ORDER TO DO AWAY WITH THE

ANNOYANCE OF SUDDEN INCREASES OR DECREASES IN VOLUME IS TO DEVISE SOME MEANS WHEREBY THE RECEIVER AUTOMATICALLY PROVIDES A VOLUME OF CONSTANT LEVEL AFTER A STATION HAS ONCE BEEN TUNED IN. IN THE LATEST TYPES OF RECEIVERS, THIS IS BEING DONE AND THIS SYSTEM OF MAINTAINING A CONSTANT VOLUME IS KNOWN AS AUTOMATIC VOLUME CONTROL -- QUITE OFTEN SPOKEN OF SIMPLY AS "A.V.C.". THIS ARRANGEMENT SHOULD PROVE TO BE ESPECIALLY INTERESTING TO YOU.

BRIEFLY, WHAT AUTOMATIC VOLUME CONTROL REALLY ACCOMPLISHES IS TO MAKE THE RECEIVER MORE SENSITIVE TO WEAK SIGNALS AND LESS SENSITIVE TO STRONG SIGNALS. IN THIS WAY, IT SERVES TO "FILL-IN" THE GAPS DURING THE VARIATION OF SIGNAL STRENGTH CAUSED BY FADING. SO WITH THIS FUNDAMENTAL IDEA IN MIND, LET US CONTINUE AND SEE JUST HOW THIS IS ALL BROUGHT ABOUT.

FUNDAMENTAL PRINCIPLES

WE SHALL BEGIN THIS EXPLANATION BY FIRST GETTING SOME BASIC PRINCIPLES FIRMLY FIXED IN YOUR MIND, STARTING WITH FIG. 2. IN FIG. 2, WE HAVE A TYPE-27 TUBE BEING USED AS A POWER DETECTOR AND A DETECTOR TUBE, YOU WILL REMEMBER, CAN ALSO BE CONSIDERED AS A "RECTIFIER TUBE".

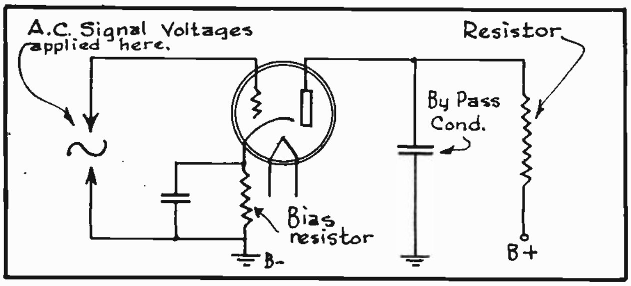

FIG. 2
Using R.F. Energy to Produce a Direct Current

NOW THEN, BY APPLYING THE R.F. SIGNAL ENERGY FROM SOME TRANSMITTER ACROSS THE GRID CIRCUIT OF THIS TUBE, PLATE CURRENT WILL BE CAUSED TO FLOW THROUGH THE TUBE. THIS PLATE CURRENT, HOWEVER, WOULD ORDINARILY BE D.C., IN ADDITION TO HAVING SOME R.F. AND AUDIO VARIATIONS INCORPORATED IN IT, FOR THE LATTER ARE INTRODUCED BY THE MODULATED CARRIER WAVE. THESE VARIATIONS IN THE PLATE CURRENT, HOWEVER, CAN BE ELIMINATED BY CONNECTING A BYPASS CONDENSER BETWEEN THE TUBE'S PLATE TERMINAL AND GROUND, THUS LEAVING ONLY A DIRECT CURRENT TO FLOW THRU THE PLATE CIRCUIT.

THIS FLOW OF PLATE CURRENT WILL DEVELOPE A VOLTAGE DROP ACROSS THE ENDS OF THE PLATE RESISTOR AND THE GREATER THE SIGNAL VOLTAGES APPLIED TO THE GRID CIRCUIT, THE GREATER WILL BE THE FLOW OF PLATE CURRENT, WHICH IN TURN MEANS A GREATER VOLTAGE DROP ACROSS THE ENDS OF THE RESISTOR. CONVERSELY, THE LESS THE SIGNAL VOLTAGE APPLIED TO THE GRID CIRCUIT IN FIG. 2, THE LESS WILL BE THE FLOW OF PLATE CURRENT AND THIS MEANS A SMALLER VOLTAGE DROP ACROSS THE ENDS OF THE PLATE RESISTOR. REMEMBER THIS BECAUSE IT IS VERY IMPORTANT AND WILL MAKE THE FOLLOWING EXPLANATION THAT MUCH EASIER FOR YOU TO UNDERSTAND.

THIS COMPLETES STEP #1 AND SO NOW LET US LOOK AT FIG. 3, WHERE A SIMPLE FORM OF AUTOMATIC VOLUME CONTROL IS ILLUSTRATED FOR YOU AND HERE WE ARE GOING TO USE THE PRINCIPLES WHICH WERE JUST EXPLAINED.

AN EFFECTIVE AUTOMATIC VOLUME CONTROL

BY INSPECTING FIG. 3 CAREFULLY, YOU WILL SEE THAT WE HAVE TWO TUBES.

ONE OF THESE IS THE 1ST R.F. TUBE OF THE RADIO RECEIVER, WHEREAS THE OTHER IS THE VOLUME CONTROL TUBE. THIS VOLUME CONTROL TUBE IS AN EXTRA TUBE ON THE RECEIVER CHASSIS AND HAS NOTHING TO DO AS FAR AS PASSING THE SIGNAL THROUGH THE AMPLIFIER IS CONCERNED. THE TUBE ARRANGEMENT OF THE RECEIVER IS CONVENTIONAL, THAT IS, THE VARIOUS R.F. STAGES ARE ALL COUPLED TOGETHER IN THE USUAL WAY AND THE VOLUME CONTROL TUBE IS SIMPLY ADDED AS AN ACCESSORY TO THE CIRCUIT.

IN THE PARTICULAR EXAMPLE ILLUSTRATED IN FIG. 3, YOU WILL OBSERVE THAT THE GRID OF THE VOLUME CONTROL TUBE IS CONNECTED TO THE GRID OF THE 1ST R.F. TUBE THROUGH A COUPLING CONDENSER. THEREFORE, WHATEVER SIGNAL ENERGY IS IMPRESSED UPON THE GRID OF THE 1ST R.F. TUBE MUST ALSO BE IMPRESSED UPON THE GRID OF THE VOLUME CONTROL TUBE. THE R.F. SIGNALS, YOU KNOW, WILL PASS THROUGH SUCH A COUPLING CONDENSER WITH EASE.

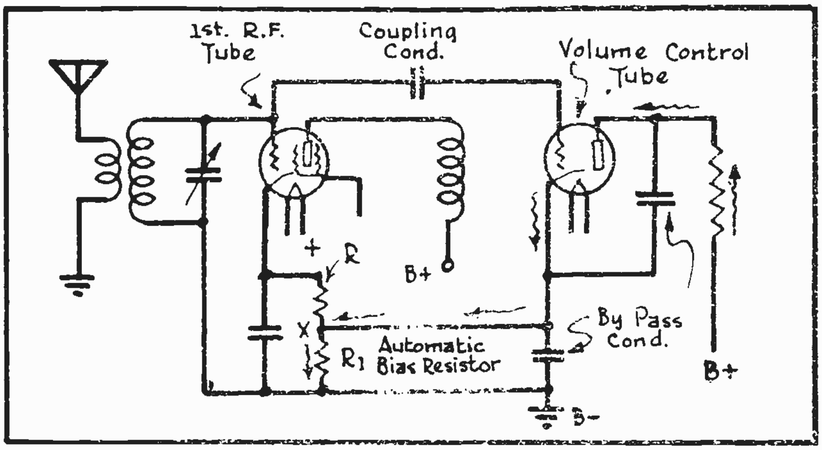

FIG. 3
A Fundamental Circuit for Automatic Volume Control.

THE NEXT THING TO NOTICE IS THAT THE CATHODES OF THE R.F. TUBE AND THE VOLUME CONTROL TUBE ARE CONNECTED TOGETHER AT POINT "X" AND THE AUTOMATIC BIAS RESISTOR R1 IS IN THE CATHODE CIRCUIT OF BOTH THESE TUBES. NOW CONSIDERING THE R.F. TUBE ALONE, WE SEE THAT AS SIGNAL VOLTAGES ACT UPON ITS GRID CIRCUIT, PLATE CURRENT WILL FLOW THROUGH THIS TUBE AND THIS PLATE CURRENT MUST ALSO FLOW THROUGH THE FIXED BIAS RESISTOR "R" AND THROUGH THE AUTOMATIC BIAS RESISTOR R1 IN ORDER TO RETURN TO B- OR GROUND. THE RESULTING VOLTAGE DROP MAKES THE UPPER END OF RESISTOR "R" OF A POSITIVE POTENTIAL AND THE LOWER END OF THE AUTOMATIC BIAS RESISTOR R1 OF A NEGATIVE POTENTIAL AND SINCE THE GRID RETURN OF THE R.F. TUBE IS CONNECTED TO THIS NEGATIVE END, IT IS CLEAR THAT A NEGATIVE GRID BIAS WILL BE IMPRESSED UPON THE R.F. TUBE.

BY APPLYING THESE SAME SIGNAL VOLTAGES TO THE GRID OF THE VOLUME CONTROL TUBE, THE PLATE CURRENT THROUGH THIS TUBE WILL TAKE THE COURSE INDICATED BY THE ARROWS, JOINING THE PLATE CURRENT OF THE R.F. TUBE AT POINT "X", SO THAT THE PLATE CURRENT FROM BOTH TUBES WILL FLOW THROUGH THE AUTOMATIC BIAS RESISTOR. THIS INCREASE OF CURRENT FLOW THROUGH THIS RESISTOR WILL MAKE ITS GROUNDED END STILL MORE NEGATIVE, SO THAT A GREATER NEGATIVE BIAS VOLTAGE IS NOW IMPRESSED UPON THE R.F. TUBE.

THUS IT STANDS TO REASON THAT THE GREATER THE SIGNAL VOLTAGE APPLIED TO THE GRID OF THE VOLUME CONTROL TUBE, THE GREATER WILL BE ITS PLATE CURRENT AND THIS INCREASE IN CURRENT FLOW THROUGH THE AUTOMATIC BIAS RESISTOR R1 PRODUCES A HIGHER NEGATIVE BIAS VOLTAGE FOR THE R.F. TUBE. THIS INCREASE IN BIAS VOLTAGE FOR THE R.F. TUBE REDUCES THIS TUBE'S AMPLIFICATION, SO THAT THE SPEAKER VOLUME IS CORRESPONDINGLY REDUCED.

ON THE OTHER HAND, IF ONLY A WEAK SIGNAL ACTS UPON THE GRID OF THE VOLUME CONTROL TUBE, THEN LESS PLATE CURRENT WILL FLOW THROUGH THIS TUBE AND THEREFORE THE COMBINED CURRENT FLOW THROUGH THE AUTOMATIC BIAS RESISTOR R1 WILL ALSO BE LESS, WITH THE RESULT THAT WE HAVE A DECREASE IN NEGATIVE BIAS FOR THE R.F. TUBE. THIS AUTOMATICALLY INCREASES THIS TUBE'S AMPLIFICATION, WHICH IN TURN RESULTS IN A CORRESPONDING INCREASE IN VOLUME. THUS YOU CAN SEE THAT THIS PROBLEM OF MAINTAINING CONSTANT SPEAKER VOLUME IS NOT AS COMPLICATED AS ONE MIGHT AT FIRST SUPPOSE.

FOR BEST PERFORMANCE, THE R.F. TUBES, AS USED IN SUCH A SYSTEM, ARE OF THE "VARIABLE-MU" TYPE BECAUSE THE AMPLIFYING ABILITY OF THESE TUBES VARIES MORE UNIFORMILY WITH VARIATIONS IN THE GRID BIAS VOLTAGE THAN WILL TUBES NOT HAVING THE VARIABLE-MU FEATURE.

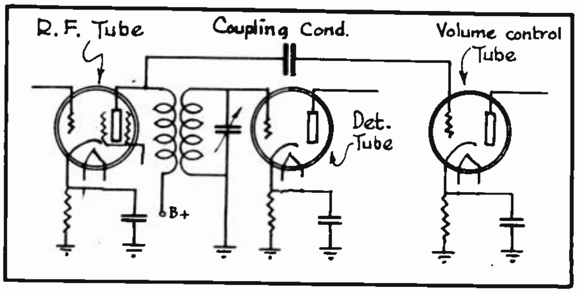

FIG. 4
The Volume Control Tube Coupled To the Plate Circuit of a Receiver Tube.

VARIOUS TYPES OF COUPLINGS

IN COMMERCIAL RECEIVERS EMPLOYING AUTOMATIC VOLUME CONTROL, YOU WILL FIND CONSIDERABLE VARIATION IN REGARDS TO THE CIRCUIT HOOK-UP BUT THE FUNDAMENTAL PRINCIPLE REMAINS THE SAME. FOR EXAMPLE, INSTEAD OF USING A COUPLING CONDENSER BETWEEN THE GRIDS OF THE R.F. AND VOLUME CONTROL TUBES, IT IS POSSIBLE TO USE A RESISTOR IN ITS PLACE. THEN, THERE ARE ALSO CASES, WHERE YOU WILL FIND THE GRID OF THE VOLUME CONTROL TUBE COUPLED TO THE DETECTOR TUBE INSTEAD OF TO AN R.F. TUBE.

STILL ANOTHER EXAMPLE IS ILLUSTRATED IN FIG. 4, WHERE YOU WILL SEE HOW IT IS ALSO POSSIBLE TO COUPLE THE GRID OF THE VOLUME CONTROL TUBE TO THE PLATE CIRCUIT OF A RECEIVER TUBE. THIS RECEIVER TUBE CAN BE EITHER AN R. F. AMPLIFIER OR ELSE THE DETECTOR. THE MAIN THING TO REMEMBER, WHEN USING A VOLUME CONTROL TUBE IN THE VARIOUS WAYS SO FAR DESCRIBED, IS THAT THE VOLUME CONTROL TUBE BE PROPERLY BIASED AND HAVE THE CORRECT PLATE VOLTAGE APPLIED TO IT SO THAT IT WILL FUNCTION AS A DETECTOR OR RECTIFIER.

CURRENT RECTIFICATION WITH A "DIODE"

AN ENTIRELY DIFFERENT METHOD OF USING A RADIO TUBE AS A RECTIFIER IS ILLUSTRATED FOR YOU IN FIG. 5. IN THIS CASE, WE CONNECT THE GRID AND PLATE TERMINALS OF THE TUBE TOGETHER WITH A PIECE OF WIRE AND SINCE THE GRID AND PLATE ARE IN THIS WAY NOW THE SAME AS ONE, WE ACTUALLY ONLY HAVE TWO ACTIVE TUBE ELEMENTS AT THIS TIME, NAMELY, THE CATHODE AND THE "GRID PLATE" ELEMENT. THE FILAMENT DOES NOT COUNT, FOR IT IS ONLY USED AS A HEATER FOR THE CATHODE. THIS IMPROVISED TUBE IS TECHNICALLY KNOWN AS A "DIODE", MEANING THEREBY THAT IT CONSISTS OF BUT TWO ACTIVE ELECTRODES OR ELEMENTS. YOU WERE ALREADY INTRODUCED TO THIS DIODE PRINCIPLE AS APPLIED TO RECTIFICATION SOME TIME AGO.

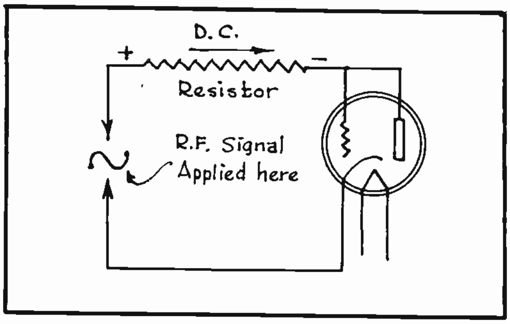

FIG. 5
Rectifying Radio Frequency Currents With a Diode Tube.

With the connections made as shown in Fig. 5, while a heating current is passed through the filament and R.F. signal voltages applied across the circuit as here indicated, you would find that a DIRECT current will flow through the circuit in the direction indicated by the arrow. This action is due to the rectifying characteristics of the tube when used in this way and this flow of current through the resistor will cause a voltage drop across it, so that its left end becomes positive and the right end negative. Notice especially, that the PLATE END of this resistor is of the lower or negative potential with respect to the resistor and that NO initial "B" voltage need be applied to the tube's plate in order to operate it.

A tube need not necessarily be of the heater type in order to operate it in this way but the same results can be obtained from a filament type tube by also connecting the grid and plate together.

USE OF THE DIODE FOR AUTOMATIC VOLUME CONTROL

An example, showing you how a "diode" can be used as an automatic volume control tube, is illustrated in Fig. 6. As you will observe, R.F. signal voltages will be applied from the plate circuit of the R.F. tube, through the by-pass condenser and thus across the grid circuit of the volume control tube.

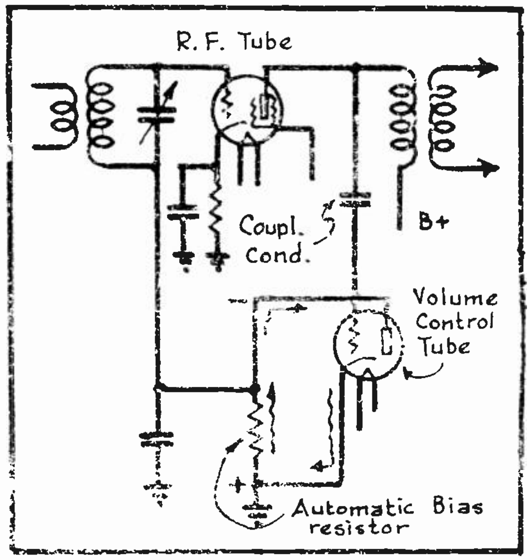

FIG. 6
Using a Diode Tube for Volume Control.

This R.F. signal current, as it is rectified by the volume control tube, will flow from this tube's cathode toward its interconnected grid and plate and all of this rectified current will have to flow through the automatic bias resistor in the direction shown. This will make the lower end of this resistor positive and its upper end negative.

The grid return of the R.F. circuit is connected to the negative end of the automatic bias resistor. Therefore, if the signal voltage through the bypass condenser is increased, the flow of rectified current through the automatic bias resistor will increase correspondingly and this will bring about a greater voltage drop across this resistor. In this way, the negative bias voltage on the R.F. tube is increased and the volume will therefore decrease. In like manner, if the signal voltage acting upon the grid-plate of the volume control tube is decreased, the flow of rectified current through the automatic bias resistor will likewise decrease, so that less bias voltage acts upon the R.F. tube. The volume therefore automatically increases.

The conventional bias resistor in the cathode circuit of the R.F. tube fixes the minimum bias at which this R.F. tube is permitted to operate.

A COMPLETE RECEIVER WITH AUTOMATIC VOLUME CONTROL

In order to give you a still better understanding of automatic volume control, we are showing you in Fig. 7, the complete circuit diagram of the Bosch Model 60 Receiver. This receiver uses a type -24 screen-grid tube as the

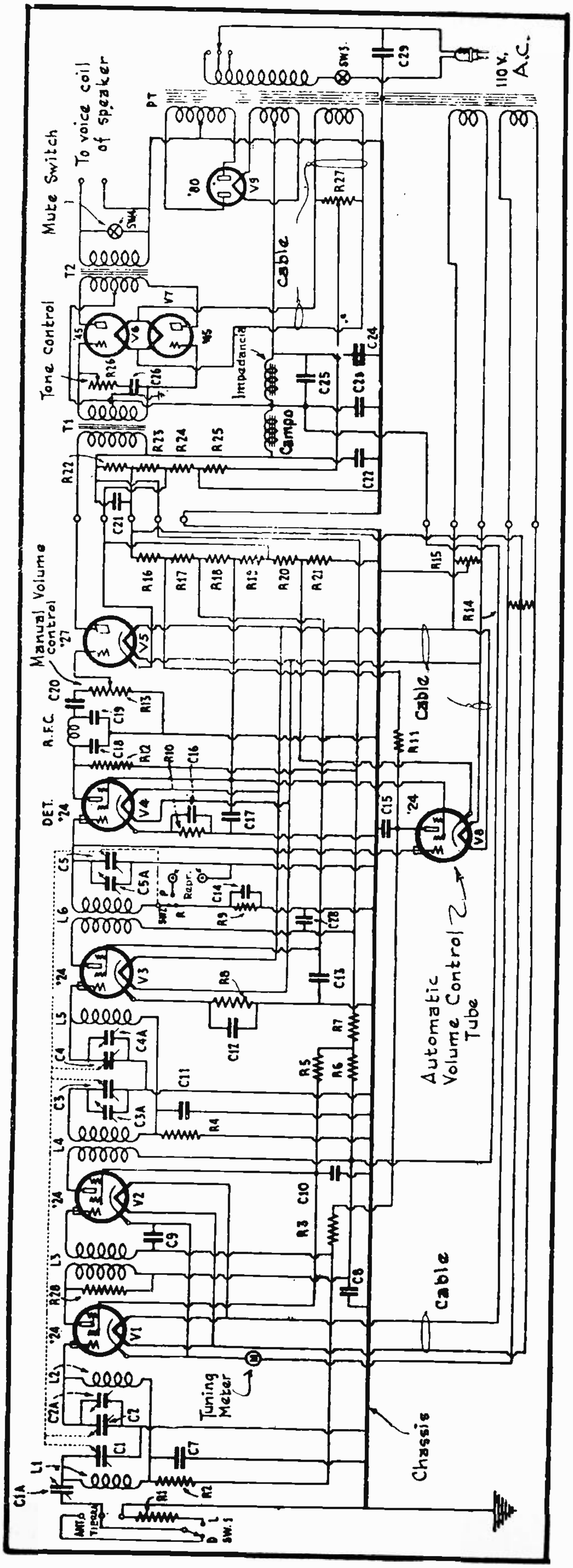

FIG. 7
Circuit Diagram of the Bosch Model 60 Receiver With Automatic Volume Control.

AUTOMATIC VOLUME CONTROL TUBE. NOTE THAT IN THIS CASE, THE GRID OF THE VOLUME CONTROL TUBE IS CONNECTED DIRECTLY TO THE GRID OF THE DETECTOR TUBE AND THE SCREEN-GRIDS OF THESE TWO TUBES ARE ALSO CONNECTED TOGETHER.

THE AUTOMATIC VOLUME CONTRÓL IN THIS PARTICULAR RECEIVER ACTS UPON BOTH OF THE FIRST R.F. TUBES, NAMELY, V1 AND V2. THE VOLUME CONTROL CIRCUIT IN THIS RECEIVER OPERATES IN THE FOLLOWING MANNER: IF A STRONG SIGNAL IS APPLIED TO THE DETECTOR TUBE, IT IS ALSO SIMULTANEOUSLY APPLIED TO THE CONTROL GRID OF THE VOLUME CONTROL TUBE. THIS CAUSES AN INCREASE IN THE PLATE CURRENT FLOWING THROUGH THE VOLUME CONTROL TUBE (V8) AND THIS CURRENT MUST ALL FLOW THROUGH RESISTOR R11.

THE GRID RETURN OF THE 1ST TWO R.F. TUBES ARE BOTH CONNECTED TO THE NEGATIVE END OF THE R11 AND THIS RESISTOR IS ALSO CONNECTED IN THE CATHODE CIRCUIT OF THESE SAME TWO TUBES. THE VOLTAGE DROP THUS DEVELOPED ACROSS THE ENDS OF R11 IS THEN IMPRESSED AS A BIAS VOLTAGE ACROSS THE GRID CIRCUIT OF THE FIRST TWO R.F. TUBES. SINCE THIS AUTOMATIC BIAS VOLTAGE IS CONTROLLED BY THE APPLIED SIGNAL VOLTAGE, THE SENSITIVETY OF THE FIRST TWO R.F. TUBES IS CORRESPONDINGLY VARIED, THUS BRINGING ABOUT AUTOMATIC VOLUME CONTROL. STUDY THE SPECIFICATIONS RELATIVE TO THE DIAGRAM IN FIG. 7 VERY CAREFULLY SO AS TO FAMILIARIZE YOURSELF WITH THE REQUIRED VALUES FOR THE PARTS.

SPECIFICATIONS FOR THE BOSCH MODEL 60 RECEIVER

C1-C2-C3-C4-C5 = TUNING CONDENSERS
C2A-C3A-C4A-C5A = TRIMMER CONDENSERS
C1A = ANTENNA TRIMMER
C7 = BAND SELECTOR COUPLING CONDENSER
C8-C10 = .25 MFD.
C9-C12-C13-C17-C28 = 0.5 MFD.
C11-C14 = .04 MFD.
C15-C20-C26 = .006 MFD.
C16 = 1 MFD.
C18-C19 = .0001 MFD.
C21-C22 = 2 MFD.
C23-C24 = 2 MFD. EACH
C25 = .075 MFD.
C27 = 0.1 MFD.

R1 = 500 OHMS
R2-R4-R8-R9 = 1000 OHMS
R3-R11-R12-R13-R26 = 0.5 MEGOHM
R5-R6 = 20,000 OHMS
R7 = 10,000 OHMS
R10-R28 = 50,000 OHMS
R14-R15-R27 = 20 OHMS CENTER TAPPED.
R16 = 900 OHMS.
R17-R19 = 5000 OHMS.
R18 = 25,000 OHMS.
R20-R21 = 2000 OHMS.
R22 = 1300 OHMS.
R23 = 2380 OHMS.
R24 = 160 OHMS
R25 = 950 OHMS

FILAMENT VOLTAGES

V1-V2-V6-V7 = 2.4 VOLTS.
V3-V4-V5-V8 = 2.3 VOLTS.
V9 = 5 VOLTS.

PLATE POTENTIALS

V1 = 170 VOLTS; V2 = 180 VOLTS
V3 = 185 VOLTS; V4 = 60 VOLTS; V5 = 150 VOLTS;
V6 AND V7 = 250 VOLTS; V8 = 30 VOLTS.

PLATE CURRENT

V1-V2 = 3 MA; V3 = 2 MA.
V4 = 0.1 MA. V5 = 6 MA.
V6-V7 = 30 MA. V8 = 2 MA.

SCREEN-GRID VOLTAGES

V1 = 70 VOLTS; V22=80 VOLTS; V3 = 85 VOLTS
V4 = 10 VOLTS; V8 = 20 VOLTS.

CONTROL GRID BIAS

V1-V2 = 2 VOLTS; V3=1.5 VOLTS;
V4 = 1 VOLT; V5 = 0.1 VOLT;
V6-V7 = 50 VOLTS; V8 = 0.2 VOLT.

NOTE:-

ALL READINGS TAKEN WITH VOLUME CONTROL "FULL ON".

ONE DIFFICULTY WITH AUTOMATIC VOLUME CONTROL

DUE TO THE FACT THAT AUTOMATIC VOLUME CONTROL HAS A NATURAL TENDENCY TO INCREASE THE SENSITIVITY OF THE RECEIVER WHENEVER LITTLE SIGNAL ENERGY IS PRESENT WITHIN THE RECEIVER CIRCUITS, IT BRINGS ABOUT AN UNDESIRABLE CONDITION. THAT IS, WHEN TUNING-IN SOME STATION, THERE WILL BE PERIODS DURING THE OPERATION OF THE TUNING DIAL WHEN NO SIGNALS ARE BEING PICKED UP. AT THESE TIMES, THE RECEIVER WILL BE EXTREMELY SENSITIVE AND IT WILL THEREFORE AMPLIFY ALL "BACKGROUND NOISES", SUCH AS STATIC DISCHARGES IN THE ATMOSPHERE ETC., WITH THE RESULT THAT ALL SORTS OF EXTRANEOUS NOISES WILL BE HEARD IN THE SPEAKER WHEN DIALING BETWEEN STATIONS.

FOR THIS VERY REASON, THE MUTE SWITCH SW4 IS CONNECTED AT THE OUTPUT OF THE AMPLIFIER IN FIG. 7. WHILE TUNING, THIS SWITCH IS CLOSED BY THE OPERATOR, THUS SHORT CIRCUITING THE VOICE COIL OF THE SPEAKER UNTIL THE RECEIVER IS TUNED TO RESONANCE WITH SOME STATION. NO DOUBT, YOU ARE WONDERING HOW A RECEIVER CAN BE TUNED WITHOUT LISTENING TO THE SPEAKER BUT THIS IS READILY ACCOMPLISHED BY MEANS OF A VISUAL TUNING METER, WHICH IS INSTALLED IN THE CATHODE CIRCUIT OF THE FIRST TWO R.F. TUBES AS POINTED OUT IN FIG. 7. THIS TYPE OF TUNING IS KNOWN AS "VISUAL TUNING" AND IT IS BEING USED ON SEVERAL OF THE LATE MODEL COMMERCIAL RECEIVERS.

OPERATING PRINCIPLES OF VISUAL TUNING

A DETAILED VIEW OF THE CONNECTIONS FOR A TUNING METER ARE SHOWN IN FIG. 8. THIS IS IN REALLITY A MILLIAMETER WHICH IS CONNECTED IN THE PLATE CIRCUIT OF ONE OR MORE R.F. TUBES, AND CONSEQUENTLY, IT WILL REGISTER THE PLATE CURRENT PASSING THROUGH IT. THIS METER IS MOUNTED ON THE CONTROL PANEL OF THE RECEIVER SO AS TO BE IN FULL VIEW OF THE OPERATOR.

NOW THE MAIN THING TO REMEMBER IN RESPECT TO THIS METER IS THAT IT WILL INDICATE A GREATER PLATE CURRENT FLOW WHEN THE RECEIVER IS MOST SENSITIVE AND AMPLIFYING AT ITS MAXIMUM. THEN NATURALLY, AS THE SENSITIVETY AND AMPLIFYING QUALITIES OF THE RECEIVER DECREASE, THE READING OF THIS METER WILL ALSO DECREASE ACCORDINGLY.

REMEMBERING THAT THIS TUNING METER IS INSTALLED IN A RECEIVER CIRCUIT WHICH IS PROVIDED WITH AUTOMATIC VOLUME CONTROL, YOU WILL BE AWARE OF THE FACT THAT THE NATURAL ACTION OF THE AUTOMATIC VOLUME CONTROL IS SUCH AS TO MAKE THE RECEIVER MOST SENSITIVE AT TUNING DIAL SETTINGS BETWEEN STATIONS AND LEAST SENSITIVE WHENEVER THE RECEIVER IS TUNED TO RESONANCE WITH SOME STATION. THEREFORE, IT IS CLEAR THAT THE TUNING METER WILL REGISTER ITS LOWEST READING WHENEVER THE RECEIVER IS TUNED TO RESONANCE WITH A STATION AND ITS READING WILL BE GREATEST WHENEVER THE TUNING CONDENSER IS SET AT SOME POINT BETWEEN STATIONS.

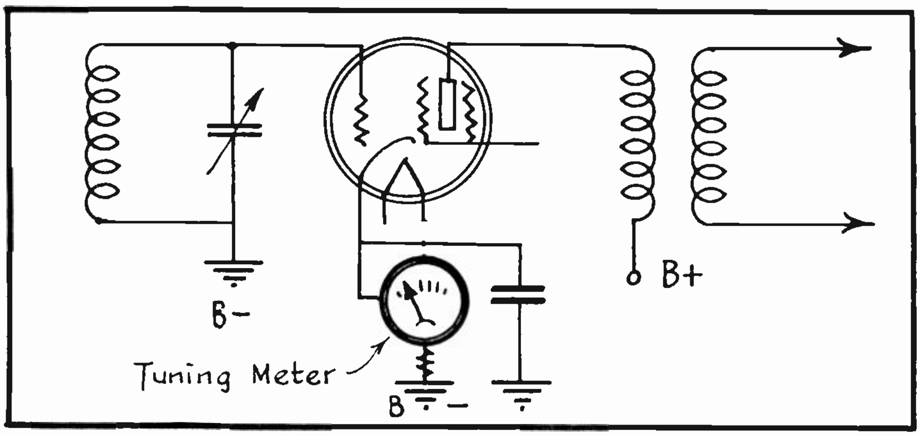

FIG. 8
A Visual Tuning Meter.

THUS YOU CAN SEE THAT IN ORDER TO TUNE THE RECEIVER WITH THE AID OF THE METER RATHER THAN BY EAR, ALL THAT YOU WOULD HAVE TO DO IS TO SET YOUR TUNING DIAL AT THE APPROXIMATE POINT FOR TUNING-IN THE STATION YOU WANT AND THEN SIMPLY ADJUST THE TUNING DIAL SLOWLY UNTIL THE METER INDICATES A MINIMUM READING.

FOR THE SAKE OF THE GENERAL PUBLIC, RADIO MANUFACTURERS ARE REVERSING THE SCALE CALIBRATION OF THESE TUNING METERS OR ELSE MOUNT THE METER UPSIDE DOWN SO THAT THEY WILL READ BACKWARDS TO THE CONVENTIONAL TYPE OF TESTING METERS. THAT IS, AS THE PLATE CURRENT DECREASES, THE METER NEEDLE WILL SWING TOWARDS THE RIGHT INSTEAD OF TOWARDS THE LEFT. THIS ACTION APPEARS AS BEING MORE NATURAL TO THOSE WHO ARE NOT FAMILIAR WITH THE TECHNICALITIES CONCERNING RADIO AND SO THE SET OWNER IS SIMPLY INSTRUCTED TO ADJUST HIS TUNING DIAL TO THE POINT WHERE THE NEEDLE OF THE TUNING METER SWINGS FARTHEST TO THE RIGHT.

THE PROPER WAY TO TUNE THE RECEIVER ILLUSTRATED IN FIG. 7, OR FOR that matter any receiver equipped with an automatic volume control, visual tuning meter and mute switch is as follows: Turn on the power for the set, close the mute switch on the control panel, set the tuning dial to the approximate position for tuning in the desired station and then adjust the dial carefully until the needle of the tuning meter swings farthest toward the right. This done, open the mute switch and adjust the hand-operated volume control, so as to providespeaker volume of the desired level

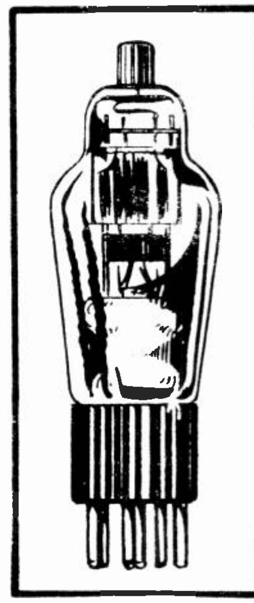

FIG.9
The Type -55 Tube.

APPLICATION OF THE DUPLEX-DIODE TRIODE

In all of the A.V.C. systems which we have studied so far in this lesson, a separate tube was required to provide this control. In the modern receivers, however, a new type of tube is being used which is capable of serving simultaneously as a detector, automatic volume control tube and A.F. amplifier. This tube is classified as a DUPLEX-DIODE TRIODE. Several different tubes of this type are available to meet different receiver requirements -- we shall start our investigation of these tubes with the "55".

THE TYPE -55 TUBE

Fig. 9 will serve to familiarize you with the general appearance of the -55 tube, while the symbol and terminal connections for this same tube are illustrated in Fig. 10.

By studying the symbol for the type -55 tube in the upper illustration of Fig. 10, you will observe that it contains the conventional filament, cathode, grid and plate but in addition, two small metal plates surround the cathode. These small metal plates are known as "DIODE PLATES" and each of them is connected to an individual prong in the tube base. Thus the base altogether has 6 prongs, the arrangement of which are as illustrated in the lower portion of Fig. 10, where you are looking at the base from below.

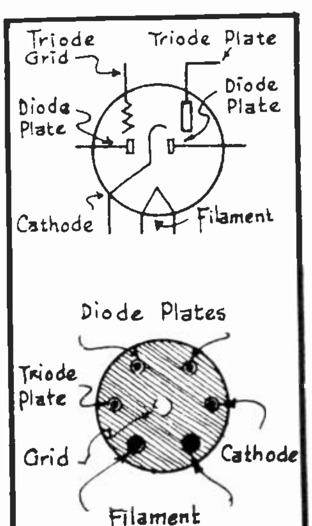

FIG. 10
Construction of the -55 Tube.

Note carefully in the base arrangements of Fig. 10 that the heater (filament) ends are connected to two of the prongs, the cathode to the third prong, plate to a fourth prong and the two diode plates to the fifth and sixth prongs. The control grid connection is made to the cap on top of the glass bulb.

In Fig. 11, you will see a typical circuit designed for the use of this new tube. This particular circuit happens to be a portion of a superheterodyne receiver and the system operates as follows:

Up to the 2nd I.F. transformer, the signal is passed through the circuit in the customary manner but from the secondary circuit of the 2nd I.F. transformer, the signal is impressed upon the two diode

PLATES, BOTH OF WHICH, YOU WILL OBSERVE, ARE TOGETHER CONNECTED TO ONE SIDE OF THE SECONDARY CIRCUIT.

SINCE THE CATHODE IS EMITTING AN ELECTRON STREAM AND THE TWO DIODE PLATES WILL TOGETHER CHANGE FROM A POSITIVE TO NEGATIVE POTENTIAL CORRESPONDING TO THE SIGNAL VOLTAGE CHANGES, IT IS CLEAR THAT THE CATHODE AND THE TWO DIODE PLATES WILL TOGETHER CONSTITUTE A RECTIFIER OR DETECTOR. BOTH DIODE PLATES BEING CONNECTED TOGETHER, THIS PORTION OF THE TUBE OPERATES AS A "DIODE" OR HALF-WAVE RECTIFIER.

THE CURRENT FLOW OCCURRING DURING THIS RECTIFICATION PROCESS WILL FLOW THROUGH THE .5 MEGOHM RESISTOR (R1) CAUSING A CORRESPONDING VOLTAGE VARIATION ACROSS BOTH THIS RESISTOR AND THE .00025 MFD. CONDENSER WHICH SHUNTS IT. THIS VOLTAGE GENERATED ACROSS THE .5 MEGOHM RESISTOR, BEING APPLIED BETWEEN THE CATHODE AND THE TUNED SECONDARY WINDING WHICH CONNECTS TO THE GRID OF THE -55 TUBE, WILL THUS NATURALLY BE APPLIED TO THE GRID OF THE TUBE ALSO.

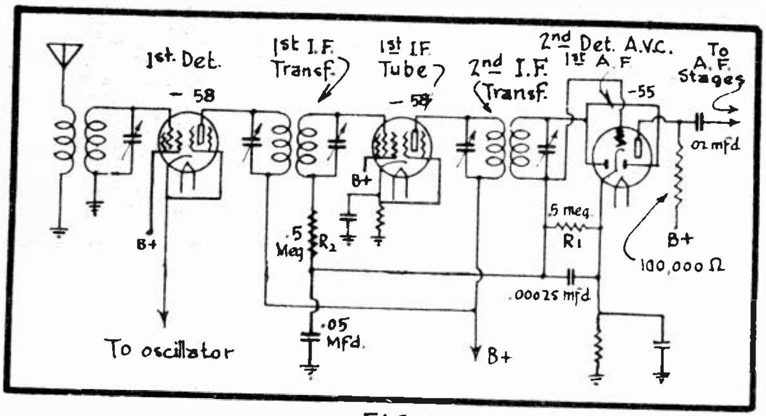

FIG. 11
Application of the Type -55 Tube in a Superheterodyne Receiver.

THIS VOLTAGE WILL ACTUATE THE GRID IN THE USUAL MANNER, CONTROLLING THE FLOW OF PLATE CURRENT BETWEEN THE TUBE'S TRIODE PLATE AND CATHODE, WHICH PRODUCES A CORRESPONDING AUDIO VOLTAGE ACROSS THE 100,000 OHM PLATE RESISTOR. THIS LATTER STEP CONSTITUTES THE AUDIO AMPLIFICATION FEATURES OF THE TUBE.

HAVING SO FAR SEEN HOW THE -55 TUBE FUNCTIONS AS A DETECTOR AND AMPLIFIER, OUR NEXT STEP WILL BE TO INVESTIGATE ITS OPERATION AS AN AUTOMATIC VOLUME CONTROL. THE GRID CIRCUIT OF THE I.F. AMPLIFIER TUBE OF FIG. 11 IS CONNECTED THROUGH A .5 MEGOHM RESISTOR (R2) TO THE GRID END OF THE .5 MEGOHM RESISTOR (R1). SINCE THE RECTIFIED SIGNAL CURRENT FLOWS THROUGH R1 FROM ITS CATHODE TO ITS GRID END, IT IS CLEAR THAT RESISTOR R2 IS CONNECTED TO THE NEGATIVE END OF R1 AND THE VOLTAGE CHANGES AT THIS LATTER RESISTOR WILL LIKEWISE BE APPLIED TO THE CONTROL GRID OF THE I.F. TUBE.

THIS VOLTAGE VARIATION CORRESPONDING TO SIGNAL INTENSITY, IT IS CLEAR THAT THE EFFECTS PRODUCED UPON THE I.F. TUBE WILL BE TO VARY ITS GRID BIAS VOLTAGE PROPORTIONATE TO THE SIGNAL INTENSITY AND THEREBY BRING ABOUT AN AUTOMATIC ACTION OF CONTROLLING THE VOLUME.

THE CHARACTERISTICS OF THE TYPE -55 TUBE

THE CHARACTERISTICS OF THE TYPE -55 TUBE ARE AS FOLLOWS:

HEATER VOLTAGE-----------------------------------2.5V. - A.C. OR D.C.
HEATER CURRENT-----------------------------------1 AMPERE.
PLATE VOLTAGE------------------------------------250 V.
GRID VOLTAGE------------------------------------ -20 V.
PLATE CURRENT------------------------------------8 MA.
AMPLIFICATION FACTOR-----------------------------8.3

THE TYPE 85 TUBE

The type 85 tube takes the place of the 55 in automobile receivers and in the same type of circuit. The characteristics of this tube are of course such as to best adapt it for automotive use. The operating characteristics of the 85 are as follows:

Heater voltage = 6.3 volts; heater current = 0.3 amp.;

PLATE VOLTAGE	GRID VOLTAGE	AMP. FACT.	PLATE CURRENT
135	-10.5	8.3	3.7 ma.
180	-13.5	8.3	6.0 ma.
250	-20.0	8.3	8.0 ma.

The 85 is equipped with a standard six prong base and a metal control grid cap.

Besides the application of the duplex diode triodes as shown you in this lesson, there are still many more ways in which this tube may be used. This additional information will all be brought to you in the following lesson as will also the specifications and application of duplex diode triodes of still more recent design.

Another interesting and valuable feature which is awaiting you in the next lesson is the method of AUTOMATICALLY reducing the background noise while dialing in between stations with receivers employing automatic volume control.

It is knowledge of this kind which keeps you in step with the advancement made in radio design and construction and you will find that thruout our entire course, we have made a special effort to keep all of our instruction up to date. This means that you will be qualified to handle all jobs satisfactorily from the oldest receivers still in use up to the most recent creations.

National training is not only up-to-date but in many important instances, it is ahead of commercial developments.

Examination Questions

These are the days for specializing. Knowledge, industry, science, all wide branches of human effort, are too big to be completely mastered by any one human mind.

1. - FOR WHAT CHIEF REASON IS AUTOMATIC VOLUME CONTROL BEING USED IN THE MODERN RECEIVERS?

2. - HOW DOES AN AUTOMATIC VOLUME CONTROL SYSTEM AFFECT THE SENSITIVITY OF A RECEIVER?

3. - DRAW A DIAGRAM OF A SIMPLE AUTOMATIC VOLUME CONTROL SYSTEM.

4. - EXPLAIN BRIEFLY HOW THE CIRCUIT WHICH YOU HAVE DRAWN IN ANSWER TO QUESTION #3 OF THIS EXAMINATION OPERATES.

5. - HOW MAY THE "DIODE PRINCIPLE" BE EMPLOYED TO ACCOMPLISH AUTOMATIC VOLUME CONTROL?

6. - WHY IS IT A NATURAL CHARACTERISTIC FOR A RECEIVER EMPLOYING AN AUTOMATIC VOLUME CONTROL SYSTEM TO BE NOISY WHEN DIALING IN BETWEEN STATIONS?

7. - WHAT IS THE PURPOSE OF A "MUTE SWITCH" ON SUCH A RECEIVER?

8. - WHAT DO WE MEAN BY "VISUAL TUNING" AND HOW IS IT ACCOMPLISHED?

9. - DESCRIBE BRIEFLY THE CONSTRUCTIONAL FEATURES OF THE TYPE 55 TUBE.

10. - WHAT ARE THE OPERATING CHARACTERISTICS OF THE TYPE 85 TUBE?

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NATIONAL SCHOOLS

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Los Angeles, California

LESSON NO. 32

MODERN A.V.C. SYSTEMS

IN THE PREVIOUS LESSON, YOU WERE SHOWN HOW THE SENSITIVITY OF A RECEIVER EQUIPPED WITH AN AUTOMATIC VOLUME CONTROL SYSTEM WAS INCREASED WHEN THE SET WAS TUNED OFF RESONANCE FROM SOME STATION AND HOW THIS EFFECT CAUSED BACKGROUND NOISE TO BE GREATLY AMPLIFIED WHILE TUNING BETWEEN STATIONS.

ALTHOUGH THE USE OF A MUTE SWITCH OFFERS A MEANS OF ELIMINATING NOISY TUNING, IT IS NEVERTHELESS SOMEWHAT BOTHERSOME AS REGARDS MANIPULATIONS. IN OTHER WORDS, IT IS AN ADDITIONAL CONTROL FOR MANUAL OPERATION (TO BE OPERATED BY HAND) AND THEREBY ADDS TO THE COMPLEXITY OF OPERATING THE RECEIVER. FOR THIS REASON, SOME MANUFACTURERS HAVE MADE SPECIAL PROVISIONS IN THEIR RECEIVER CIRCUITS WHEREBY THRU AUTOMATIC ACTION NO SIGNAL IS PERMITTED TO PASS THRU THE AUDIO SYSTEM UNTIL IT IS ABOVE A CERTAIN INTENSITY. SYSTEMS AS THIS ARE GENERALLY KNOWN BY SUCH NAMES AS AUTOMATIC NOISE SUPPRESSOR, QUIET AUTOMATIC VOLUME CONTROL (Q.A.V.C.) OR SQUELCH CONTROL.

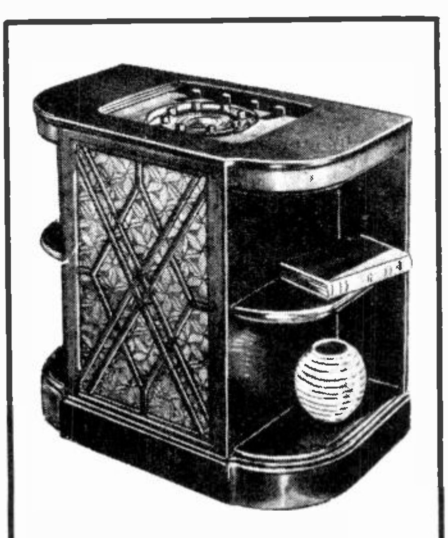

FIG. 1
MODERNISTIC RECEIVER DESIGN.

AUTOMATIC NOISE SUPPRESSION

WHEN OPERATING A RECEIVER WHICH IS EQUIPPED WITH ANY OF THESE AUTOMATIC NOISE SUPPRESSION SYSTEMS, THE SIGNAL DISAPPEARS AS THE RECEIVER IS TUNED OFF RESONANCE WITH A STATION, AND NO BACKGROUND NOISE NOR SIGNAL IS HEARD UNTIL THE NEXT CHANNEL IS REACHED, AT WHICH TIME THE PURE SIGNAL COMES THRU.

IN FIG. 2 A CIRCUIT IS ILLUSTRATED BY MEANS OF WHICH AUTOMATIC NOISE SUPPRESSION CAN BE ACCOMPLISHED. AS YOU WILL OBSERVE, THIS SYSTEM EMPLOYS THREE INDIVIDUAL TUBES, NAMELY, A DIODE DETECTOR, A NOISE SUPPRESSOR TUBE AND A CONTROLLED A. F. AMPLIFIER TUBE. ALTHOUGH BATTERIES ARE SHOWN AS BEING THE SOURCE OF E.M.F. IN PORTIONS OF THIS CIRCUIT, YET THESE SAME VOLTAGE SOURCES COULD NATURALLY BE FURNISHED EQUALLY WELL BY A RESISTANCE NET-WORK SUCH AS USED IN VOLTAGE DIVIDER SYSTEMS.

NOW THEN, WITH NO SIGNAL AVAILABLE ACROSS THE SECONDARY CIRCUIT OF THE I.F. TRANSFORMER, NO PLATE CURRENT WILL PASS THROUGH THE DIODE DETECTOR TUBE. AT THIS SAME TIME, THERE IS NO BIAS VOLTAGE APPLIED TO THE GRID OF THE NOISE SUPPRESSOR TUBE BECAUSE THE CATHODE OF THIS TUBE IS CONNECTED DIRECTLY TO B- AND ITS GRID RETURN CIRCUIT IS CONNECTED TO RESISTOR R THROUGH WHICH NO CURRENT IS NOW FLOWING.

DUE TO THE ABSENCE OF A BIAS VOLTAGE UPON THE GRID CIRCUIT OF THE NOISE SUPPRESSOR TUBE, THE PLATE CURRENT FLOW THROUGH THIS TUBE WILL BE AT ITS MAXIMUM VALUE. THIS MEANS THAT MAXIMUM CURRENT WILL BE FLOWING THROUGH RESISTOR R2 SO THAT A MAXIMUM D.C. VOLTAGE WILL BE DEVELOPED ACROSS ITS EXTREMETIES -- ITS UPPER END BECOMING NEGATIVE WITH RESPECT TO ITS LOWER END.

THE GRID OF THE CONTROLLED A.F. AMPLIFIER TUBE IS CONNECTED TO THE NEGATIVE END OF R2 THROUGH THE RESISTOR R4 AND SINCE MAXIMUM VOLTAGE IS BEING DEVELOPED ACROSS R2, THIS VOLTAGE WILL BE EFFECTIVE UPON THE GRID OF THE CONTROLLED A.F. AMPLIFIER TUBE AS A NEGATIVE BIAS, BEING ADDED TO THIS TUBE'S NORMAL BIAS VOLTAGE. IN FACT, THE VOLTAGE DEVELOPED ACROSS

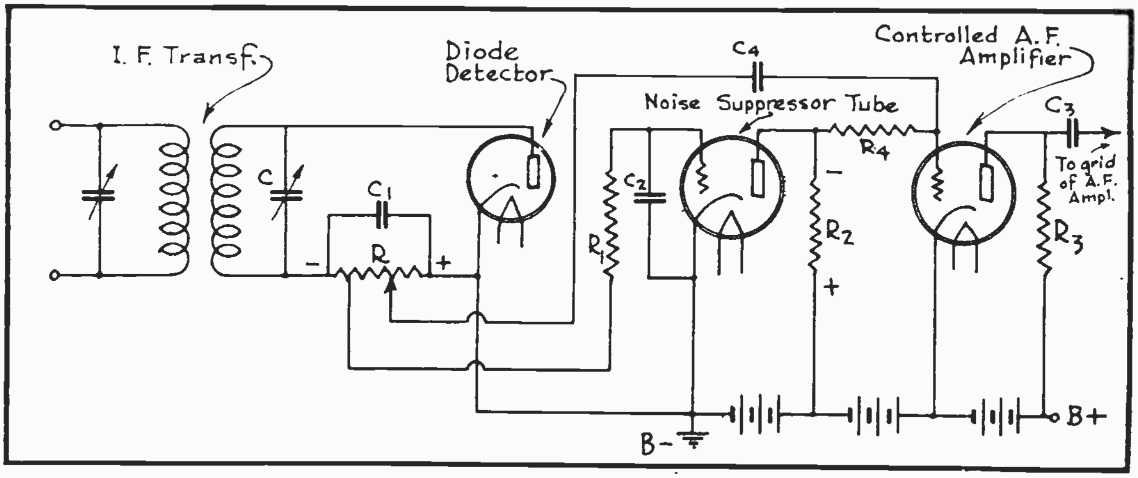

FIG. 2
An Automatic Noise Suppression Circuit.

R2 IS SUFFICIENT AT THIS TIME SO AS TO INCREASE THE NEGATIVE BIAS UPON THE CONTROLLED A.F. AMPLIFIER TUBE TO SUCH A POINT THAT IT WILL PREVENT ANY FLOW OF PLATE CURRENT THROUGH IT. WE THEN SAY THAT THIS TUBE IS CAUSED TO "CUT-OFF" AND CAN THEREFORE NOT AMPLIFY. AS A RESULT, THE A.F. AMPLIFIER OF THE RECEIVER IS CAUSED TO BECOME INOPERATIVE AND CONSEQUENTLY NO NOISE WILL BE AMPLIFIED BY IT.

WHENEVER A SIGNAL VOLTAGE IS DEVELOPED ACROSS THE SECONDARY CIRCUIT OF THE I.F. TRANSFORMER IN FIG. 2, PLATE CURRENT WILL FLOW THROUGH THE DIODE DETECTOR AND BOTH D.C. AND A.F. VOLTAGES WILL BE DEVELOPED ACROSS RESISTOR R. AS TO THE D.C. VOLTAGE PRODUCED ACROSS R, ITS LEFT END BECOMES NEGATIVE WITH RESPECT TO ITS RIGHT END AND SINCE THE CATHODE OF BOTH THE DIODE DETECTOR AND THE NOISE SUPPRESSOR TUBE ARE OF THE SAME POTENTIAL DUE TO THEIR COMMON CONNECTION, THE D.C. VOLTAGE DEVELOPED ACROSS R WILL BE APPLIED TO THE GRID OF THE NOISE SUPPRESSOR TUBE THRU R1 AS A BIAS VOLTAGE -- THE GRID RETURN END OF R1 BEING CONNECTED TO THE NEGATIVE END OF R.

THE BIAS VOLTAGE IMPRESSED UPON THE GRID OF THE NOISE SUPPRESSOR TUBE AT THIS TIME IS SUFFICIENTLY LARGE TO CAUSE THIS TUBE TO CUT-OFF AND PREVENT ITS DRAWING ANY PLATE CURRENT THROUGH RESISTOR R2. SINCE NO PLATE CURRENT WILL NOW BE FLOWING THROUGH R2, NO VOLTAGE DROP WILL BE DEVELOPED ACROSS IT AND THEREFORE R2 WILL FURNISH NO ADDITIONAL VOLTAGE FOR BIASING THE CONTROLLED A.F. AMPLIFIER TUBE AND SO THIS TUBE WILL BE SUBJECTED TO ITS NORMAL BIAS VOLTAGE ONLY. CONDITIONS BEING SUCH, THIS TUBE CAN FUNCTION AS AN AMPLIFIER, DRAWING ITS PLATE CURRENT THROUGH R3, ITS GRID BEING SUBJECTED TO THE A.F. SIGNAL VOLTAGES WHICH ARE APPLIED TO IT THROUGH THE COUPLING CONDENSER C4 FROM R.

FROM THE CONTROLLED A.F. AMPLIFIER TUBE, THE AUDIO FREQUENCIES ARE PASSED ON THROUGH COUPLING CONDENSER C3 TO THE FOLLOWING A.F. STAGES FOR FURTHER AMPLIFICATION.

DELAYED AUTOMATIC VOLUME CONTROL

QUITE OFTEN, IT IS DESIRABLE TO DELAY THE ACTION OR RESPONSE OF THE AUTOMATIC VOLUME CONTROL SYSTEM SLIGHTLY SO THAT IT WILL NOT COMMENCE TO OPERATE UNTIL A SIGNAL OF A CERTAIN MINIMUM INTENSITY OR AMPLITUDE IS BEING RECEIVED. ANY AUTOMATIC VOLUME CONTROL SYSTEM WHICH BEHAVES IN THIS MANNER IS KNOWN AS DELAYED AUTOMATIC VOLUME CONTROL. FOR THE SAKE OF SIMPLICITY, THIS IS FREQUENTLY ABREVIATED AS D.A.V.C.

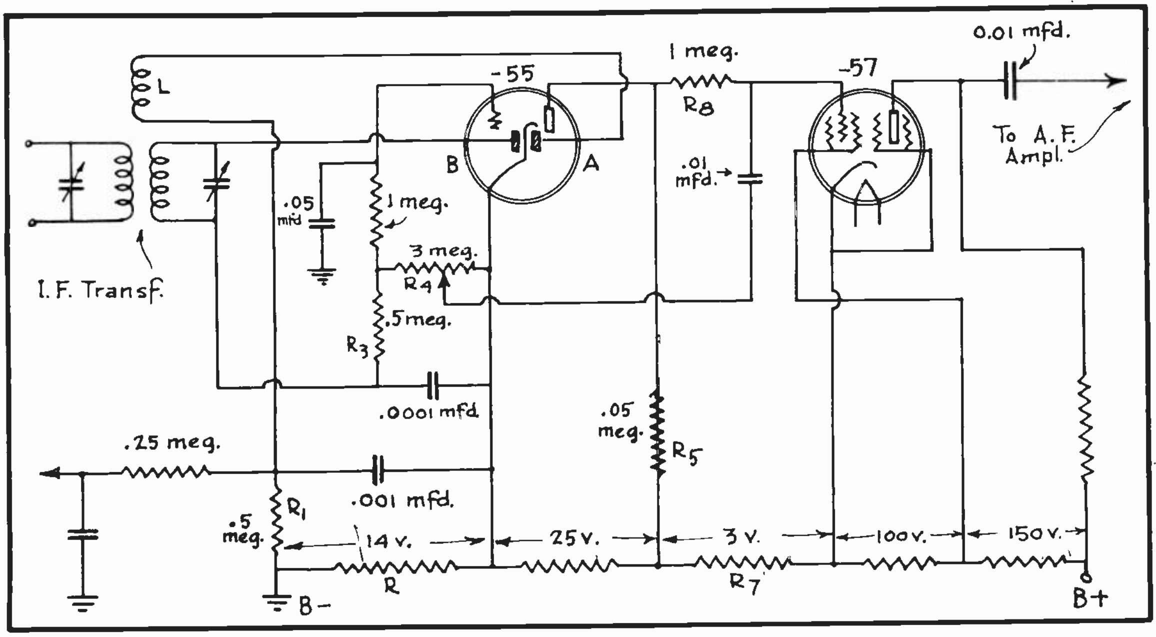

FIG. 3
A Delayed A.V.C. and Noise Suppression Circuit.

THIS FEATURE IS ACCOMPLISHED BY APPLYING A NEGATIVE D.C. VOLTAGE TO THE DIODE PLATE SO THAT THE POSITIVE SWING OF THE PEAK SIGNAL MUST BE SLIGHTLY MORE THAN THE APPLIED NEGATIVE D.C. VOLTAGE JUST MENTIONED BEFORE ANY DIODE CURRENT CAN FLOW THROUGH THE CIRCUIT.

DELAYED AUTOMATIC VOLUME CONTROL WITH AUTOMATIC NOISE SUPPRESSION

IN FIG. 3 WE HAVE A CIRCUIT WHICH IS ARRANGED SO AS TO OFFER DIODE

DETECTION, DELAYED AUTOMATIC VOLUME CONTROL AND AUTOMATIC NOISE SUPPRESSION. ONE DIODE SECTION OF THE 55 TUBE HANDLES THE DELAYED A.V.C. ACTION, WHILE THE OTHER DIODE SECTION OF THIS SAME TUBE TAKES CARE OF DETECTION. THE TRIODE SECTION OF THIS SAME TUBE TAKES CARE OF THE NOISE SUPPRESSION FEATURES. THE 57 TUBE IN THIS CIRCUIT ACTS AS AN A.F. AMPLIFIER.

NOW THEN, WITH SIGNAL VOLTAGES APPLIED ACROSS THE I.F. TRANSFORMER, CORRESPONDING SIGNAL VOLTAGE CHANGES WILL BE INDUCED INTO COIL "L" WHICH IS CLOSELY COUPLED TO THE PRIMARY WINDING OF THE I.F. TRANSFORMER. THESE CORRESPONDING VOLTAGE CHANGES WILL BE IMPRESSED UPON DIODE "A" OF THE 55 TUBE AND "DIODE CURRENT" WILL THEREFORE FLOW THROUGH THIS TUBE FROM DIODE "A", THROUGH RESISTORS R AND R1, RETURNING TO DIODE "A" THROUGH COIL L.

DIODE "A" IS CONNECTED TO THE NEGATIVE END OF RESISTOR R AND THE 14 VOLT DROP DEVELOPED ACROSS THE ENDS OF R BY THE FLOW OF BLEEDER CURRENT THROUGH IT IS THEREFORE APPLIED TO DIODE "A" AS A NEGATIVE BIAS. THIS FACT SERVES TO BRING ABOUT THE DELAYED ACTION OF THE AUTOMATIC VOLUME

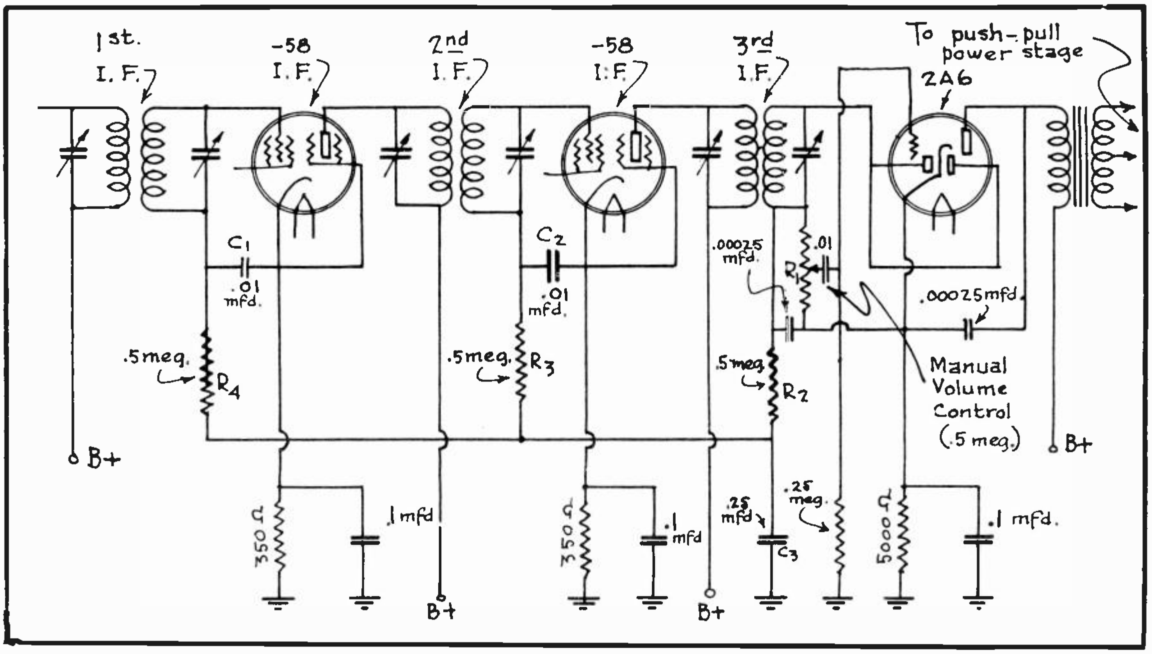

FIG. 4
Application of the 2A6 Tube.

CONTROL. IN OTHER WORDS, THE CURRENT FROM DIODE "A" DOESN'T ACTUALLY COMMENCE TO FLOW UNTIL THE PEAK SIGNAL AS APPLIED TO DIODE "A" RISES TO A VALUE SLIGHTLY ABOVE 14 VOLTS. AS THIS DIODE CURRENT COMMENCES TO FLOW, A.V.C. VOLTAGE IS DEVELOPED ACROSS R1.

AT THE SAME TIME, SIGNAL VOLTAGES ARE ALSO BEING IMPRESSED UPON DIODE B OF THE 55 TUBE AND THEREFORE CURRENT WILL ALSO BE FLOWING FROM DIODE B THROUGH RESISTORS R4 AND R3 AND BACK TO DIODE B BY WAY OF THE I.F. TRANSFORMER'S SECONDARY WINDING. THIS CURRENT FLOW THROUGH RESISTORS R3 AND R4 WILL DEVELOPE BOTH D.C. AND A.F. VOLTAGE DROPS ACROSS THEM, WITH THEIR LEFT ENDS BEING NEGATIVE WITH RESPECT TO THEIR RIGHT ENDS AS FAR AS THE D.C. IS CONCERNED.

The control grid of the 55 tube is connected to the negative end of R4 and so the D.C. voltage drop across R4 will be impressed upon the grid of this tube in the form of a negative bias. At the same time, A.F. voltages are impressed upon the grid of the 57 A.F. amplifier tube through the .01 mfd. condenser from the point where this condenser is connected to R4.

The constants of the circuit are so chosen that the bias voltage impressed upon the grid of the 55 tube during the reception of signals will be sufficiently negative to cause the 55 tube to cut-off. Plate current will therefore not be passed by the 55 tube and no current will be flowing through resistor R5 and for this reason, only the voltage drop of 3 volts across R7 will be applied as a bias to the 57 tube. This tube can therefore, function normally as an A.F. amplifier and pass the A.F. signal to the rest of the stages for further amplification.

When no signal voltages are impressed upon the I.F. transformer, no diode current flows through either of the 55 tube's two diode sections. Con

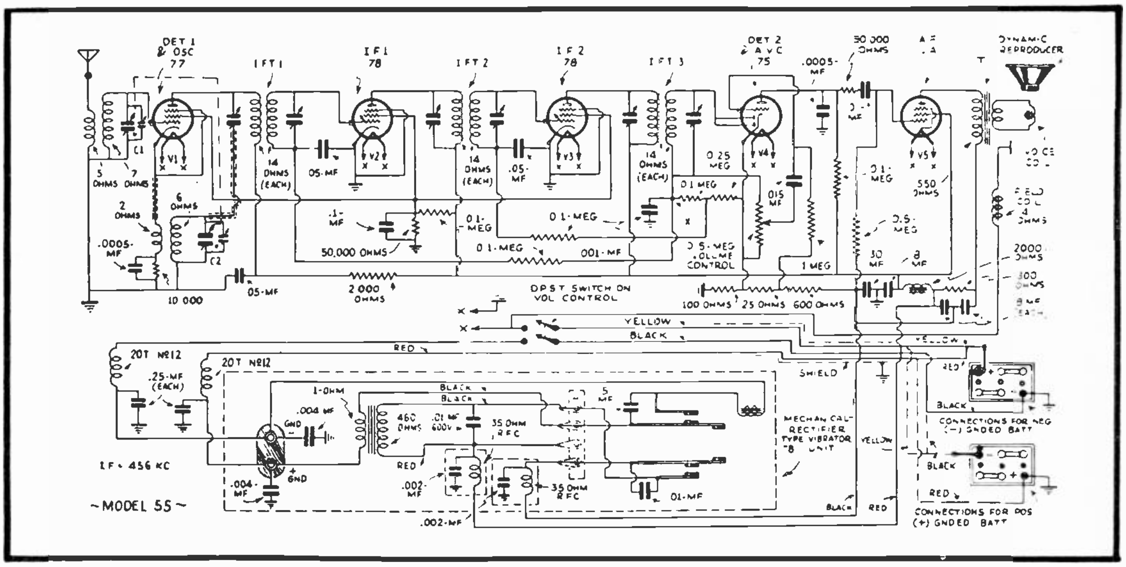

FIG. 5

A Modern Auto Receiver Circuit

sequently, there is no A.V.C. action because diode "A" is biased 14 volts negative. Under these conditions a minimum negative bias voltage will be impressed upon the grid of the 55 tube and so the plate current passed through this tube, as well as resistor R5, will be at a maximum value.

The voltage drop across R5 caused by this current flow through it, makes its upper end negative with respect to its lower end and since the control grid of the 57 is connected to the negative end of R5 by way of resistor R8 a maximum negative bias voltage will be impressed upon the 57 tube. In fact, so great is the negative bias voltage upon the 57 tube at this time that this tube cuts-off and no amplification of the audio signal occurs. In other words, no A.F. voltages are impressed upon the A.F. amplifier and so no sounds will be reproduced by the speaker.

For small degrees of detuning under conditions of signal input, the noise suppression circuit will not function until the A.V.C. circuit no

LONGER ACTS TO MAINTAIN THE DETECTOR INPUT CONSTANT. FOR THIS REASON, ALTHOUGH NOISE SUPPRESSION WILL BE OBTAINED WHEN THE SET IS CONSIDERABLY DETUNED, YET THERE IS A TENDENCY FOR SOME NOISE OR CARRIER HISS TO BE HEARD WHEN TUNING IS AT OR NEAR THE SIDE-BAND LIMITS. THIS MAKES IT DESIRABLE TO REDUCE THE DELAY IN NOISE SUPPRESSION CONTROL TO A MINIMUM.

IN ORDER TO OBTAIN THIS RESULT, THE A.V.C. AND NOISE SUPPRESSION TUBE SHOULD OBTAIN THEIR SIGNAL VOLTAGES FROM SEPARATE INPUTS AND FOR A SMALL AMOUNT OF DETUNING, THE SIGNAL ACTUATING THE NOISE SUPPRESSION TUBE MUST BE REDUCED MORE SHARPLY THAN THAT SUPPLYING THE AUTOMATIC VOLUME CONTROL TUBE.

IN THE CIRCUIT OF FIG. 3, FOR INSTANCE, THE OVERALL SELECTIVITY AT THE SECONDARY WINDING OF THE I.F. TRANSFORMER IS GREATER THAN THAT AT THE COUPLING COIL "L" AND THEREFORE, WHEN DETUNING, THE SIGNAL ON DIODE "B" IS REDUCED TO A GREATER EXTENT THAN THE SIGNAL ON DIODE "A". THE CHIEF REASON WHY THE SELECTIVITY OF THE COUPLING COIL "L" IS LESS THAN THAT OF THE I.F. TRANSFORMER'S SECONDARY WINDING IS THAT THE COUPLING COIL "L" IS MORE CLOSELY COUPLED TO THE PRIMARY WINDING OF THE I.F. TRANSFORMER.

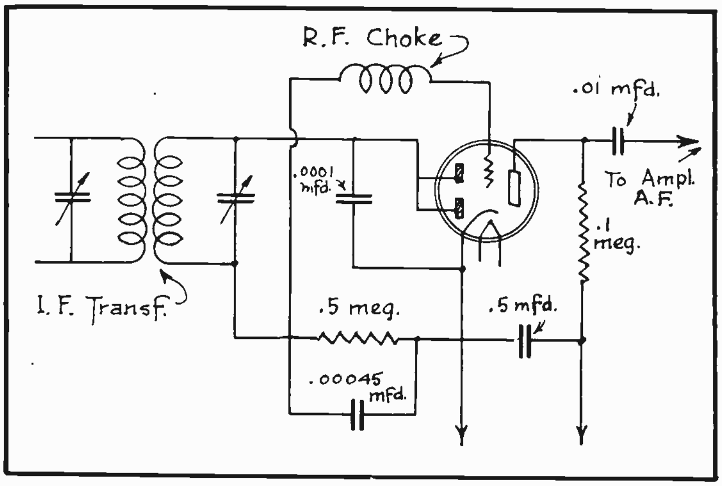

FIG. 6
Half-wave Detector, Diode Biased Amplifier.

BY USING THIS ARRANGEMENT, THE DESIRED SUPPRESSION CAN BE OBTAINED APPRECIABLY BEFORE THE A.V.C. ACTION INCREASES THE RECEIVER SENSITIVITY TO MAXIMUM.

THE 2A6

THE 2A6 IS ALSO A DUPLEX-DIODE TRIODE AND IN GENERAL APPEARANCE, THEORY OF OPERATION AND APPLICATION IS PRACTICALLY IDENTICAL TO THE 55. THE MAIN DIFFERENCE, HOWEVER, IS THAT THE 2A6 HAS A HIGHER AMPLIFICATION FACTOR THAN THE 55 AND FOR THIS REASON IS GENERALLY REFERRED TO AS BEING A "DUPLEX-DIODE HIGH-MU TRIODE". ITS OPERATING CHARACTERISTICS ARE AS FOLLOWS:

HEATER VOLTAGE = 2.5 VOLTS; HEATER CURRENT = 0.8 AMP; PLATE VOLTAGE = 250 VOLTS MAXIMUM; GRID BIAS = -2 VOLTS; PLATE CURRENT = 0.8 MA.; AMPLIFICATION FACTOR = 100.

IN FIG. 4 YOU ARE SHOWN A PORTION OF A SUPERHETERODYNE RECEIVER CIRCUIT IN WHICH THIS TUBE IS EMPLOYED. NOTICE FIRST HOW THE 2A6 CONSISTS OF A HEATER, CATHODE, TWO DIODE PLATES, A GRID AND A PLATE. THIS TUBE HAS A STANDARD SIX PRONG BASE AND ALL CONNECTIONS ARE MADE TO IT IN THE SAME MANNER AS ALREADY DESCRIBED RELATIVE TO THE 55.

NOW AS TO THE GENERAL HOOK-UP OF THIS CIRCUIT IN FIG. 4 YOU WILL NO

TICE THAT THE TWO DIODE PLATES OF THE TUBE ARE TOGETHER CONNECTED TO ONE SIDE OF THE LAST I.F. TRANSFORMER'S SECONDARY CIRCUIT, WHILE THE CATHODE OF THIS TUBE IS CONNECTED TO GROUND THROUGH THE 5000 OHM FIXED RESISTOR SO AS TO PROVIDE THE FIXED BIAS VOLTAGE FOR THIS TUBE.

THE .5 MEGOHM POTENTIOMETER R1 HAS ONE OF ITS END TERMINALS CONNECTED TO THE CATHODE OF THE 2A6 WHILE ITS OTHER END TERMINAL IS CONNECTED TO THE "GRID RETURN END" OF THE THIRD I.F. TRANSFORMER WHICH WORKS INTO THIS TUBE. THIS POTENTIOMETER, TOGETHER WITH THE .00025 MFD. WHICH IS CONNECTED ACROSS IT, SERVES THE SAME PURPOSE AS ALREADY DESCRIBED RELATIVE TO R1 AND ITS ASSOCIATED .00025 MFD. CONDENSER IN THE CIRCUIT OF FIG. 11 OF THE PREVIOUS LESSON.

A .5 MEGOHM FIXED RESISTOR R2 IS CONNECTED TO THE NEGATIVE END OF THE .5 MEGOHM POTENTIOMETER IN THE CIRCUIT OF FIG. 4 AND THE OTHER END OF R2 LEADS TO THE GRID RETURN CIRCUITS OF THE TWO PRECEDING I.F. STAGES THROUGH THE .5 MEGOHM RESISTORS R3 AND R4.

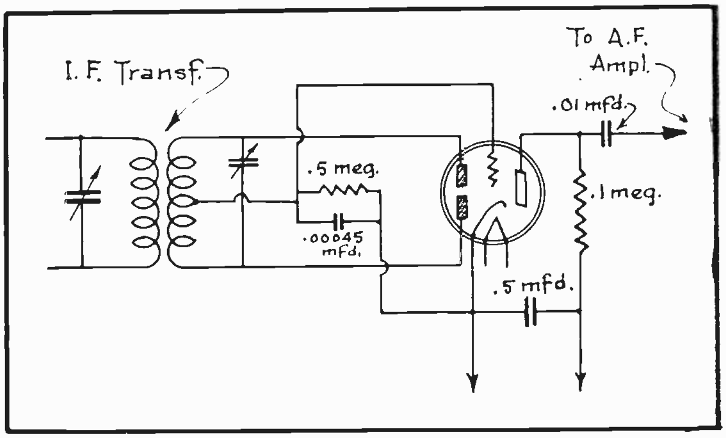

FIG. 7
Full-wave Detector Diode Biased Amplifier

THE NEXT POINT TO CONSIDER REGARDING THE CIRCUIT OF FIG. 4 WILL BE THE REASON FOR USING RESISTORS R2, R3 AND R4 IN THIS SYSTEM AND ALSO CONDENSERS C1, C2 AND C3.

TO BEGIN WITH, THE VOLTAGE DEVELOPED ACROSS R1, DUE TO THE CURRENT FLOW THROUGH IT, IS NOT STRICTLY D.C. IN ADDITION, A.C. COMPONENTS ARE ALSO DEVELOPED ACROSS THIS SAME RESISTOR, THAT IS, AN A.C. VOLTAGE PROPORTIONAL TO THE MODULATION OF THE CARRIER AND AN A.C. VOLTAGE PROPORTIONAL TO THE CARRIER ITSELF. ONLY THE D.C. VOLTAGE DEVELOPED ACROSS R1 IS DESIRED TO BE APPLIED AS BIAS VOLTAGE TO THE PRECEDING I.F. TUBES. SHOULD ANY R.F. VOLTAGE FROM THIS POINT BE FED BACK TO THE GRID CIRCUITS OF THE PRECEDING TUBES, THEN THE AMPLIFIER WOULD COMMENCE TO OSCILLATE. WHEREAS ANY FEED BACK OF A.F. FROM THIS POINT WOULD CAUSE THE GAIN OF THE TUBES THEREBY AFFECTED TO BE VARIED AT AN AUDIO FREQUENCY AND THUS RESULT IN DISTORTION.

TO CARRY OUT THE PLAN AS DESIRED, THE LOGICAL THING TO DO IS TO PREVENT ANY OF THE A.C. COMPONENT BEING RETURNED TO THE GRID CIRCUITS OF THE PRECEDING TUBES AND TO PERMIT D.C. CHARGES ONLY TO ACT UPON THESE GRID CIRCUITS. THIS CAN BE ACCOMPLISHED VERY NICELY BY MEANS OF A FILTER SYSTEM AND SUCH IS THE PURPOSE OF R2, R3, R4, C1, C2 AND C3 IN THE CIRCUIT OF FIG. 4.

FOR INSTANCE, R2 AND C3 TOGETHER FORM THE FIRST SECTION OF THE FILTER SYSTEM INCLUDED BETWEEN R1 AND THE GRID CIRCUITS TO BE CONTROLLED.

IN LIKE MANNER, R3 AND C2 TOGETHER FORM ANOTHER FILTER SECTION AS DO ALSO R4 AND C1. THROUGH THIS METHOD, THE EFFECTS OF ANY R.F. OR A.F.

ENERGY IN THIS SYSTEM WILL BE PRACTICALLY ELIMINATED AND ONLY PURE D.C. VOLTAGES WILL BE EFFECTIVE UPON THE GRIDS OF THE TWO I.F. TUBES WITH WHICH TO ALTER THE BIAS VOLTAGE AND SENSITIVITY OF THESE TUBES THRU THE A.V.C. ACTION OF THIS CIRCUIT.

RESISTORS R2, R3, AND R4, DO NOT INTRODUCE A D.C. VOLT DROP BECAUSE IT IS ONLY VOLTAGE WHICH IS APPLIED THROUGH THEM UPON THE CONTROLLED GRID CIRCUITS. NO CURRENT ACTUALLY FLOWS THROUGH THESE RESISTORS TO DEVELOPE A VOLTAGE DROP.

THE TYPE 75 TUBE

THE 75 IS A DUPLEX-DIODE HIGH-MU TRIODE DESIGNED FOR AUTOMOTIVE USE AND IS EQUIVALENT TO THE 2A6 AS USED IN A.C. RECEIVERS. IT HAS A STANDARD SIX PRONG BASE AND CONTROL GRID CONNECTION CAP ON TOP OF THE GLASS BULB. THE OPERATING CHARACTERISTICS OF THE 75 ARE:

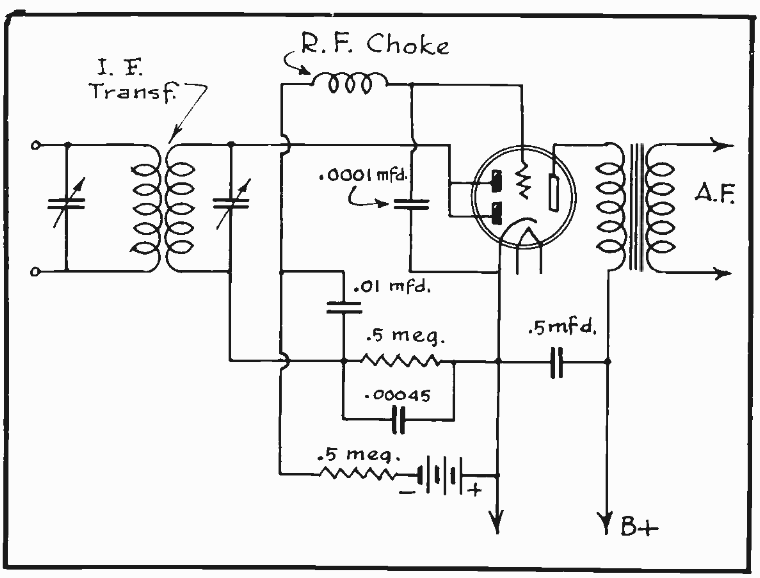

FIG. 8
The Half-Wave Detector, Fixed Bias Amplifier.

HEATER VOLTAGE = 6.3 VOLTS; HEATER CURRENT = 0.3 AMP.; PLATE VOLTAGE = 250 VOLTS MAXIMUM; GRID BIAS = -2 VOLTS; PLATE CURRENT = 0.8 MA; AMPLIFICATION FACTOR = 100.

IN ONE OF YOUR PREVIOUS LESSONS DEALING WITH AUTOMOBILE RECEIVERS, YOU WERE SHOWN A CIRCUIT DIAGRAM OF AN AUTOMOBILE RECEIVER IN WHICH THE 75 TUBE IS USED. WE ARE REPRODUCING THIS CIRCUIT DIAGRAM FOR YOU AGAIN HERE IN FIG. 5 SO THAT YOU CAN STUDY IT ONCE MORE, AT THIS TIME, NOTING ESPECIALLY HOW THE PRINCIPLES OF A.V.C. WHICH YOU LEARNED IN THIS LESSON CAN ALSO BE APPLIED TO AN AUTOMOBILE RECEIVER.

VARIOUS APPLICATIONS OF DUPLEX-DIODE TRIODES

THE CONSTRUCTIONAL FEATURES OF THE DUPLEX-DIODE TRIODES, AS WELL AS THE OPERATING CHARACTERISTICS OF THESE SAME TUBES, PERMITS USING THEM IN SEVERAL DIFFERENT ARRANGEMENTS SO AS TO MEET VARIOUS REQUIREMENTS. FOR INSTANCE, IN FIG. 6 ONE OF THESE TUBES IS BEING USED AS A HALF-WAVE DETECTOR, DIODE BIASED AMPLIFIER.

NOTICE THAT IN THIS CASE, THE TWO DIODES ARE TOGETHER CONNECTED TO ONE END OF THE TUNED CIRCUIT, WHILE THE OTHER END OF THE TUNED CIRCUIT IS CONNECTED TO THE CATHODE THROUGH THE .5 MEGOHM RESISTOR.

THE TWO DIODES, IN THIS WAY ACT AS ONE AND THEREFORE PERMIT THE DIODE

CURRENT TO FLOW ONLY WHEN THE DIODES ARE POSITIVELY CHARGED. FOR THIS REASON, THIS ARRANGEMENT PROVIDES US WITH ONLY HALF-WAVE RECTIFICATION OF THE SIGNAL OR HALF-WAVE DETECTION, AS WE GENERALLY SAY IN THIS CASE.

FULL-WAVE DETECTION

IN FIG. 7 YOU ARE SHOWN A CIRCUIT DIAGRAM IN WHICH CONDITIONS ARE SUCH THAT FULL-WAVE DETECTION IS OBTAINED. HERE, ONE DIODE IS CONNECTED TO EACH END OF THE TUNED CIRCUIT AND THE CATHODE OF THE TUBE IS CONNECTED TO THE CENTER TAP OF THE I.F. TRANSFORMER'S SECONDARY WINDING THROUGH THE .5 MEGOHM RESISTOR.

WITH THE DIODE CIRCUITS COMPLETED IN THIS MANNER, DIODE CURRENT WILL ALWAYS BE FLOWING FROM ONE OR THE OTHER OF THE TWO DIODE PLATES TO THE CATHODE, DEPENDING UPON WHICH OF THEM HAPPENS TO BE POSITIVELY CHARGED BY THE SIGNAL AT ANY ONE PARTICULAR INSTANT. IN OTHER WORDS, WE HAVE FULL-WAVE SIGNAL RECTIFICATION OR FULL-WAVE DETECTION AS IT WERE.

THE GRID OF THE TUBE IN FIGS. 6 AND 7 IS CONNECTED TO THE NEGATIVE END OF THE .5 MEGOHM RESISTOR, WITH RESPECT TO THE D.C. OF THE DIODE CURRENT PASSING THROUGH THIS RESISTOR AND SO WE SAY THAT THE TUBE IS "DIODE BIASED."

THE HALF-WAVE ARRANGEMENT WILL PROVIDE APPROXIMATELY TWICE THE RECTIFIED VOLTAGE AS COMPARED WITH THE FULL WAVE ARRANGEMENT. IN THE MAJORITY OF COMMERCIAL RECEIVERS WHICH EMPLOY A DUPLEX-DIODE TRIODE TUBE, YOU WILL FIND THE HALF-WAVE DETECTION PRINCIPLE USED.

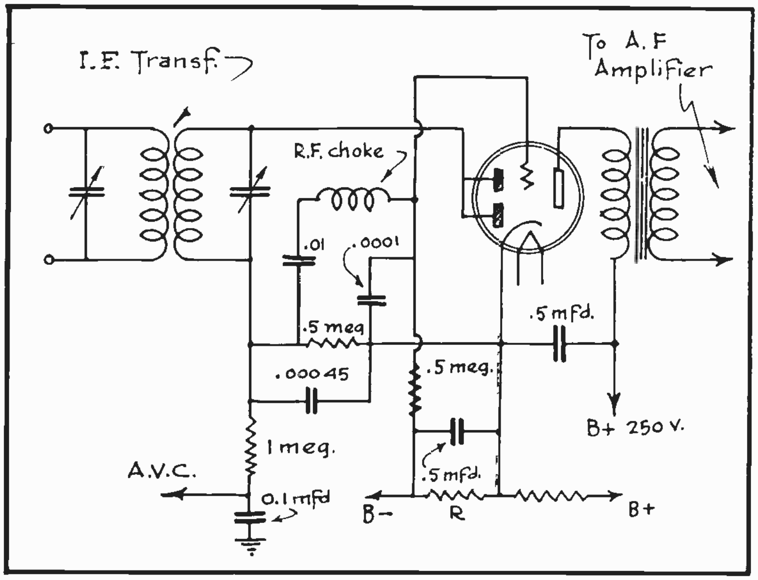

FIG. 9

The Half-Wave Detector, Fixed Bias Ampl. With A.V.C.

HALF-WAVE DETECTION, FIXED BIAS AMPLIFIER

THE CIRCUIT WHICH IS ILLUSTRATED FOR YOU IN FIG. 8 USES A DUPLEX-DIODE TRIODE AS A HALF-WAVE DETECTOR THE SAME AS IN FIG. 6 OF THIS LESSON. HOWEVER, INSTEAD OF THE TUBE'S GRID BEING CONNECTED DIRECTLY TO THE DIODE CIRCUIT, IT HAS A FIXED BIAS VOLTAGE IMPRESSED UPON IT AND THE E.M.F. OF WHICH ORIGINATES BETWEEN THE CATHODE AND GRID. THIS IS INDICATED BY THE BATTERY SYMBOL IN THE CIRCUIT DIAGRAM.

THE A.F. VOLTAGE, HOWEVER, CAN STILL BE APPLIED TO THE GRID OF THE TUBE THROUGH THE .01 MFD. CONDENSER.

THE IMPORTANT THING TO REMEMBER REGARDING THE BIASING OF THE TRIODE UNIT IS THAT DIODE BIASING OF THE TRIODE UNIT MAY BE EMPLOYED ONLY WHEN AT LEAST 20,000 OHMS IS USED IN THE TRIODE-PLATE CIRCUIT. WHEN THE PLATE CIR

CUIT LOAD IS COMPARATIVELY SMALL, SUCH AS WHEN USING TRANSFORMER COUPLING BETWEEN THE TRIODE SECTION AND THE FOLLOWING STAGES OF A.F. AMPLIFICATION AS ILLUSTRATED IN FIG. 8, THEN THE TRIODE SECTION SHOULD BE BIASED INDEPENDENTLY OF THE DIODE CIRCUIT.

HALF-WAVE DETECTOR, FIXED BIAS AMPLIFIER, WITH A.V.C.

IN FIG. 9, THE CIRCUIT ARRANGEMENT IS SUCH THAT THE TUBE IS USED AS A HALF-WAVE DETECTOR, FIXED BIAS AMPLIFIER AND AUTOMATIC VOLUME CONTROL. HERE THE TWO DIODE PLATES ARE TOGETHER CONNECTED TO ONE END OF THE TUNED CIRCUIT AND THE TRIODE SECTION IS INDEPENDENTLY BIASED BY RESISTOR R.

THE A.V.C. ACTION IS DIRECTED TOWARDS THE GRID RETURN CIRCUIT OF PRECEDING TUBES, BEING FED THROUGH THE 1 MEGOHM RESISTOR WHICH IS CONNECTED TO THE NEGATIVE END OF THE .5 MEGOHM RESISTOR THROUGH WHICH THE DIODE CURRENT PASSES.

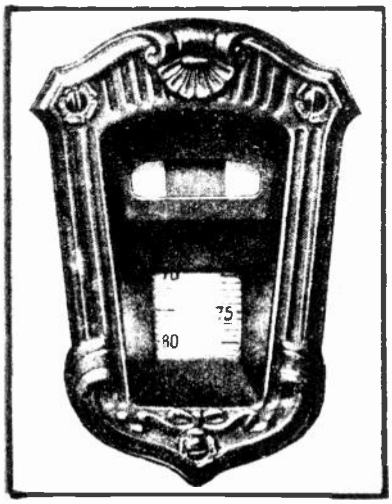

FIG. 10
Shadow Tuning.

THE PURPOSE OF THE R.F. CHOKE IN THE CIRCUITS ILLUSTRATED IS TO PREVENT RADIO FREQUENCY VOLTAGES TO BE IMPRESSED UPON THE GRID OF THE TRIODE SECTION OF THE TUBE, FOR THIS SECTION IS INTENDED TO AMPLIFY A.F. ONLY.

SHADOW TUNING

ALTHOUGH THE ORDINARY TUNING METER CAN BE USED WITHOUT DIFFICULTY BY THE AVERAGE SET OWNER, YET THE MERE FACT THAT IT HAS THE APPEARANCE OF AN ELECTRIC METER, MAKES IT SEEM AS BEING SOMEWHAT MYSTERIOUS OR COMPLEX TO THE OPERATOR WHO IS NOT TECHNICALLY MINDED. TO OVERCOME THIS CONDITION, SEVERAL RECEIVER MANUFACTURERS HAVE DEVELOPED DEVICES WHICH WILL INDICATE THE CONDITION OF RESONANCE TO THE LAYMAN IN A VERY EASY TO UNDERSTAND MANNER.

A VERY POPULAR METHOD OF ACCOMPLISHING THIS PURPOSE IS KNOWN AS SHADOW TUNING AND IN FIG. 10, A DIAL ASSEMBLY WHICH EMPLOYS THE SHADOW TUNING PRINCIPLE IS ILLUSTRATED FOR YOU.

BY STUDYING FIG. 10, YOU WILL OBSERVE THAT THE TUNING DIAL ITSELF IS QUITE CONVENTIONAL BUT AN ADDITIONAL SMALL RECTANGULAR-SHAPED WINDOW IS PROVIDED DIRECTLY ABOVE THE DIAL WINDOW. THIS ADDITIONAL WINDOW HAS A TRANSPARENT SCREEN MOUNTED BEHIND IT AND UPON WHICH A DARK SHADOW IS CAST.

AS THE RECEIVER IS TUNED TO RESONANCE WITH A SIGNAL, THE SHADOW WILL DECREASE IN WIDTH AND AS THE RECEIVER IS DETUNED FROM RESONANCE, THE WIDTH OF THE SHADOW WILL INCREASE IN WIDTH. IN OTHER WORDS, WHEN TUNING A RECEIVER EQUIPPED WITH SHADOW TUNING FEATURES, WE SIMPLY TUNE THE SET UNTIL THE DESIRED STATION IS BROUGHT IN AND THEN TO BE SURE THAT THE SET IS TUNED EXACTLY TO RESONANCE WITH THIS STATION, WE SET THE DIAL CAREFULLY SO THAT THE SHADOW ON THE SCREEN WILL BE OF MINIMUM WIDTH.

THE SHADOW TUNING MECHANISM IS ILLUSTRATED FOR YOU IN DETAIL IN FIG. 11. AS YOU WILL OBSERVE, IT CONSISTS OF A SMALL SHADOW BOX IN WHICH THE

MOVEMENT OF THE DEVICE IS ENCLOSED.

THE TRANSPARENT SCREEN FORMS ONE END OF THE SHADOW BOX WHILE THE REST OF THE BOX IS MADE OF BLACKENED METAL. A SMALL SLIT IS CUT INTO THE FAR END OF THE SHADOW BOX AND A LAMP IS MOUNTED OUTSIDE OF THE BOX DIRECTLY BEHIND THE SLIT. THE INTERIOR OF THE SHADOW BOX IS ENVELOPED IN COMPLETE DARKNESS, WITH THE EXCEPTION OF THE LIGHT BEAM WHICH THE SLIT PERMITS TO PASS THROUGH IT AND BE FOCUSED UPON THE SCREEN AT THE FRONT END OF THE BOX.

THE MOVING PART OF THE DEVICE IS LOCATED WITHIN THE SHADOW BOX AND ESSENTIALLY CONSISTS OF NOTHING MORE THAN A MILLIAMETER IN WHICH THE INDICATING NEEDLE IS REPLACED WITH A LIGHT RECTANGULAR SHAPED VANE. THUS WITH THE METER COIL CONNECTED IN THE RECEIVER CIRCUIT IN THE SAME MANNER AS THE CONVENTIONAL TUNING METER, THE POSITION OF THE VANE WILL BE CHANGED JUST AS WILL AN INDICATING NEEDLE WHEN THE CURRENT FLOW THROUGH THE COIL VARIES.

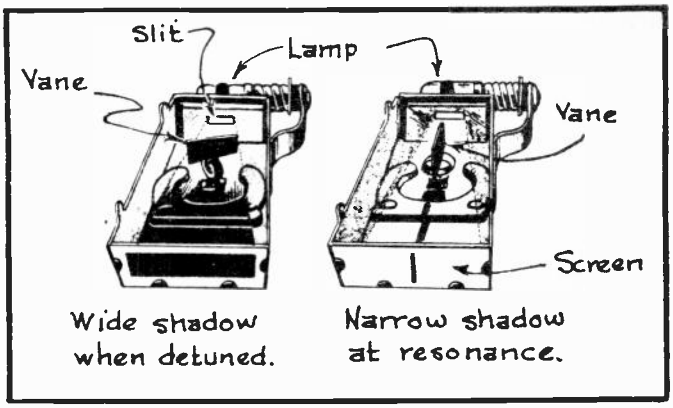

FIG. 11
Shadow Tuning Mechanism.

THE POSITION OF THE VANE IS SUCH THAT IT WILL OBSTRUCT THE LIGHT BEAM AS IT PASSES THROUGH THE BOX FROM THE SLIT TOWARDS THE SCREEN AND THEREFORE THE SHADOW OF THE VANE WILL BE CAST UPON THE SCREEN. THE UNIT IS SO ADJUSTED SO THAT WHEN THE SET IS TUNED TO RESONANCE WITH A SIGNAL, THE VANE WILL TAKE THE POSITION AS SHOWN FOR RESONANCE IN FIG. 11, AT THIS TIME OFFERING THE SMALLEST POSSIBLE OBSTRUCTION TO THE LIGHT BEAM. THE SHADOW OF THE VANE UPON THE SCREEN WILL THEREFORE BE NOTHING MORE THAN A STRAIGHT VERTICAL LINE CENTERED UPON THE SCREEN.

WHEN THE RECEIVER IS DETUNED FROM RESONANCE, THE VANE WILL APPROACH A POINT WHERE IT INTERCEPTS THE LIGHT BEAM AT RIGHT ANGLES AND THUS OFFERS A GREATER OBSTRUCTION TO THE LIGHT BEAM. THE IMAGE OF THE VANE WILL THEN BE IMPRESSED UPON THE SCREEN MORE BROADLY AS SHOWN FOR THE DETUNED POSITION IN FIG. 11.

NO DOUBT, YOU HAVE FOUND THESE LAST TWO LESSONS ESPECIALLY INTERESTING IN THAT MANY NEW RADIO PRINCIPLES WERE ADDED TO YOUR EVER INCREASING KNOWLEDGE OF THIS FASCINATING INDUSTRY.

BY GAINING A GOOD WORKING KNOWLEDGE OF ALL THESE CIRCUITS AT THIS TIME, YOU WILL FIND THE DESIGN LESSONS IN THE MORE ADVANCED SECTION OF THE COURSE TO BE OF STILL GREATER VALUE TO YOU SO THAT UPON COMPLETING NATIONAL TRAINING, YOU WILL HAVE FULL CONFIDENCE IN YOUR ABILITY TO TACKLE ANY RADIO PROBLEM.

EXAMINATION QUESTIONS

LESSON NO. 32

1. - WHAT DO WE MEAN BY THE EXPRESSION AUTOMATIC NOISE SUPPRESSION OR SQUELCH CONTROL?

2. - WHAT IS MEANT BY DELAYED AUTOMATIC VOLUME CONTROL?

3. - DRAW A DIAGRAM OF A CIRCUIT WHICH WILL PROVIDE AUTOMATIC NOISE SUPPRESSION.

4. - WHAT ARE THE OPERATING CHARACTERISTICS OF THE 2A6 TUBE?

5. - WHY IS A .5 MEGOHM FIXED RESISTOR CONNECTED BETWEEN THE GRID RETURN CIRCUIT OF EACH OF THE CONTROLLED TUBES AND THE A.V.C. TUBE IN THE CIRCUIT OF FIG. 4?

6. - WHAT ARE THE OPERATING CHARACTERISTICS OF THE 75 TUBE?

7. - HOW MAY FULL-WAVE DETECTION BE OBTAINED WITH A DUPLEX-DIODE TRIODE?

8. - WHAT ADVANTAGE DOES HALF-WAVE DIODE DETECTION OFFER OVER FULL-WAVE DIODE DETECTION?

9. - WHAT ADVANTAGES DOES THE 2A6 TUBE OFFER OVER THE 55?

10. - DESCRIBE BRIEFLY THE OPERATING PRINCIPLES OF "SHADOW TUNING"?

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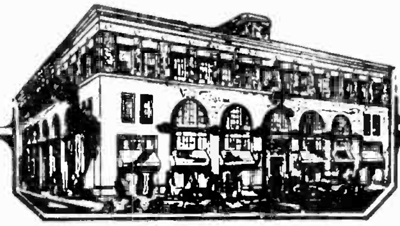

LESSON NO. 33

• STORAGE BATTERIES - SERVICING •

In the previous lesson, you were already told about the construction and operation of the lead-acid storage battery. With this firmly fixed in mind, let us continue with our studies of battery servicing. You see, even though the modern storage battery is carefully constructed, yet it demands a definite amount of attention in order to faithfully continue its work and give the best service possible.

In this lesson you will learn what the service needs of the storage battery are, as well as the proper method of keeping this type of battery up to its highest efficiency.

First, let us consider just the care, which a NORMAL storage battery, such as the one in Fig. 1 requires in order to prevent it from developing many of the serious troubles to which it is continually subjected. Among these important items, we find that it is absolutely essential to always keep the outside of the battery clean and dry.

Fig.1

KEEPING THE BATTERY CLEAN

There should be no doubt in your mind as to why this precaution is so necessary, if you will only consider the fact that moisture and dirt offer a combination, which has sufficiently good electrical conducting qualities so that it will permit a leakage of current between the cells. Continuous current leakage of this nature will in due time permit a good battery to discharge itself. It is a good policy to occassionally wipe the top of the battery clean with a rag moistened with ammonia or a solution of baking soda and water. The reason for doing this, is that ammonia and baking soda will counteract or neutralize any acid, which may be present on the top of the battery.

CORRECTING CORRODED TERMINALS

If you carefully examine a neglected storage battery, you will no-

TICE THAT A FLUFFY, GREENISH LOOKING SUBSTANCE HAS COLLECTED AROUND THE TERMINALS. THIS SUBSTANCE IS CAUSED BY CORROSION, WHICH IS DUE TO THE ACTION OF THE ACID ON THE METALLIC IMPURITIES WHICH ARE PRESENT ON THE TERMINALS.

SHOULD THIS CORROSION BE ALLOWED TO CONTINUE, THEN THE CONNECTION WILL SOON BE ENTIRELY EATEN AWAY SO THAT EITHER AN EXTREMELY HIGH ELECTRICAL RESISTANCE WILL BE OFFERED BY THE JOINT OR ELSE THE JOINT MAY EVEN BECOME OPEN CIRCUITED ALTOGETHER.

WHEN YOU FIND SUCH A CORRODED CONDITION, IT IS NECESSARY FOR YOU TO REMEDY IT IMMEDIATELY AND ALTHOUGH IT IS A SIMPLE MATTER TO DO THIS, YET IT IS A MOST IMPORTANT ONE. THE FIRST THING TO DO, WHEN YOU WISH TO REMEDY THIS CONDITION, IS TO SCRAPE OFF ALL OF THIS SUBSTANCE, BEING CAREFUL, HOWEVER, NOT TO PERMIT ANY OF IT FROM FINDING ITS WAY INTO ANY OF THE CELLS. IN FACT, IF THE TERMINAL IS CORRODED EXTREMELY BAD, IT WILL BE NECESSARY TO REMOVE THE CONNECTION WHILE SCRAPING SO THAT ALL SURFACES WILL BECOME BRIGHT AGAIN BEFORE REPLACING THE CONNECTION.

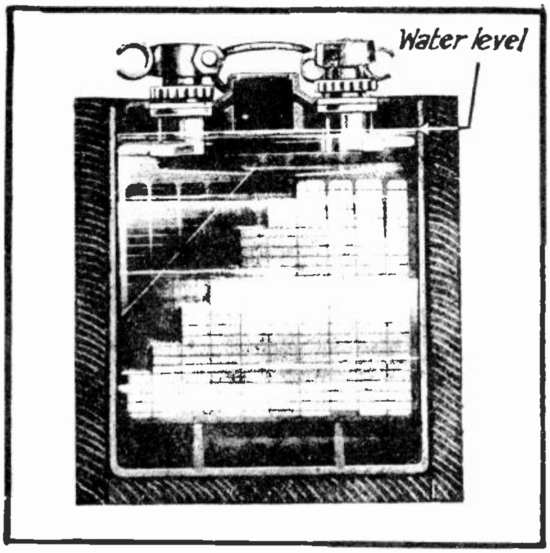

FIG. 2
Level of the Electrolyte.

SOMETIMES, TERMINALS BECOME SO BADLY EATEN AWAY THAT IT IS NECESSARY TO REPLACE THEM WITH AN ENTIRELY NEW CONNECTION.

AFTER THE CORRODED TERMINAL HAS BEEN CAREFULLY CLEANED, IT SHOULD BE WIPED WITH A CLOTH MOISTENED WITH AMMONIA OR A SOLUTION OF BAKING SODA AND WATER. THE CONNECTION SHOULD THEN BE THOROUGHLY TIGHTENED AND A COATING OF VASELINE SHOULD BE APPLIED TO IT.

"A STICH IN TIME, SAVES NINE"

IF A SIMPLE JOB AS THIS IS DONE IN TIME, IT WILL PREVENT THE FAILURE OF THE BATTERY, WHICH WAS BOUND TO COME SOONER OR LATER BECAUSE OF THIS DEVELOPING CONDITION.

THE BATTERY NEEDS WATER

A CAMEL CAN CONTINUE DOING ACTIVE WORK FOR A CONSIDERABLE TIME WITHOUT NEEDING A DRINK, HOWEVER, THE TIME COMES SOON WHEN HE TOO MUST HAVE A DRINK OF WATER IN ORDER TO KEEP GOING. WE HAVE A SIMILAR CONDITION PRESENT IN THE STORAGE BATTERY BECAUSE THIS UNIT DOESN'T REQUIRE AN ADDITION OF WATER EVERY DAY BUT YET THE TIME DOES COME WHEN WATER MUST BE ADDED TO EACH CELL.

THE CORRECT LEVEL OF THE ELECTROLYTE

IT IS ADVISABLE TO REMOVE THE VENT PLUGS FROM EACH CELL ABOUT EVERY

TWO WEEKS DURING THE WINTER MONTHS AND ABOUT EVERY WEEK DURING THE SUMMER MONTHS, SO THAT THE LEVEL OF THE ELECTROLYTE IN EACH OF THE CELLS CAN BE INSPECTED. THE LEVEL OF THE ELECTROLYTE SHOULD NEVER BE ALLOWED TO BECOME LOWER THAN A POINT $\frac{1}{2}$" ABOVE THE TOP OF THE PLATES, AS SHOWN IN FIG. 2.

USE DISTILLED WATER

WHEN IT BECOMES NECESSARY TO RAISE THE LEVEL OF THE ELECTROLYTE IN A CELL, NOTHING SHOULD BE ADDED EXCEPT DISTILLED WATER. ANY OTHER WATER, ALTHOUGH IT MAY BE EXCELLENT DRINKING WATER, IS NOT SUITABLE FOR BATTERY PURPOSES BECAUSE IT CONTAINS MINERALS AND VEGETABLE MATTER WHICH WHEN BROUGHT IN CONTACT WITH THE ACID WITHIN THE CELL, WOULD PRODUCE VERY UNDESIRABLE EFFECTS. DISTILLED WATER DOES NOT CONTAIN ANY MINERALS OR PRODUCTS OF VEGETATION AND THEREFORE IT IS THE ONLY KIND OF WATER WHICH SHOULD BE USED IN A CELL, IF GOOD RESULTS ARE TO BE EXPECTED.

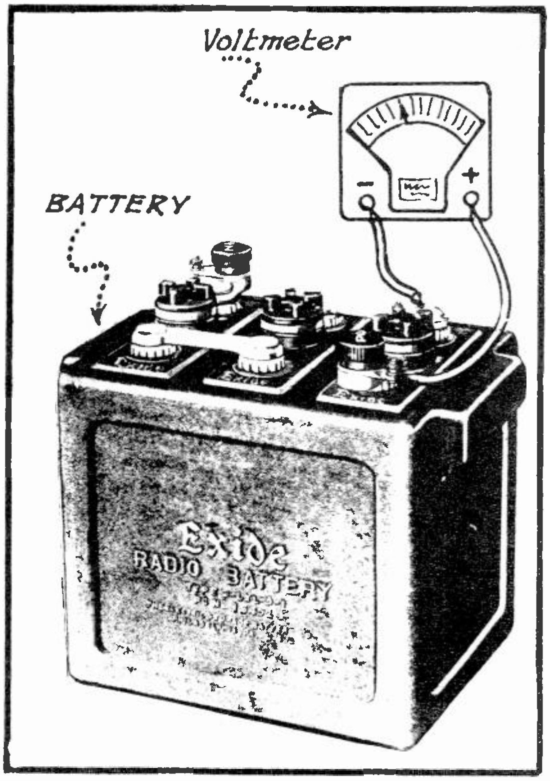

FIG. 3
Testing the Cell Voltage.

THE WATER EVAPORATES

PROBABLY YOU ARE THINKING THAT IF WE ONLY ADD PURE WATER, OUR ELECTROLYTE WILL GRADUALLY BECOME WEAKER AND WEAKER BUT YOU SEE, IT IS THE WATER OF THE ELECTROLYTE WHICH EVAPORATES AND NOT THE ACID. NOT ONLY DOES THE WATER EVAPORATE DUE TO ORDINARY CAUSES BUT WHILE THE BATTERY IS BEING CHARGED, THE CHEMICAL COMPOSITION OF THE WATER IS FREQUENTLY BROKEN UP INTO HYDROGEN GAS AND OXYGEN GAS, WHICH ARE REALLY THE TWO ELEMENTS OF WHICH WATER IS COMPOSED.

METHOD OF ADDING WATER TO THE CELLS

WHEN ADDING WATER, YOU MUST BE CAREFUL THAT THE WATER DOES NOT COME IN CONTACT WITH ANY METALLIC SUBSTANCES AND THIS CAN BE DONE VERY EASILY BY KEEPING THE WATER IN A GLASS CONTAINER AND SQUIRTING THE WATER INTO THE CELLS BY MEANS OF A RUBBER SYRINGE OR ELSE THE HYDROMETER SYRINGE, WHICH YOU SAW IN AN EARLIER LESSON.

TESTING THE SPECIFIC GRAVITY OF THE ELECTROLYTE

ABOUT EVERY TWO WEEKS, THE SPECIFIC GRAVITY OF THE ELECTROLYTE SHOULD BE CHECKED BY MEANS OF THE HYDROMETER AND SHOULD YOU FIND THE SPECIFIC GRAVITY TO HAVE FALLEN TO A READING OF 1.150, THEN IT BECOMES NECESSARY TO TAKE ACTIVE STEPS.

FIRST, OF COURSE, WE MUST DETERMINE WHETHER THIS LOW GRAVITY IS DUE MERELY BECAUSE THE BATTERY IS IN A DISCHARGED CONDITION OR WHETHER THE ELECTROLYTE ITSELF IS OUT OF PROPORTION. TO DETERMINE THIS, A VOLTMETER

SHOULD BE USED IN CONJUNCTION WITH THE HYDROMETER AND IF THE CELL VOLTAGES ARE PROPORTIONAL TO THE HYDROMETER READINGS, THEN IT IS JUST NECESSARY TO RECHARGE THE BATTERY. HOWEVER, IF THE CELL VOLTAGES ARE OUT OF PROPORTION TO THE HYDROMETER READINGS, THEN IT EVEN BECOMES NECESSARY TO RE-BALANCE THE ELECTROLYTE.

RELATIONS BETWEEN CELL VOLTAGE & SPECIFIC GRAVITY READINGS

TO ILLUSTRATE THIS POINT STILL CLEARER, LET US ASSUME THAT WHEN WE TEST THE SPECIFIC GRAVITY OF A CELL WITH A HYDROMETER, WE FIND THE GRAVITY TO BE 1.275. THEN WHEN WE TAKE A VOLTMETER AND TEST THE CELL VOLTAGE AS SHOWN IN FIG. 3, WE FIND IT TO BE 2.1 VOLTS. THIS RELATIONSHIP BETWEEN THE SPECIFIC GRAVITY READING AND VOLTMETER READING, WOULD TELL US THAT THE CELL IS IN A GOOD CHARGED CONDITION.

NEXT, LET US SUPPOSE THAT WE SHOULD TEST A CELL, FINDING ITS SPECIFIC GRAVITY TO BE 1.275 WHILE THE CELL VOLTAGE IS ONLY 1.9 VOLTS. THIS WOULD INDICATE THAT THE SPECIFIC GRAVITY OF THE CELL IS TOO HIGH FOR THE EXISTING VOLTAGE AND SUCH A CONDITION WOULD CALL FOR A RE-BALANCING OF THE ELECTROLYTE; AS WELL AS A RE-CHARGE.

SHOULD YOU FIND THE SPECIFIC GRAVITY TO BE ABOUT 1.200 WITH A CELL VOLTAGE OF 2.1 VOLTS, THEN THE SPECIFIC GRAVITY IS TOO LOW FOR THE EXISTING VOLTAGE AND THIS WOULD LIKEWISE REQUIRE A RE-BALANCING OF THE ELECTROLYTE. HOWEVER, IF THE SPECIFIC GRAVITY READINGS SHOULD BE 1.150 AND THE CELL VOLTAGES 1.75 VOLTS, THEN THE BATTERY SIMPLY REQUIRES A RECHARGE, WHICH WILL AGAIN BRING IT UP TO NORMAL.

CHECKING THE SPECIFIC GRAVITY BEFORE ADDING ANY WATER

WHEN CHECKING THE SPECIFIC GRAVITY OF A CELL, ALWAYS CHECK IT BEFORE YOU ADD ANY WATER TO REPLACE EVAPORATION. THE REASON FOR THIS IS THAT THE WATER WILL NOT IMMEDIATELY MIX THOROUGHLY WITH THE ACID AND YOU WOULD THEREFORE OBTAIN A LOWER HYDROMETER READING THAN WOULD ACTUALLY EXIST AFTER THE WATER AND ACID HAVE HAD A CHANCE TO MIX.

BATTERIES REQUIRING A RECHARGE

LET US ASSUME THAT BY MAKING THE HYDROMETER AND CELL VOLTAGE TESTS ON EACH OF THE CELLS, WE HAVE DETERMINED THAT THE BATTERY SIMPLY REQUIRES TO BE CHARGED. THAT IS, IT HAS BECOME RUN DOWN OR DISCHARGED SO THAT THE SPECIFIC GRAVITY READING OF EACH CELL IS LOW (APPROACHING THAT OF WATER) AND THE PLATES CONTAIN A GREAT DEAL OF SULPHATE.

NOW WE ALREADY KNOW FROM A PREVIOUS LESSON, THAT AS THIS CHEMICAL CHANGE WAS GRADUALLY TAKING PLACE, AN ELECTRIC CURRENT WAS CAUSED TO FLOW THROUGH A COMPLETED CIRCUIT. HOWEVER, AS SOON AS THE CHEMICAL CHANGE WITHIN THE CELLS HAS REACHED A CERTAIN POINT, THE BATTERY IS NO LONGER EFFICIENT. IN FACT, IF WE SHOULD STILL FORCE THE BATTERY TO CONTINUE DISCHARGING UNTIL THE VOLTAGE OF EACH OF ITS CELLS DROPS BELOW 1.7 OR 1.6 VOLTS, AND ITS SPECIFIC GRAVITY BELOW 1.150, WE ARE PERMITTING SERIOUS TROUBLE TO DEVELOP WITHIN THE CELL.

REVERSED CHEMICAL ACTION

OUR NEXT STEP THEN IS TO CAUSE A CHEMICAL ACTION TO TAKE PLACE SO THAT

THE SULPHATE IS DRIVEN OUT OF THE PLATES AND INTO THE ELECTROLYTE AND IN THIS WAY RESTORE OUR BATTERY TO A CHARGED CONDITION SO THAT IT WILL AGAIN BE READY TO SUPPLY US WITH AN ELECTRICAL CURRENT. WE CALL THIS RESTORATION OR REJUVINATING ACTION "CHARGING THE BATTERY".

IN ORDER TO CHARGE THE BATTERY, IT IS NECESSARY TO DO JUST THE OPPOSITE TO WHAT TOOK PLACE DURING THE DISCHARGE OF THE BATTERY. THAT IS, WE MUST PASS AN ELECTRIC CURRENT THROUGH THE BATTERY IN A DIRECTION OPPOSITE TO THAT IN WHICH THE CURRENT FLOWED WHILE THE BATTERY WAS DISCHARGING. LET US NOW SEE HOW WE CAN ACCOMPLISH THIS.

A DIRECT CURRENT FOR CHARGING PURPOSES

FIRST, IT IS NECESSARY TO HAVE A DIRECT CURRENT AT OUR DISPOSAL AND THIS TYPE OF CURRENT, YOU WILL REMEMBER, ALWAYS TRAVELS IN ONE DIRECTION ONLY.

IN SOME LOCALITIES THIS TYPE OF CURRENT IS SUPPLIED TO THE VARIOUS BUILDINGS BY A CENTRAL POWER PLANT. IN SUCH A CASE, WE CAN USE THIS CURRENT FROM THE POWER LINES, HOWEVER, WE MUST TAKE CERTAIN CONDITIONS INTO CONSIDERATION.

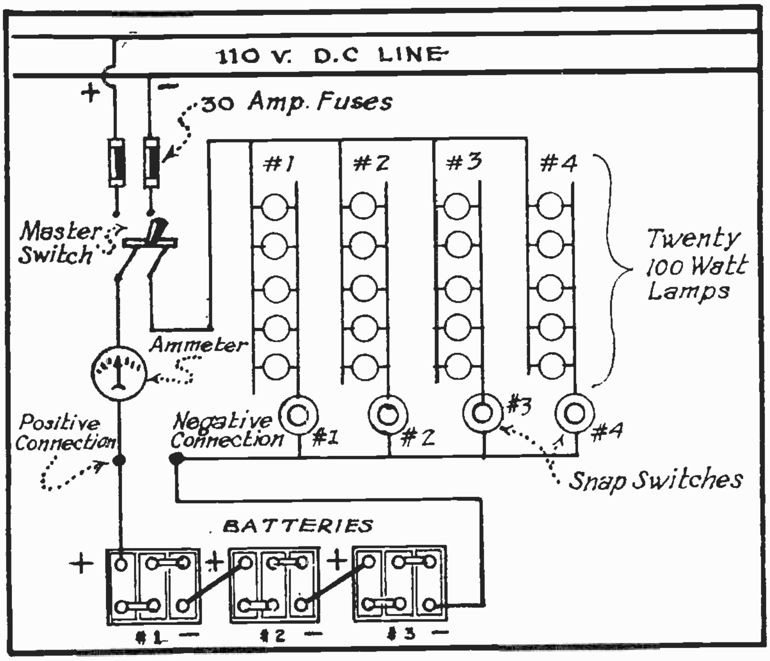

FIG. 4
Battery Charging When D.C. is Available.

IN FIG. 4 YOU WILL SEE HOW WE CAN GET A SUITABLE BATTERY CHARGING CURRENT BY THIS MEANS.

USING D.C. DIRECT FROM POWER LINES

HERE YOU WILL SEE THAT TWO WIRES LEAD FROM THE 110 V-D. C., LINE, THROUGH THE FUSES TO THE TERMINALS OF THE SINGLE THROW, DOUBLE POLE SWITCH. AS LONG AS THIS MASTER SWITCH IS OPEN, NO CURRENT WILL FLOW THROUGH THE BATTERIES.

NOW WHEN THE MASTER SWITCH IS CLOSED, CURRENT WILL FLOW FROM THE POSITIVE SIDE OF THE 110 V. LINE, THROUGH THE SWITCH, AMMETER AND TO THE POSITIVE CONNECTION. NEXT, OBSERVE THAT THREE BATTERIES HAPPEN TO BE CONNECTED IN SERIES. THAT IS, THE (-) TERMINAL OF ONE IS CONNECTED TO THE (+) TERMINAL OF THE NEXT AND SO ON. ALSO NOTICE THAT THE (+) TERMINAL OF BATTERY #1 IS CONNECTED TO THE POSITIVE CONNECTION OF THE LINE.

THE CHARGING CURRENT PASSES THROUGH THE BATTERIES

THE VOLTAGE OR PRESSURE OF THE LINE IS GREATER THAN THAT OF THE BATTERIES IN SERIES SO THAT THE CURRENT FROM THE LINE WILL BE FORCED INTO THE POSITIVE TERMINAL OF BATTERY #1, THROUGH ALL THE CELLS OF BATTERY #1 AND

IT LEAVES BATTERY #1 FROM THE (-) TERMINAL. SINCE THE NEGATIVE TERMINAL OF BATTERY #1 IS CONNECTED TO THE POSITIVE TERMINAL OF BATTERY #2 BY MEANS OF A WIRE, THE CURRENT WILL CONTINUE ON ITS JOURNEY THROUGH THIS WIRE, AND WILL THEN PASS THROUGH BATTERY #2, FROM THE POSITIVE TO NEGATIVE TERMINAL, JUST AS IT DID THROUGH BATTERY #1.

FROM BATTERY #2, THE CURRENT FLOWS THROUGH BATTERY #3 AND BECAUSE OF THE NEGATIVE TERMINAL OF BATTERY #3 BEING CONNECTED TO THE NEGATIVE CONNECTION OF THE LINE, THE CURRENT WILL FLOW TO THIS LATTER POINT.

SO FAR WE HAVE GOTTEN OUR DIRECT CURRENT TO PASS THROUGH THREE BATTERIES AT ONE TIME, IN THE PROPER DIRECTION SO THAT THE CHEMICAL ACTION WITHIN THE BATTERIES WILL BE REVERSED AND THE BATTERIES CHARGED. HOWEVER, WE STILL HAVE SOME IMPORTANT PROBLEMS TO CONFRONT BEFORE THIS CIRCUIT IS COMPLETE, SO LET US CONTINUE TRAILING OUR CURRENT FROM THE NEGATIVE CONNECTION OF THE LINE THROUGH THE BALANCE OF THE SYSTEM.

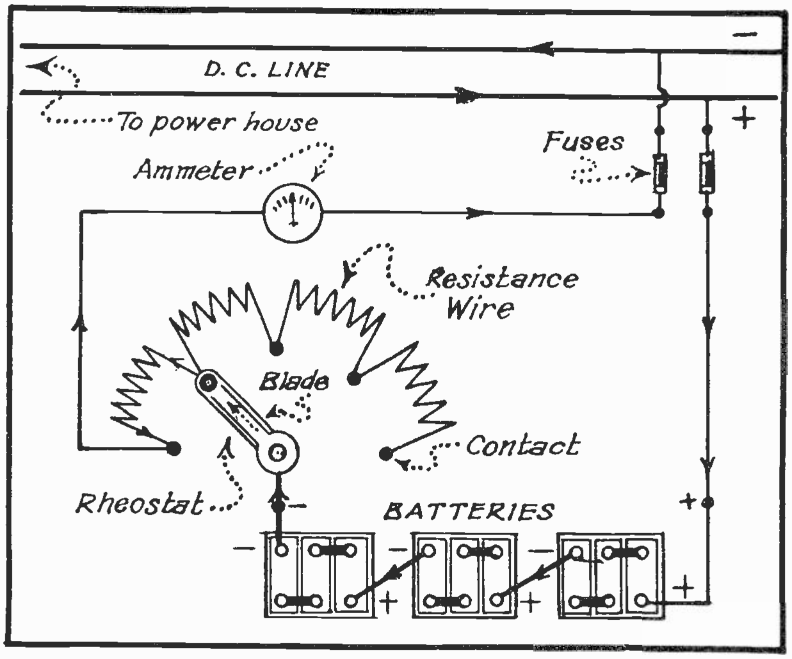

FIG. 5
Controlling the Charge With a Rheostat.

THE SNAP SWITCH

FOUR SNAP SWITCHES ARE CONNECTED TO THE WIRE LEADING FROM THIS NEGATIVE CONNECTION AND THEREFORE, THE CURRENT WILL CONTINUE ON ITS JOURNEY, FLOWING THRU WHICHEVER OF THESE SNAP SWITCHES HAPPENS TO BE CLOSED. LET US FIRST ASSUME THAT ONLY SWITCH #1 IS CLOSED, WHILE THE OTHER SNAP SWITCHES ARE OPEN. BECAUSE OF THIS CONDITION, THE CURRENT WILL ALL FLOW THROUGH SNAP SWITCH #1 AND THENCE IT WILL DIVIDE ITSELF BETWEEN THE FIVE LAMPS, WHICH ARE OF EQUAL RESISTANCE, AND THEN IT WILL FLOW THROUGH THE WIRE LEADING TO THE NEGATIVE SIDE OF THE MASTER SWITCH AND BACK TO THE NEGATIVE LINE OF THE 110 VOLT D.C. POWER LINE.

THIS, YOU WILL SEE, GIVES US A COMPLETE CIRCUIT THROUGH WHICH A DIRECT CURRENT WILL FLOW AND ALL DURING THIS FLOWING OF THE CURRENT, THE BATTERIES ARE GRADUALLY BEING CHARGED, DUE TO THE CURRENT BEING FORCED THROUGH THEM IN THE PROPER DIRECTION.

THE PURPOSE OF THE LAMPS

SO FAR WE HAVEN'T CONSIDERED WHAT THE TWENTY LAMPS ARE FOR, SO NOW LET US GET THIS POINT SETTLED. FIRST, IT IS NOT ONLY NECESSARY TO SEND A DIRECT CURRENT THROUGH THE BATTERIES IN ORDER TO CHARGE THEM BUT THE CHARGING CURRENT MUST BE CONTROLLED. GENERALLY SPEAKING, BATTERIES SHOULD BE

CHARGED AT THE RATE OF ABOUT ½ AMPERE PER PLATE PER CELL. THAT IS, AN 11 PLATE BATTERY SHOULD BE CHARGED AT THE RATE OF ABOUT 5.5 AMPERES FOR BEST RESULTS.

NOW, ANY LAMP OFFERS A DEFINITE RESISTANCE TO CURRENT FLOW AND BY CONNECTING THE LAMPS AS IN GROUP #1, THE CURRENT CAN DIVIDE ITSELF AMONG THE FIVE LAMPS. THEN IF EACH LAMP OFFERS SUFFICIENT RESISTANCE SO THAT ONLY ABOUT 1 AMPERE CAN FLOW THROUGH IT, THEN 5 LAMPS, AS CONNECTED IN GROUP #1, OFFER FIVE OF SUCH PATHS AND THEREBY MAKES THE FLOW OF CURRENT FIVE TIMES AS EASY. THAT IS, ONLY 1/5 OF THE RESISTANCE IS ENCOUNTERED BY THE FLOWING CURRENT TO THAT WHICH IS OFFERED BY ONLY ONE LAMP. THEREFORE, INSTEAD OF 1 AMPERE FLOWING THROUGH THIS CIRCUIT, THERE WILL BE 5 AMPERES.

SINCE ALL THE CURRENT, WHICH FLOWS THROUGH THE BATTERIES MUST ALSO PASS THROUGH LAMP GROUP #1, THIS LAMP GROUP CONTROLS THE CURRENT FLOW SO THAT 110 VOLTS CAN ONLY FORCE ABOUT 5 AMPERES THROUGH THE SYSTEM.

AN ADJUSTMENT REQUIRED WHEN MORE BATTERIES ARE ADDED

NOW IF MORE BATTERIES SHOULD BE CONNECTED IN SERIES IN ORDER TO BE CHARGED, THEY WOULD OFFER STILL MORE RESISTANCE FOR THE CURRENT FLOW, SO THAT IF WE JUST LEFT LAMP GROUP #1 BURNING, OUR CHARGING RATE WOULD DROP, SO WE CAN NOW ALSO CLOSE THE CIRCUIT THROUGH LAMP GROUP #2 BY TURNING ON SWITCH #2. THIS WOULD AGAIN REDUCE THE RESISTANCE THROUGH THE LAMPS SO THAT MORE CURRENT COULD FLOW THROUGH THE BATTERIES THAN WITH ONLY THE LAMPS OF GROUP #1 BURNING.

SO YOU SEE, BY WATCHING THE AMMETER, WE CAN REGULATE THE NUMBER OF LIGHTS, WHICH ARE BURNING, AND IN THIS WAY CONTROL THE RATE AT WHICH OUR BATTERIES ARE BEING CHARGED.

CONTROLLING THE RATE OF CHARGE WITH A RHEOSTAT

IN FIG. 5 STILL ANOTHER WAY OF CONTROLLING THE CURRENT FLOW THROUGH A BATTERY CHARGING CIRCUIT, WHICH IS USING DIRECT CURRENT AS SUPPLIED BY A POWER COMPANY, IS ILLUSTRATED. IN THIS CASE INSTEAD OF CONTROLLING THE CHARGING CURRENT WITH A GROUP OF LAMPS, WE USE A DEVICE KNOWN AS A RHEOSTAT. THE RHEOSTAT CONSISTS OF A GROUP OF WIRE COILS, WHICH ARE CONNECTED TO CONTACTS AT CERTAIN INTERVALS. A BLADE IS ROTATED BY THE OPERATOR BY MEANS OF A HANDLE. THE TIP OF THIS BLADE MAKES CONTACT WITH ONE OF THE EQUALLY SPACED CONTACTS AT A TIME, AS THE BLADE IS ROTATED.

THE FARTHER THAT THE BLADE IS TURNED TO THE RIGHT, THE MORE RESISTANCE WIRE WILL BE ADDED TO THE CIRCUIT SO THAT THE CURRENT FLOW WILL BE RETARDED THAT MUCH MORE. HENCE BY WATCHING THE AMMETER, THE RHEOSTAT CAN BE SET SO THAT THE PROPER AMOUNT OF CURRENT WILL BE FLOWING THROUGH THE CHARGING BATTERIES. THE CURRENT IN THIS CASE, WILL FLOW IN THE DIRECTION OF THE ARROWS.

SOME POWER HOUSES SUPPLY ALTERNATING CURRENT

NOW SUPPOSE THAT THE POWER HOUSE IN YOUR VICINITY DOESN'T FURNISH DIRECT CURRENT BUT SUPPLIES ALTERNATING CURRENT INSTEAD. THIS IS REALLY

THE CASE IN MOST PLACES AT THE PRESENT TIME, SO WE MUST HAVE SOME MEANS OF OBTAINING A DIRECT CURRENT FOR BATTERY CHARGING.

THE REASON WHY ALTERNATING CURRENT WILL NOT CHARGE A BATTERY

THE TROUBLE WITH ALTERNATING CURRENT IS THIS: IT FLOWS FIRST IN ONE DIRECTION AND THEN SIMPLY TURNS AROUND AND REVERSES ITSELF SO THAT IT FLOWS IN THE OPPOSITE DIRECTION. IF WE SHOULD TRY TO USE THIS KIND OF A CURRENT FOR BATTERY CHARGING, WE WOULD FIND THAT DURING THE INSTANT THE CURRENT WAS FLOWING IN ONE DIRECTION, IT WOULD PROVIDE A CHARGING CURRENT ALRIGHT, BUT AS SOON AS IT TURNS AROUND AND FLOWS THE OPPOSITE WAY, IT WOULD DISCHARGE THE BATTERY. CONSEQUENTLY, SINCE IT FLOWS BACK AND FORTH ABOUT 60 TIMES EVERY SECOND, WE COULD NOT USE IT FOR BATTERY CHARGING AS IT IS, BECAUSE WE NEED A CURRENT WHICH ONLY FLOWS IN ONE DIRECTION ALL THE TIME.

THE RECTIFIER

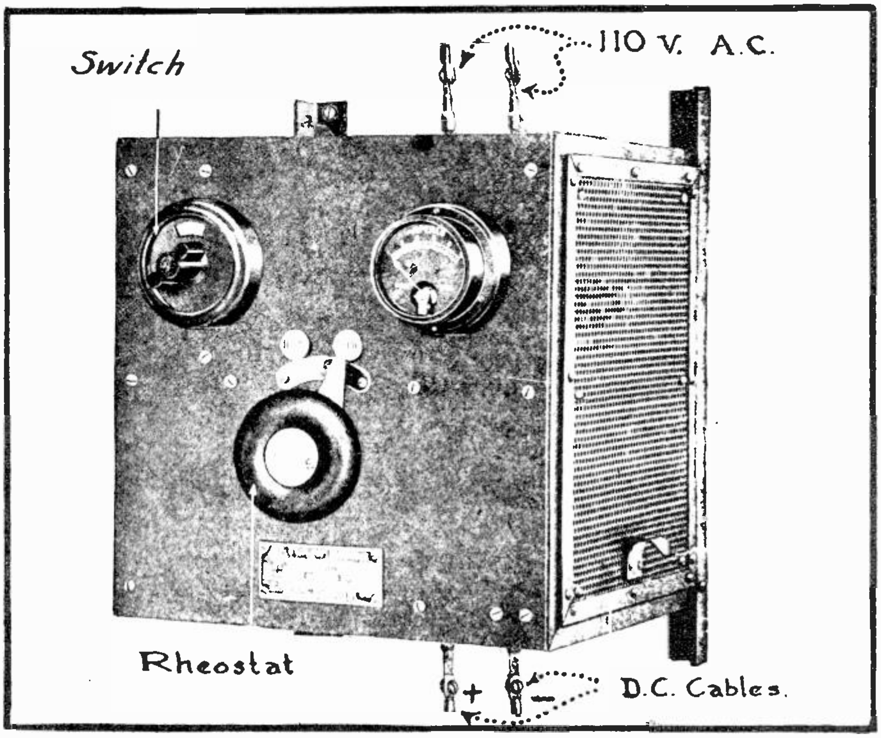

FIG. 6
A Typical Tungar Rectifier.

WE MUST GET AROUND THIS CONDITION SOMEHOW, SO WE USE A UNIT, WHICH IS KNOWN AS A RECITIFIER, AND SOMETIMES WE JUST CALL IT A BATTERY CHARGER.

THERE ARE VARIOUS TYPES OF RECTIFIERS, BUT THEY ALL SERVE THE SAME PURPOSE WHICH IS TO MAKE USE OF THE SUPPLIED ALTERNATING CURRENT IN SUCH A WAY THAT A DIRECT CURRENT CAN BE PRODUCED WITH WHICH TO CHARGE THE BATTERIES.

THE TUNGAR RECTIFIER

IN FIG. 6 YOU WILL SEE A CHARGER WHICH IS CAPABLE OF CHARGING TEN BATTERIES AT ONE TIME AND IT IS KNOWN AS THE TUNGAR RECTIFIER.

THE TWO LEADS, WHICH PROTRUDE FROM THE TOP OF THE CHARGER, ARE CONNECTED TO THE ALTERNATING CURRENT LINE AND THE TWO LEADS, WHICH PROTRUDE FROM THE BOTTOM OF THE CHARGER, OFFER THE CONNECTION TO WHICH THE BATTERIES ARE CONNECTED. IN FIG. 7 YOU WILL SEE WHAT THE INSIDE OF THIS SAME CHARGER LOOKS LIKE.

THE TUNGAR RECTIFIER AT WORK

ALTHOUGH THIS RECTIFIER CHARGES TEN BATTERIES AT THE SAME TIME, IT CAN ALSO BE CONNECTED SO THAT IT WILL CHARGE A FEWER NUMBER. FIG. 8 SHOWS HOW THIS CHARGER IS CONNECTED WHEN CHARGING ONLY SIX BATTERIES. NOTICE THAT ALL OF THE BATTERIES ARE CONNECTED IN SERIES AND THE POSITIVE TERMINAL OF ONE OF THE END BATTERIES IS CONNECTED TO THE POSITIVE TERMINAL OF THE RECTIFIER, WHEREAS THE NEGATIVE TERMINAL OF THE OTHER END BATTERY IS CONNECTED TO THE NEGATIVE TERMINAL OF THE RECTIFIER.

YOU MUST REMEMBER, HOWEVER, NOT TO CONNECT MORE BATTERIES TO A CHARGING CIRCUIT, THAN THE CHARGER IS CAPABLE OF HANDLING. ALL RECTIFIERS ARE PROVIDED WITH A NAME PLATE, WHICH STATES THE LOAD FOR WHICH THE PARTICULAR RECTIFIER WAS DESIGNED.

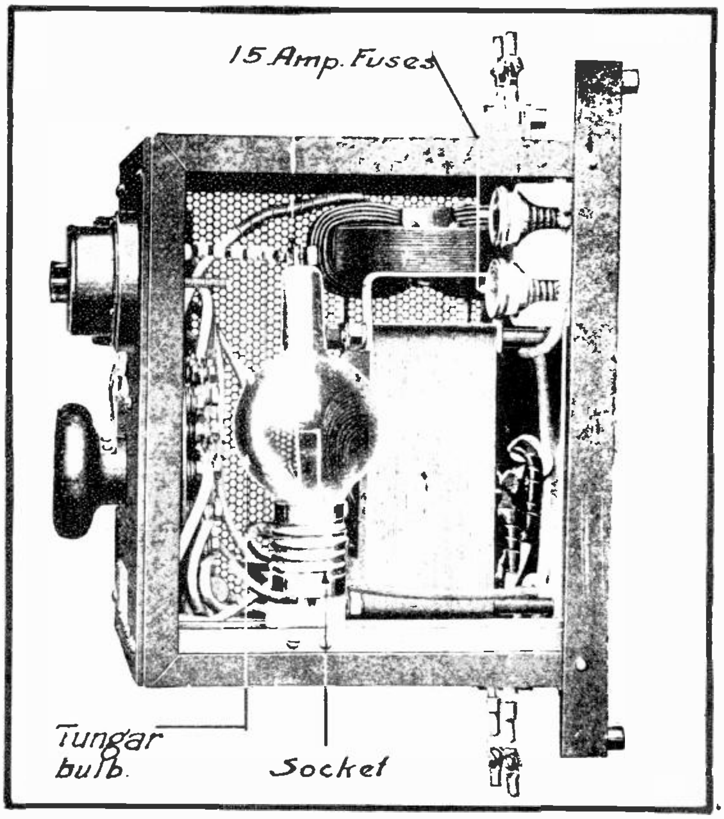

FIG. 7
Inside of the Same Tungar Rectifier.

OPERATING THE TUNGAR SET

WITH OUR BATTERIES CONNECTED AS SHOWN IN FIG. 8, THE FIRST THING THAT WE DO IS TO REMOVE THE VENT PLUGS AND ALSO SEE THAT THE HANDLE OF THE RHEOSTAT IS TURNED TO THE POSITION OFFERING THE MAXIMUM AMOUNT OF RESISTANCE SO THAT PRACTICALLY NO CURRENT CAN FLOW. THE SWITCH OF THE RECTIFIER IS THEN TURNED ON AND AS SOON AS THE BULB INSIDE OF THE RECTIFIER BECOMES ILLUMINATED, THEN THE RHEOSTAT HANDLE SHOULD GRADUALLY BE TURNED UNTIL THE AMMETER NEEDLE COMES UP TO 5 OR 6 AMPERES.

SOME OF THESE BULB RECTIFIERS DO NOT HAVE A SEPARATE SNAP SWITCH AND THE CIRCUIT IS AUTOMATICALLY OPEN CIRCUITED WHEN THE RHEOSTAT IS IN THE "OFF" POSITION.

ALTHOUGH AN ALTERNATING CURRENT IS FLOWING FROM THE POWER LINES THRU THE RECTIFIER, YET A PULSATING DIRECT CURRENT IS FLOWING THROUGH THE BATTERIES, AS INDICATED BY THE ARROWS IN FIG. 8.

SUFFICIENT WATER IN BATTERIES WHILE ON CHARGE

DURING THE PROCESS OF CHARGING, IT IS NECESSARY TO SEE THAT THE CELLS ARE ALL SUPPLIED WITH THE REQUIRED AMOUNT OF DISTILLED WATER SO THAT THE PLATES WILL BE COVERED. THE BATTERIES CAN NOW BE LEFT ALONE, WHILE THEY ARE GRADUALLY BEING CHARGED, HOWEVER, THE SYSTEM SHOULD BE INSPECTED OCCASIONALLY TO BE SURE THAT THE CURRENT FLOW IS CORRECT AND THAT THE BATTERIES ARE NOT IN NEED OF WATER.

THE LENGTH OF TIME REQUIRED FOR A CHARGE

NOW THE QUESTION PROBABLY ARISES IN YOUR MIND AS TO HOW LONG THE BATTERIES WILL HAVE TO BE CHARGED UNTIL THEY REACH A FULLY CHARGED CONDITION. THIS, OF COURSE, DEPENDS UPON THE TYPE OF CHARGER USED, AS WELL AS THE CONDITION OF THE BATTERIES THEMSELVES. HOWEVER, THE CHARGER SHOWN IN FIGS. 6 AND 7 WILL CHARGE THE AVERAGE BATTERY IN ABOUT 24 HOURS. THERE ARE ALSO SOME TUNGAR SETS WHICH WILL CHARGE THE AVERAGE BATTERY IN ABOUT 12 TO 16 HOURS BUT IN THIS CASE, TWICE THE CHARGING RATE OF THE SMALLER CHARGER IS USED.

AS WE GO ALONG, YOU WILL SEE THAT SOME CHARGERS WILL EVEN COMPLETELY CHARGE THE AVERAGE BATTERY IN A STILL SHORTER TIME.

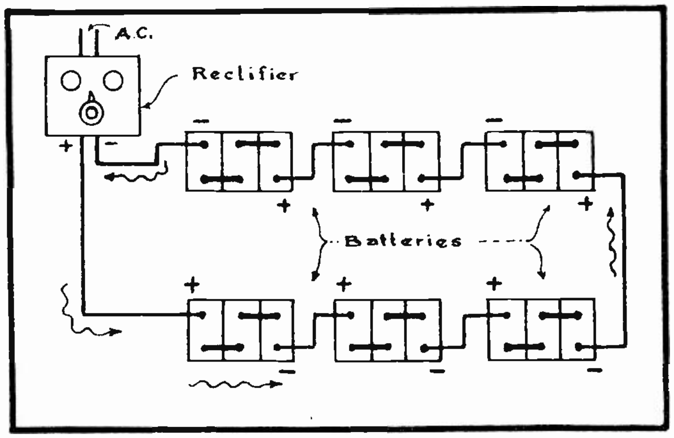

FIG. 8
Tungar Rectifier Charging 6 Batteries

WE DON'T FIGURE THE EXTENT OF CHARGE ACCORDING TO TIME

THESE FIGURES WILL GIVE YOU SOMEWHAT OF AN IDEA AS TO HOW LONG A TUNGAR RECTIFIER WILL TAKE TO CHARGE THE AVERAGE BATTERY BUT SINCE THE CONDITION OF ALL THE VARIOUS BATTERIES VARY MORE OR LESS, WE DO NOT JUDGE THEIR CONDITION OF CHARGE ACCORDING TO TIME. INSTEAD OF SUCH A METHOD, WE DETERMINE EACH INDIVIDUAL BATTERY'S CONDITION BY MEANS OF TESTS.

WHEN IS A BATTERY CHARGED?

LET US SUPPOSE, FOR EXAMPLE, THAT OUR BATTERY HAS BEEN CHARGING FOR ABOUT 10 HOURS. WE WILL TAKE OUR HYDROMETER AND TEST THE ELECTROLYTE OF EACH CELL AND THEN WE WILL MAKE A VOLTMETER TEST ON EACH CELL. IF THE SPECIFIC GRAVITY HASN'T COME UP TO 1.280 OR 1.300 AND THE CELL VOLTAGES HAVEN'T COME UP TO ABOUT 2.5 VOLTS WHILE THE CHARGER IS STILL OPERATING, WE WILL PERMIT THE BATTERY TO CONTINUE TO CHARGE.

YOU WILL FIND THAT AS A GENERAL RULE, THE BATTERY'S CHARGE WILL INCREASE FASTER DURING THE BEGINNING OF THE CHARGE THAN IT WILL NEAR THE END OF THE CHARGE.

GASSING OF CELLS

YOU WILL ALSO FIND THAT AT THE END OF THE CHARGE, BUBBLES WILL RISE

IN THE ELECTROLYTE, JUST AS IF THE CELL WERE BOILING. THIS IS DUE TO THE FACT THAT THE SULPHATE HAS PRACTICALLY ALL BEEN DRIVEN OUT OF THE PLATES AND COMBINED WITH THE WATER BUT SINCE NO ADDITIONAL SULPHATE WILL COMBINE WITH THE WATER, THE ELECTRIC CURRENT OF THE CHARGER WILL DECOMPOSE THE WATER INTO THE TWO GASES, HYDROGEN AND OXYGEN. THESE GASES THEN RISE TO THE SURFACE IN THE FORM OF BUBBLES AND WE CALL THIS ACTION GASSING.

YOU MUST BE VERY CAREFUL NOT TO GET ANY FLAME NEAR SUCH A GASSING CELL, AS HYDROGEN WHEN IGNITED, WILL CAUSE A MINIATURE EXPLOSION, WHICH MIGHT EVEN BLOW OFF THE TOP OF THE BATTERY.

SOMETIMES BUBBLES WILL ALSO BE CAUSED BY TOO HIGH A CHARGING RATE. AT ANY RATE, DON'T ALLOW GASSING TO CONTINUE BECAUSE IT IS JUST A WASTE OF CURRENT, A WASTE OF WATER, AND AT THE SAME TIME, IT IS INJURIOUS TO THE BATTERY IN GENERAL.

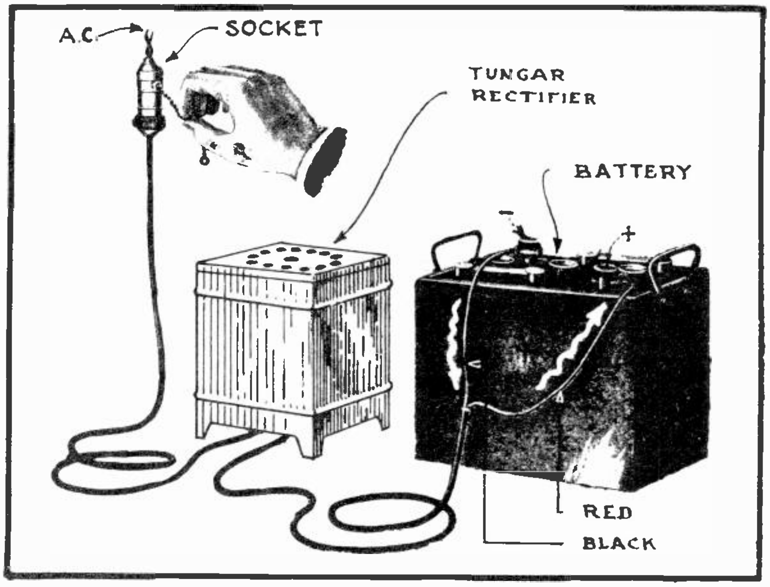

FIG. 9

Tungar Set for Home Use

THE FULLY CHARGED BATTERY

SO YOU SEE, JUST KEEP THE BATTERY CHARGING UNTIL ALL THE CELL VOLTAGES COME UP TO ABOUT 2.5 VOLTS WHILE STILL ON THE LINE AND THE SPECIFIC GRAVITY TO ABOUT 1.280 OR 1.300. WHEN THIS CONDITION IS REACHED, THE BATTERY IS FULLY CHARGED AND READY TO BE TAKEN FROM THE CHARGING LINE. AFTER IT IS REMOVED FROM THE LINE, YOU WILL FIND THE CELL VOLTAGES TO DROP TO 2.2 VOLTS.

BALANCING AN ELECTROLYTE, WHOSE GRAVITY IS TOO LOW

AT TIMES, YOU WILL FIND THAT THE CELL VOLTAGES WILL COME UP TO PAR BUT THE SPECIFIC GRAVITY IS STILL LOW OR VICE VERSA. IF THIS IS THE CASE, ALLOW THE BATTERY TO CONTINUE CHARGING UNTIL NEITHER THE CELL VOLTAGES NOR THE SPECIFIC GRAVITY WILL RISE HIGHER. THEN IF YOU SHOULD FIND THAT THE CELL VOLTAGES WILL COME UP TO THEIR REQUIRED POINT BUT THE SPECIFIC GRAVITY IS TOO LOW, WITHDRAW SOME OF THE ELECTROLYTE FROM THE LOW GRAVITY CELL OR CELLS BY MEANS OF A SYRINGE. GENERALLY, IT IS ADVISABLE TO WITHDRAW ENOUGH OF THE ELECTROLYTE SO THAT THE LEVEL WILL DROP TO THE TOP OF THE SEPERATORS. NOW YOUR NEXT STEP IS TO REPLACE THIS REMOVED ELECTROLYTE WITH AN EQUAL AMOUNT OF SULPHURIC ACID, WHICH HAS A SPECIFIC GRAVITY OF 1.400 (THIS IS THE STRENGTH OF ACID THE BATTERY MAN BUYS.) HAVING REPLACED THE AMOUNT OF ELECTROLYTE YOU HAVE WITHDRAWN, WITH AN EQUAL AMOUNT OF 1.400 SULPHURIC ACID, ALLOW THE BATTERY TO CONTINUE CHARGING FOR ANOTHER HOUR.

THIS HOUR'S CHARGE WILL PERMIT THE ADDED SULPHURIC ACID TO MIX THOR

OUGHLY WITH THE REST OF THE ELECTROLYTE WHICH WAS ALREADY IN THE CELL. AFTER THIS HOUR OF CHARGING, TEST THE ELECTROLYTE AGAIN AND IF THE SPECIFIC GRAVITY IS STILL TOO LOW, REPEAT THE ADDITION OF 1.400 ACID IN THE SAME CAREFUL MANNER AS WAS JUST SHOWN YOU. THEN AFTER ANOTHER HOUR'S CHARGE, TEST THE ELECTROLYTE AGAIN AND YOU JUST CONTINUE BALANCING THE ELECTROLYTE IN THIS WAY UNTIL THE HYDROMETER READING COMES UP TO 1.280 OR 1.300 WHEN THE CELL VOLTAGES ARE 2.5 VOLTS (WHILE ON THE LINE).

BALANCING AN ELECTROLYTE, WHOSE SPECIFIC GRAVITY IS TOO HIGH

SHOULD YOU, HOWEVER, FIND THAT THE SPECIFIC GRAVITY OF THE ELECTROLYTE IS TOO HIGH, AFTER THE CHARGING LIMIT HAS BEEN REACHED, THEN DRAW OFF SUFFICIENT ELECTROLYTE SO THAT ITS LEVEL WILL BE JUST EVEN WITH THE TOPS OF THE SEPARATORS. REPLACE THIS WITHDRAWN ELECTROLYTE WITH AN EQUAL VOLUME OF DISTILLED WATER. CONTINUE CHARGING FOR ANOTHER HOUR AND TEST THE ELECTROLYTE AGAIN AND IF YOU STILL FIND THE READING TOO HIGH, DILUTE IT ONCE MORE IN THE SAME CAREFUL MANNER. BY BALANCING THE ELECTROLYTE GRADUALLY IN THIS WAY, YOU WILL OBTAIN MUCH MORE ACCURATE RESULTS, THAN BY JUST HAPHAZARDLY GUESSING AT THE REQUIRED AMOUNTS OF ACID OR WATER TO ADD.

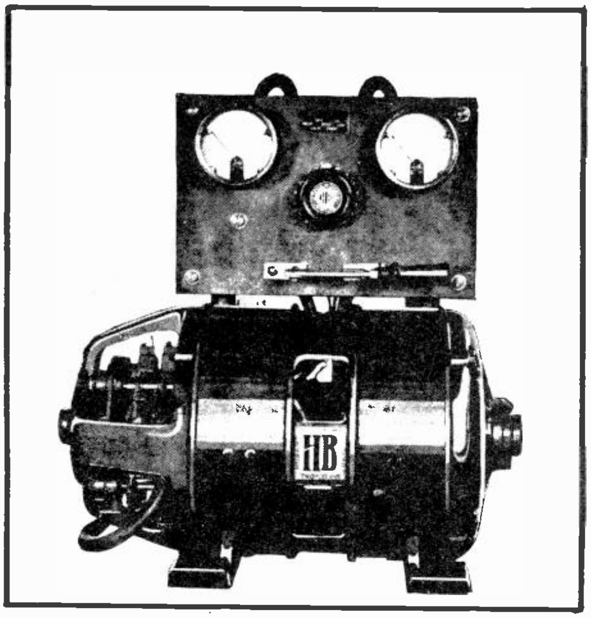

FIG. 10
A Typical Motor-Generator Set for Battery Charging.

REMOVING THE CHARGED BATTERY FROM THE LINE

AFTER THE BATTERY IS FULLY CHARGED, SO THAT THE VOLTAGE IS UP AND THE SPECIFIC GRAVITY OF THE ELECTROLYTE IS CORRECT, TURN BACK THE RHEOSTAT SO THAT NO CURRENT FLOWS AND SNAP OFF THE SWITCH OF THE RECTIFIER.

NOW REMOVE THE BATTERY FROM THE LINE AND SEE TO IT THAT THE WATER LEVEL IS CORRECT IN EACH CELL. REPLACE THE VENT PLUGS, WASH OFF THE OUTSIDE OF THE BATTERY WITH A SOLUTION OF WATER AND SODA OR AMMONIA, AND THE BATTERY IS NOW READY TO GO BACK INTO ACTIVE SERVICE.

THE TUNGAR SET FOR HOME USE

IN FIG. 9 YOU WILL SEE A SMALL TUNGAR BULB RECTIFIER, WHICH CAN BE ADVANTAGEOUSLY USED AROUND A HOME TO CHARGE ONE BATTERY AT A TIME. IN THIS WAY, A MOTORIST CAN RECHARGE HIS AUTOMOBILE BATTERY; THE RADIO FAN, HIS RADIO BATTERY, ETC.

THE RED WIRE OF THIS CHARGER IS CONNECTED TO THE POSITIVE TERMINAL OF THE BATTERY AND THE BLACK WIRE IS CONNECTED TO THE NEGATIVE TERMINAL OF THE BATTERY. BY TURNING ON THE CHARGER, ALTERNATING CURRENT IS USED IN THE PROPER MANNER SO THAT A DIRECT CURRENT WILL CHARGE THE BATTERY. THE CHARGING CURRENT WILL FLOW IN THE DIRECTION AS INDICATED BY THE ARROWS.

THE MOTOR GENERATOR SET

SO FAR, WE HAVE ONLY CONSIDERED THE SLOW METHOD OF CHARGING BATTERIES, BUT IN FIG. 10 YOU WILL SEE A MOTOR-GENERATOR CHARGING SET, WHICH WILL CHARGE THE BATTERIES MUCH QUICKER THAN THE TUNGAR RECTIFIER.

THE MOTOR-GENERATOR SET OR M.G. SET, AS THE ELECTRICAL MAN CALLS IT, CONSISTS OF AN ELECTRIC MOTOR, WHICH IS OPERATED BY MEANS OF ALTERNATING CURRENT, SUCH AS SUPPLIED BY THE POWER COMPANY. THIS ELECTRIC MOTOR IS COUPLED DIRECTLY TO A DIRECT CURRENT GENERATOR SO THAT AS THE A.C. (ALTERNATING CURRENT) MOTOR IS CAUSED TO ROTATE BY A.C. CURRENT, IT WILL OPERATE THE D.C. GENERATOR, WHICH IN TURN WILL SUPPLY THE BATTERIES WITH A DIRECT CURRENT.

IN OTHER WORDS, ALL THE A.C. MOTOR DOES IS TO OPERATE THE D.C. GENERATOR AND THE GENERATOR ACTUALLY SUPPLIES THE BATTERIES WITH THE CHARGING CURRENT.

CHARGING BATTERIES WITH M.G. SET

IN FIG. 11 YOU WILL SEE HOW SIX DIFFERENT BATTERIES ARE ALL CONNECTED TO THIS M.G. SET AT ONE TIME. NOTICE THAT ONE WIRE, WHICH COMES FROM THE GENERATOR, IS POSITIVE (+), ANOTHER IS NEGATIVE (-) AND THE CENTER ONE IS NEUTRAL (N). INSTEAD OF THESE CONDUCTORS BEING FLEXIBLE WIRE, YOU WILL GENERALLY FIND THEM TO BE RIGID COPPER RODS ABOUT 3/4" IN DIAMETER AND WE CALL THEM BUSS BARS.

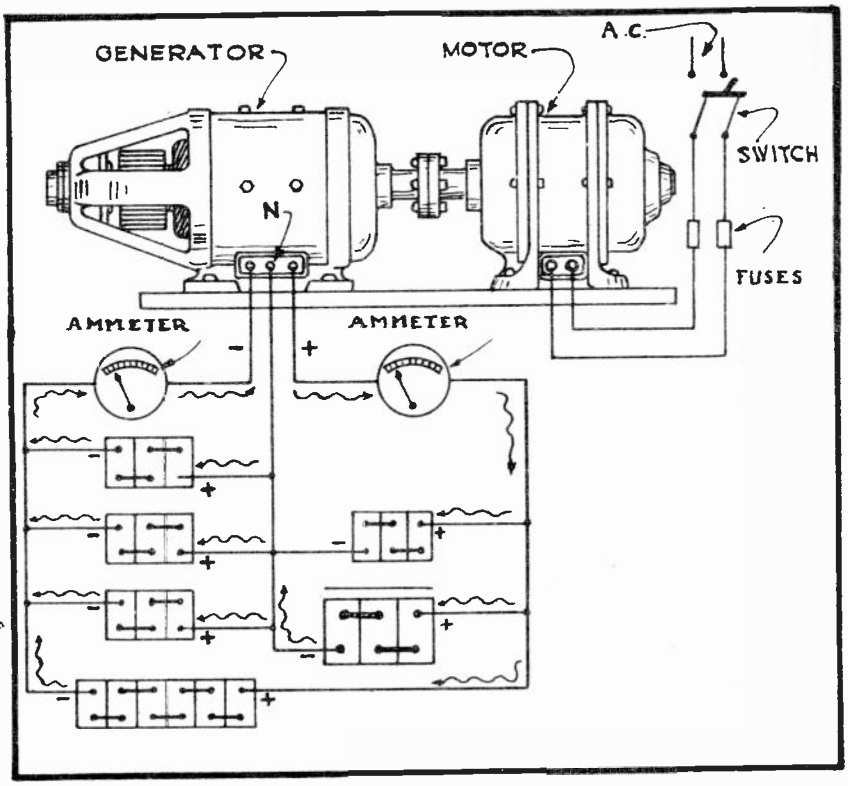

FIG. 11
The Charging Circuit of an M.G. Set.

OBSERVE CAREFULLY THAT THE A.C. LINES HAVE NO ELECTRICAL CONNECTION WHATEVER WITH THE BATTERY CHARGING CIRCUIT. THEY JUST SUPPLY THE MOTOR WITH CURRENT AND THAT IS ALL.

TRACING THE CHARGING CURRENT

WHEN THE SET IS IN OPERATION, THE CHARGING CURRENT WILL FLOW FROM THE (+) TERMINAL OF THE GENERATOR, THROUGH THE RIGHT HAND AMMETER AND THEN IT DIVIDES ITSELF BETWEEN THE DIFFERENT BATTERIES, RETURNING TO THE GENERATOR THROUGH THE NEGATIVE (-) TERMINAL. THE NEUTRAL (N) BUSS BAR CAN EITHER BE POSITIVE OR NEGATIVE, DEPENDING UPON THE EXISTING CONDITIONS.

BATTERIES ARE CHARGED ACCORDING TO THEIR OWN RESISTANCE

SINCE YOU ALREADY KNOW THAT THE LESS RESISTANCE WHICH A CIRCUIT OFFERS, THE MORE CURRENT WILL FLOW THROUGH IT, IT IS OBVIOUS THAT THE CURRENT WILL DIVIDE BETWEEN THE DIFFERENT BATTERIES IN PROPORTION TO THE RESISTANCE WHICH EACH OFFERS.

THE VOLTAGE OF THE M.G. SET IS KEPT CONSTANT

THE VOLTAGE OF THIS CHARGING OUTFIT IS KEPT CONSTANT, BEING 15 VOLTS ACROSS THE OUTER (+) AND (-) BUSS BARS AND $7\frac{1}{2}$ VOLTS BETWEEN EITHER OF THESE BUSS BARS AND THE NEUTRAL (N) BUSS BAR. SO IF THE RESISTANCE OF THE DIFFERENT BATTERIES VARY DUE TO SIZE, CONDITION, ETC., IT IS EVIDENT THAT MOST OF THE CURRENT WILL FLOW THROUGH THE BATTERIES, WHICH HAVE THE LOWEST RESISTANCE. THEREFORE, IT IS LIKEWISE TRUE THAT A DISCHARGED BATTERY WILL TAKE A HIGHER CHARGING RATE THAN A FULLY CHARGED BATTERY BECAUSE A DISCHARGED BATTERY OFFERS LESS RESISTANCE OR OPPOSING VOLTAGE TO THE CHARGING CURRENT.

EACH BATTERY CONTROLS ITS OWN CHARGING RATE

SINCE THE CHARGING RATE OF EACH BATTERY IS REDUCED AS THE STATE OF CHARGE OF THE BATTERY IS INCREASED, YOU CAN SEE THAT THE BATTERY ITSELF WILL CONTROL ITS OWN CHARGING RATE, PROVIDED THAT THE VOLTAGE OF THE CHARGING CIRCUIT IS KEPT CONSTANT.

BECAUSE OF THE COMPARATIVELY HIGH RATE OF CHARGE, WHICH IS FORCED THROUGH THE CHARGING BATTERY, IT IS POSSIBLE TO CHARGE AN AVERAGE BATTERY IN ABOUT 8 HOURS. THIS METHOD OF CHARGING IS OFTEN SPOKEN OF AS THE 8 HOUR CHARGE, CONSTANT-POTENTIAL CHARGING, AND PARALLEL CHARGING.

ALTHOUGH THERE ARE STILL OTHER TYPES OF CHARGERS, YET THOSE DISCUSSED IN THIS LESSON ARE THE ONES WHICH ARE MOST COMMONLY USED.

ADDITIONAL INFORMATION

SO FAR, WE HAVE DISCUSSED ONLY CASES WHERE THE BATTERY WAS IN A NORMAL CONDITION AND DISCHARGED. CONSEQUENTLY EVERYTHING WENT ALONG SMOOTHLY, BUT THIS CONDITION IS MORE OR LESS IDEALISTIC.

IN ACTUAL PRACTICE, THE BATTERY BUSINESS OFFERS A NUMBER OF PROBLEMS, WHICH MUST BE DEALT WITH INTELLIGENTLY. SO IN THE NEXT LESSON, WE WILL GO INTO THE SERVICING OF THE MANY OF THE SERIOUS BATTERY TROUBLES, AS WELL AS TO SHOW YOU MANY HELPFUL TRICKS IN DEALING WITH BATTERIES, WHICH DO NOT RESPOND TO THE ACTIONS OF THE CHARGER AS EAGERLY AS THEY DO UNDER NORMAL CONDITIONS.

AFTER YOU HAVE ANSWERED THE EXAMINATION QUESTIONS, WHICH HAVE BEEN PREPARED FOR YOU IN THIS LESSON, WE WILL CONTINUE IN THE NEXT LESSON, BY SOLVING MANY OF THE BATTERY TROUBLES, WHICH ARE BROUGHT TO THE EXPERT TO BE CORRECTED.

THE EDISON STORAGE BATTERY

UP TO THIS TIME, THE ONLY STORAGE BATTERY WITH WHICH WE DEALT, WAS THE LEAD-ACID TYPE. HOWEVER, IN ADDITION TO THIS UNIT, ANOTHER FORM OF STORAGE BATTERY IS BEING MANUFACTURED AND IS KNOWN AS THE EDISON STORAGE BATTERY. A CUT-AWAY ILLUSTRATION OF ONE EDISON STORAGE CELL IS SHOWN YOU IN FIG. 12.

THE POSITIVE PLATES IN THIS CELL CONSIST OF CYLINDRICAL TUBES OF NICKLEPLATED, PERFORATED, SPIRALLY SEAMED THIN STEEL RIBBON, FILLED WITH ALTERNATE LAYERS OF A SPECIALLY PREPARED NICKEL HYDRATE AND FLAKES OF PURE METALLIC NICKLE; THE FORMER BEING THE INITIAL STATE OF THE POSITIVE ACTIVE MATERIAL, WHILE THE LATTER IS THE CONDUCTIVE MEDIUM.

THE NEGATIVE PLATES CONSIST OF RECTANGULAR POCKETS OF NICKLE PLATED, PERFORATED STEEL RIBBON FILLED WITH A SOLID MASS OF SPECIALLY PREPARED ELECTRO-CHEMICALLY ACTIVE IRON OXIDE AND A SMALL AMOUNT OF MERCURY OXIDE EVENLY DISTRIBUTED; THE FORMER BEING THE INITIAL STATE OF THE ACTIVE MATERIAL WHILE THE LATTER SERVES AS THE CONDUCTING MEDIUM.

THE ELECTROLYTE IS AN ALKALINE SOLUTION CONSISTING OF SPECIALLY PREPARED POTASSUIM AND LITHIUM HYDROXIDE IN DISTILLED WATER.

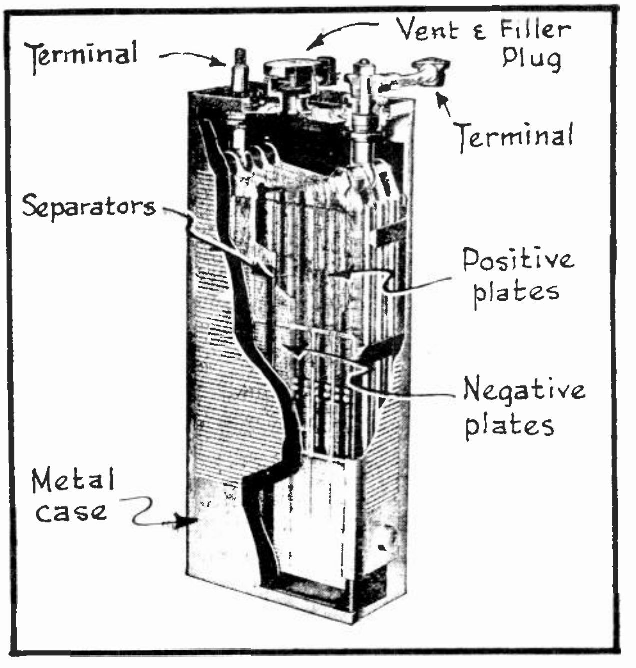

FIG. 12
The Edison Storage Cell.

THE AVERAGE VOLTAGE PRODUCED BY THE EDISON STORAGE CELL IS 1.2 VOLTS AND TO INCREASE, THE VOLTAGE, CELLS CAN BE CONNECTED IN SERIES.

THE CHIEF ADVANTAGES OF THE EDISON STORAGE OVER THE LEAD-ACID CELL ARE ITS LIGHT WEIGHT, ENDURANCE, RELIABILITY AND RUGGEDNESS. HOWEVER, ITS INITIAL COST IS GREATER THAN THAT OF THE LEAD-ACID TYPE STORAGE BATTERY.

THE EDISON BATTERY, WHEN DISCHARGED, CAN OF COURSE BE RECHARGED IN THE SAME MANNER AS ALREADY DESCRIBED RELATIVE TO THE LEAD-ACID TYPE STORAGE BATTERIES. DISTILLED WATER SHOULD BE USED TO REPLACE EVAPORATION.

Examination Questions

LESSON NO. 33

Every moment spent in study is an investment in the future --- and one good investment can accomplish more than a lifetime of Toil.

1. - WHY IS IT SO IMPORTANT TO KEEP THE OUTSIDE OF THE BATTERY CLEAN?

2. - HOW WOULD YOU TAKE CARE OF A CORRODED BATTERY TERMINAL?

3. - HOW CAN YOU TELL WHEN A CELL REQUIRES WATER? WHAT KIND OF WATER WOULD YOU USE AND HOW WOULD YOU ADD IT TO THE CELL?

4. - WHAT TESTS WOULD YOU MAKE TO DETERMINE THE STATE OF CHARGE OF EACH OF THE CELLS OF A LEAD-ACID STORAGE BATTERY?

5. - BRIEFLY DESCRIBE ONE WAY HOW YOU CAN CHARGE BATTERIES WITH D.C. WHEN IT IS SUPPLIED BY THE POWER LINES.

6. - WHY ARE RECTIFIERS USED FOR BATTERY CHARGING?

7. - HOW CAN YOU TELL WHEN A STORAGE BATTERY HAS FINISHED ITS CHARGE ON THE LINE?

8. - WHEN DOES IT BECOME NECESSARY TO BALANCE THE ELECTROLYTE? HOW WOULD YOU DO THIS JOB?

9. - BRIEFLY DESCRIBE HOW BATTERIES ARE CHARGED WITH THE M. G. SET WHICH WAS DESCRIBED IN THIS LESSON.

10. - HOW DOES THE M.G. CHARGING METHOD DIFFER FROM THAT OF THE TUNGAR RECTIFIER?

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LESSON NO. 34

DETERMINING AND CORRECTING BATTERY TROUBLES

All through our battery work so far, we have been dealing with batteries which were more or less in a normal condition but in this lesson we are going to deal with batteries which aren't so good and we are going to take these diseased batteries and cure them so that they can again become useful electrical citizens.

If you have had any contact at all with storage batteries or even with other people, who make use of storage batteries in one way or another, you have often heard about one person obtaining considerably more "trouble free" battery service than another person. In fact, the same persons may have identical batteries to start with and yet one party is constantly having his battery repaired, whereas the other party is always happy, due to the marvelous efficiency of his battery. Why is this so? Well, you are going to be shown the reason for this right here.

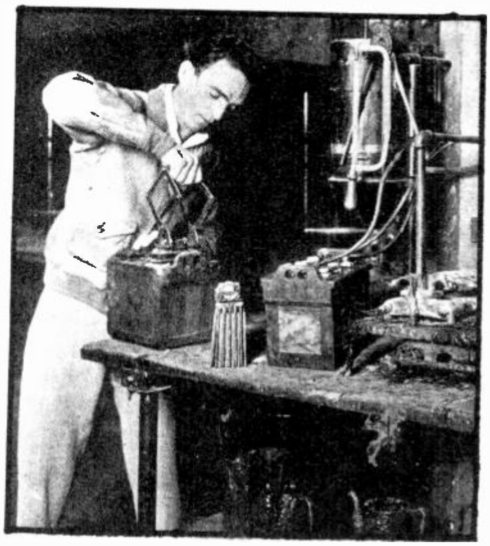

Fig.1
Lead-Acid Storage Battery.

BATTERIES DEMAND ATTENTION

Batteries are like people, they will stand just so much strain and abuse but no more. Should you try and go about your daily tasks without treating yourself to a drink or food occasionally, you would gradually become weaker and weaker and if you should continue this fast long enough you would finally die. Even though batteries are by no means alive, as we ordinarily consider life, yet they are decidedly active and demand proper attention, just as well as we humans do. Time after time, you will be able to trace back the history of a "lifeless" battery and find its condition due to a neglect by its owner.

Now you are probably interested in knowing just what serious battery troubles

WILL DEVELOPE FROM THE VARIOUS TYPES OF NEGLECT, SO HERE WE GO.

BATTERY CLEANLINESS

FIRST, SHOULD YOU PERMIT DIRT TO ACCUMULATE ON TOP OF THE BATTERY, A SUITABLE ELECTRICAL PATH IS LIKELY TO FORM, WHICH WILL PERMIT THE BATTERY TO GRADUALLY DISCHARGE ITSELF, AS YOU WERE ALREADY TOLD IN THE LAST LESSON.

THE FORMATION OF LEAD SULPHATE COATING

IF THE ELECTROLYTE LEVEL IS NEGLECTED, THEN THE WATER WILL CONTINUE TO EVAPORATE AND IN DOING SO, THE ELECTROLYTE WILL BECOME STRONGER, AS WELL AS DROPPING TO AN ABNORMALLY LOW LEVEL. BY PERMITTING PLATES TO BE PARTIALLY EXPOSED TO THE EFFECTS OF THE AIR IN THIS WAY, THE EXPOSED PORTION OF THEM WILL HARDEN AND A COATING OF THICK LEAD SULPHATE (A WHITE CHALKY LOOKING SUBSTANCE) WILL FROM ON THEM. YOU WILL SEE SUCH A GROUP OF BADLY SULPHATED NEGATIVE PLATES IN FIG. 2.

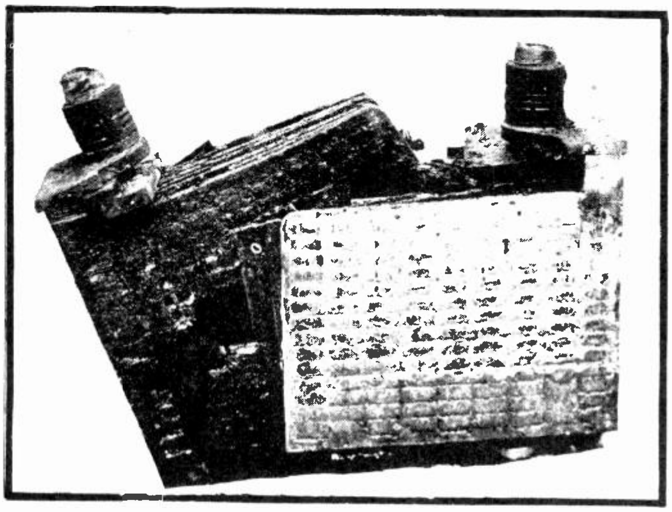

FIG. 2
Badly Sulphated & Disintegrated Plates.

AN ACID OF EXTREMELY HIGH SPECIFIC GRAVITY WILL ALSO CAUSE THE PLATES TO BECOME SULPHATED. SO BY HAVING THE COMBINED EFFECTS OF A STRONG ACID, CAUSED BY WATER EVAPORATION, AS WELL AS A LOW ELECTROLYTE LEVEL, THERE SHOULD BE NO DOUBT IN YOUR MIND THAT THE PLATES ARE BOUND TO BECOME SULPHATED.

ANOTHER COMMON CAUSE FOR SULPHATED PLATES, IS THAT THE BATTERY HAS BEEN LEFT IN A DISCHARGED CONDITION FOR TOO LONG A TIME, OR ELSE OVER-DISCHARGED. BY OVER-DISCHARGING, WE MEAN THAT THE BATTERY WAS FORCED TO REMAIN IN SERVICE, AFTER ITS SPECIFIC GRAVITY HAS DROPPED TO A POINT BELOW 1.150 AND ITS CELL VOLTAGES BELOW 1.6 VOLTS.

THE NORMAL LEAD SULPHATE FORMATION

KNOWING THAT SULPHATION IS EXTREMELY DETRIMENTAL TO BATTERY EFFICIENCY, LET US NOW SEE JUST EXACTLY WHY IT ACTS IN THIS PECULIAR WAY. YOU HAVE ALREADY LEARNED THAT AS A BATTERY DISCHARGES, THE CHEMICAL CHANGES ARE SUCH THAT THE SULPHATE GOES OUT OF THE ELECTROLYTE AND GOES INTO THE ACTIVE MATERIAL OF THE PLATES, THEREBY CAUSING A DEPOSIT OF LEAD SULPHATE TO FORM ON THE SURFACE OF THE PLATES.

DURING THE NORMAL DISCHARGE OF THE BATTERY, THIS LEAD SULPHATE IS SOFT AND POROUS AND FOR THIS REASON, THE ELECTROLYTE STILL HAS ACCESS TO THE ACTIVE MATERIAL OF THE PLATES. WITH THE LEAD SULPHATE IN THIS SOFT FORM, IT CAN READILY BE DRIVEN FROM THE PLATES DURING THE TIME THE BATTERY IS BEING CHARGED. A CONDITION, SUCH AS THIS, IS NORMAL, AS FAR AS THE

OPERATION OF THE BATTERY IS CONCERNED.

THE EFFECTS OF HARDENED LEAD SULPHATE

NOW IF WE SHOULD PERMIT THIS SULPHATE TO FORM IN TOO GREAT AN ABUNDANCE ON THE PLATES AND BECOME HARD, IT WOULD NATURALLY LOSE ITS POROSITY AND THEREBY FORM A COMPARATIVELY SOLID COATING OVER THE SURFACE OF THE PLATES. LEAD SULPHATE, ITSELF, IS A POOR ELECTRICAL CONDUCTOR, SO IT NOT ONLY PREVENTS THE ELECTROLYTE FROM COMING INTO CONTACT WITH THE ACTIVE MATERIAL OF THE PLATES BUT IT ALSO OFFERS A HIGH ELECTRICAL RESISTANCE.

SHOULD A LARGE CURRENT BE FORCED TO FLOW THROUGH SULPHATED PLATES, THE RESISTANCE OFFERED BY THE LEAD SULPHATE COATING WOULD CAUSE HEAT TO BE GENERATED AND THIS HEAT WOULD IN TURN CAUSE THE ACID TO BECOME HOT AND HOT ACID IS EXTREMELY ACTIVE AND WILL IN A SHORT TIME DESTROY THE GOOD QUALITIES OF THE LEAD-ACID CELL.

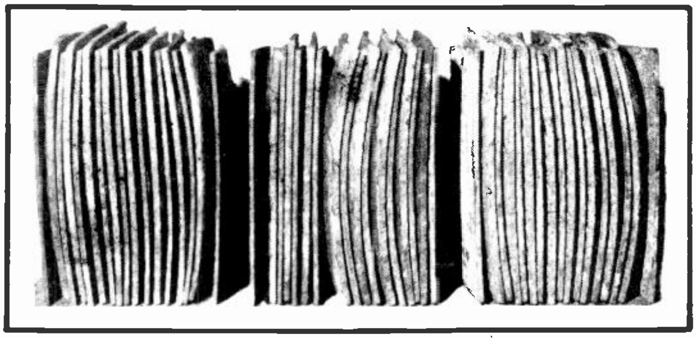

FIG. 3
Buckled Plates.

YOUR INTEREST IS NO DOUBT NOW AROUSED AS TO HOW WE CAN REMOVE LEAD SULPHATE DEPOSITS FROM SUCH AN AFFLICTED BATTERY, SO WHEN YOU COME TO THE LATTER PART OF THIS LESSON, YOU WILL BE TOLD WHAT TO DO WHEN YOU ARE CONFRONTED WITH SUCH A PROBLEM.

BUCKLED PLATES

ANOTHER SERIOUS PLATE TROUBLE IS BUCKLING, YOU WILL SEE A SET OF BUCKLED PLATES IN FIG. 3 AND YOU WILL FIND SEVERAL DIFFERENT ACTIONS CAPABLE OF CAUSING SUCH A CONDITION.

FIRST, IF A CELL IS PERMITTED TO OVER-DISCHARGE, LARGE ACCUMULATIONS OF LEAD SULPHATE WILL FORM ON THE PLATES. THESE SULPHATE DEPOSITS WILL NATURALLY NOT REMAIN UNIFORM AND CONSEQUENTLY THE PORTIONS OF THE PLATES, WHICH ARE STILL ACCESSABLE TO THE ACTION OF THE ELECTROLYTE, WILL BE CARRYING THE BURDEN OF CONDUCTING THE CURRENT.

DUE TO THIS REDUCTION IN PLATE AREA, THE SMALL SPACES, WHICH ARE STILL ACTIVE, WILL BECOME OVER-HEATED AND AN UNEQUAL DISTRIBUTION OF HEAT WILL NATURALLY CAUSE THE PLATES TO WARP OR BUCKLE.

IT IS LIKEWISE TRUE THAT UNEVEN DISTRIBUTION OF LEAD SULPHATE DEPOSITS CAN CAUSE THE PLATES TO LOSE THEIR NORMAL SHAPE.

YOU WILL ALSO FIND BUCKLING TO BE CAUSED BY EXCESSIVELY HIGH RATES OF CHARGE AND DISCHARGE, WHICH WILL OF COURSE PRODUCE AN ABNORMAL AMOUNT OF HEAT, WHICH MAY RESULT IN A DEFORMATION OF THE PLATES. IN FACT, SHORT CIRCUITING A CELL OR BATTERY IS ONE OF THE EVILS, WHICH ARE CAPABLE OF BRINGING ABOUT BUCKLED PLATES.

SOMETIMES YOU WILL COME ACROSS A CELL WITH A SET OF BUCKLED PLATES,

WHICH WERE CAUSED BY AN ACCIDENTAL SHORT CIRCUIT WITHIN THE CELL ITSELF. SUCH A SHORT CAN READILY BE PRODUCED IF ANY PORTION OF A SEPARATOR SHOULD FALL DOWN ON THE JOB SO THAT A CONTACT IS ESTABLISHED BETWEEN A POSITIVE AND NEGATIVE PLATE. IT ONLY TAKES ONE SUCH CONTACT TO SHORT OUT AN ENTIRE CELL BECAUSE ALL POSITIVE AND ALL NEGATIVE PLATES ARE MECHANICALLY CONNECTED TO ONE ANOTHER.

EFFECT OF BUCKLED PLATES

WHEN PLATES BECOME BUCKLED, OUR CORRECTIVE MEASURES ARE GOVERNED BY THE EXTENT OF THEIR BUCKLING. THAT IS, IF THE AMOUNT OF BUCKLING IS ONLY SLIGHT, THEN THE CELL AND BATTERY MAY CONTINUE THEIR USEFUL WORK FOR A PRACTICALLY UNLIMITED LENGTH OF TIME. SHOULD WE ON THE OTHER HAND, PERMIT BADLY BUCKLED PLATES TO REMAIN IN A CELL, THEY WILL IN DUE TIME EXERT UNEQUAL PRESSURES AGAINST THE SEPARATORS AND THEREBY CAUSE THE SEPARATORS TO BECOME WORN THROUGH, SO THAT AN ELECTRICAL CONNECTION WILL BE ESTABLISHED BETWEEN THE POSITIVE AND NEGATIVE PLATE GROUPS. THIS WOULD, OF COURSE, MEAN THE PRESENCE OF A SHORT CIRCUIT.

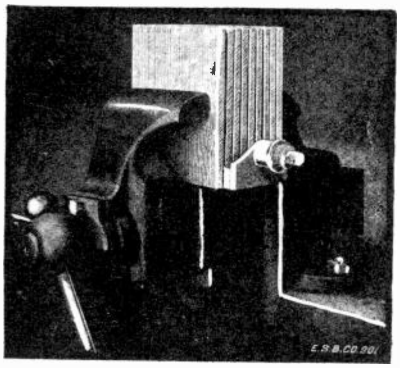

FIG. 4
Straightening Buckled Plates.

STRAIGHTENING BUCKLED PLATES

SHOULD THE EXTENT OF BUCKLING NOT BE TOO GREAT, THEN THE PLATE GROUP WITH THE BUCKLED PLATES CAN BE PLACED IN A VICE, AS SHOWN IN FIG. 4. NOTICE THAT THE SPACES BETWEEN THE PLATES ARE FILLED BY MEANS OF BOARDS, WHICH ARE CALLED TRANSIT BOARDS. THERE IS ALSO SUCH A BOARD RESTING AGAINST THE OUTER SURFACE OF EACH OF THE OUTER PLATES. THE BRITTLE STRUCTURE OF THE ACTIVE MATERIAL ON THE POSITIVE PLATES DOES NOT GENERALLY PERMIT STRAIGHTENING BUT THE NEGATIVE PLATES, WHEN IN A CHARGED CONDITION CAN BE STRAIGHTENED QUITE READILY.

WHEN PRESSURE IS APPLIED BY THE VICE, THE COMPARATIVELY PLIABLE NEGATIVE PLATES WILL YIELD TO THIS PRESSURE AND A GOOD JOB OF STRAIGHTENING CAN BE ACCOMPLISHED.

IN CASES WHERE EXTREME BUCKLING IS FOUND, IT WILL BE NECESSARY TO REPLACE THE BUCKLED PLATES WITH NEW ONES.

SHEDDING OF THE PLATES

IN FIG. 5, YOU WILL SEE STILL ANOTHER DEFECTIVE PLATE CONDITION, WHICH WE CALL SHEDDING. THIS DISEASED CONDITION MAKES ITSELF KNOWN BY THE FACT THAT THE PASTE OR ACTIVE MATERIAL CRUMBLES OFF THE GRIDS OR SUPPORTING MEMBERS. THIS ACTION IS FREQUENTLY FOUND IN OLD BATTERIES AND MAY GENERALLY BE BLAMED ON OLD AGE. HOWEVER, RELATIVELY YOUNG BATTERIES CAN "CATCH" THIS SICKNESS AND IN THIS CASE IT MAY BE CAUSED BY EXCESSIVE ACCUMULATION OF LEAD SULPHATE, OVER-DISCHARGING, AND OVER-CHARGING.

BY OVER-CHARGING, WE MEAN THAT IN SPITE OF THE BATTERY ALREADY BEING FULLY CHARGED, WE JUST STUBBORNLY TRY TO "RAM" AN EXCESSIVE AMOUNT OF CHARGE INTO IT. REMEMBER, YOU CAN'T "OVER-STUFF" A BATTERY, AND GET AWAY

WITH IT, ANYMORE THAN YOU CAN CONTINUALLY OVER-EAT AND EXPECT TO STAY IN GOOD HEALTH.

THE NORMAL AMOUNT OF SHEDDING

IN REGARDS TO SHEDDING OF THE PLATES, YOU MUST, OF COURSE, BEAR IN MIND THAT A SLIGHT AMOUNT OF SHEDDING IS PERFECTLY NATURAL BUT WHAT WE WANT TO AVOID IS THE EXCESSIVE AMOUNT OF SHEDDING. YOU SEE, ONE OF THE REASONS WHY WE ALWAYS PLACE THE SEPARATORS IN SUCH A POSITION SO THAT THE GROOVES ARE NEXT TO THE POSITIVE PLATES AND IN A VERTICAL OR UP AND DOWN PLANE, IS SO THAT THESE GROOVES WILL PERMIT THE SHEDDED MATERIAL FROM THE POSITIVE PLATES TO WORK ITS WAY DOWNWARDS INTO THE SEDIMENT BASINS AT THE BOTTOM OF THE JAR OF THE CELL. IT IS THE POSITIVE PLATES, WHICH ARE MOSTLY SUBJECT TO SHEDDING, RATHER THAN THE NEGATIVE PLATES

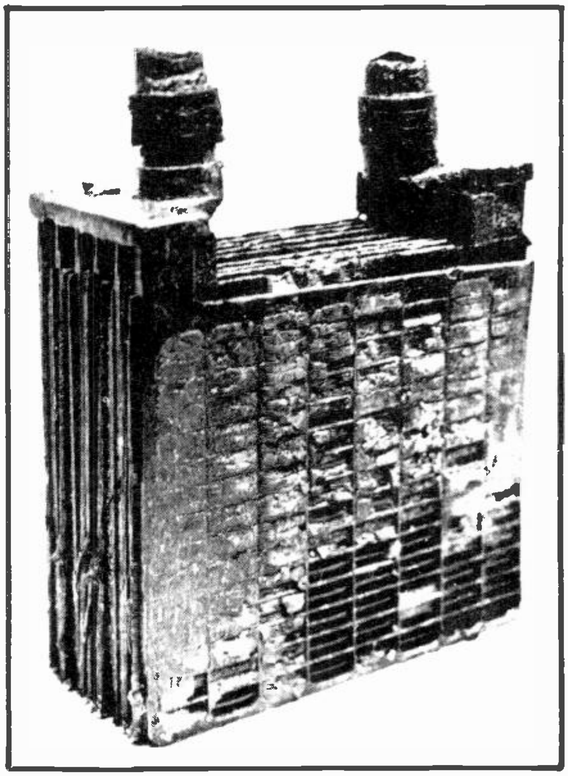

FIG. 5
Shedding Plates.

THE EFFECTS OF SHEDDING

AS THE PROCESS OF SHEDDING CONTINUES, MORE AND MORE OF THE ACTIVE MATERIAL WILL BE LOST FROM THE PLATES, SO THAT THE CAPACITY OF THE CELLS WILL BE CORRESPONDINGLY REDUCED, AND EVENTUALLY, SUFFICIENT ACTIVE MATERIAL WILL BE LOST FROM THE PLATES, SO THAT THE ONLY REMEDY LEFT IS TO REPLACE THESE SHEDDED PLATES WITH NEW ONES.

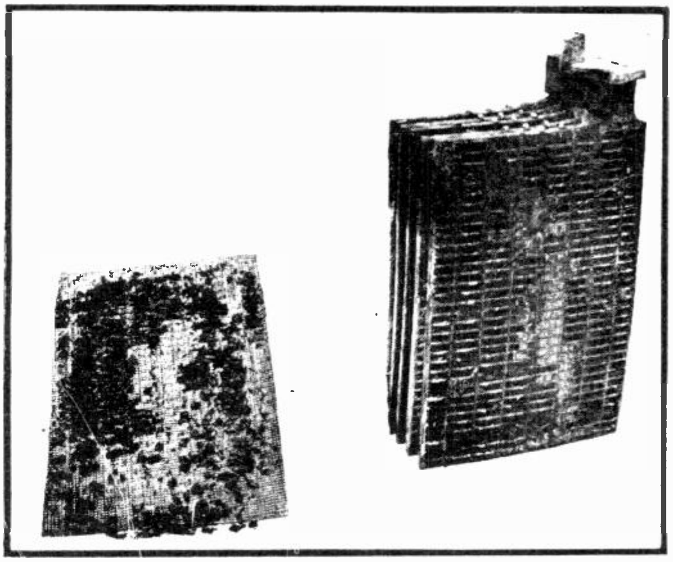

FIG. 6
Group Removed from a Frozen Cell. (Note active material on separators.)

FROZEN BATTERIES

ONE OF THE MOST IN-EXCUSABLE BATTERY TROUBLES IS A FROZEN BATTERY AND THIS CONDITION IS A DIRECT RESULT OF UTTER NEGLECT ON THE PART OF THE OWNER. TO PROVE THIS TO YOU, WE ARE GIVING YOU SOME FACTS WHICH SHOW THE RELATION BETWEEN FREEZING POINTS OF ELECTROLYTES AND THEIR SPECIFIC GRAVITY. HERE THEY ARE:

A BATTERY, WHICH IS DISCHARGED SUFFICIENTLY SO THAT ITS SPECIFIC GRAVITY IS 1.150, WILL FREEZE AT A TEMPERATURE OF ABOUT 5°F. ABOVE ZERO. HOWEVER, A BATTERY, WHOSE ELECTROLYTE HAS A SPECIFIC GRAVITY

OF 1.280, WILL FREEZE AT THE VERY LOW TEMPERATURE OF ABOUT 92° F. BELOW ZERO. SOME DIFFERENCE, ISN'T THERE? THIS SHOWS THAT THERE ISN'T MUCH CHANCE OF A CHARGED BATTERY BECOMING FROZEN BUT IT DOESN'T HAVE TO BE SO VERY COLD IN ORDER TO FREEZE A PARTIALLY OR COMPLETELY DISCHARGED BATTERY.

WHEN THE ELECTROLYTE FREEZES IN A LOW BATTERY, IT WILL NATURALLY EXPAND JUST LIKE WATER DOES WHEN IT TURNS TO ICE. SINCE THE PLATES ARE FILLED WITH A CERTAIN AMOUNT OF ELECTROLYTE, THIS EXPANSION OF THE FREEZING ELECTROLYTE WILL TEND TO FORCE THE ACTIVE MATERIAL OUT OF THE GRIDS. MISPLACED ACTIVE MATERIAL CAN, OF COURSE, ONLY BE REPLACED IN THE CELL BY EQUIPPING THE CELL WITH A NEW SET OF PLATES OR ELSE BUYING A NEW BATTERY. YOU WILL SEE THE EFFECTS OF A FROZEN CELL IN FIG. 6.

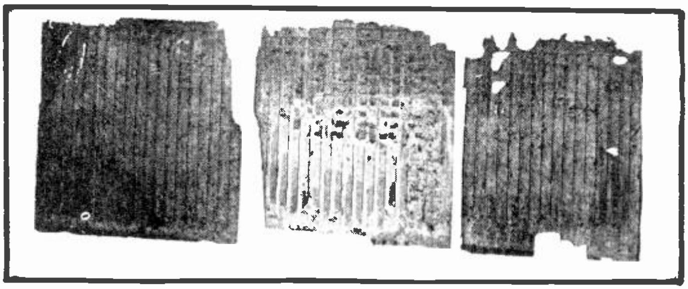

FIG. 7
Worn Wooded Separators.

THE BREAKING DOWN OF SEPARATORS

ABOUT THE FIRST PARTS TO BREAK DOWN IN AN AVERAGE BATTERY ARE THE SEPARATORS, PROVIDED THAT THEY ARE WOODEN ONES. WOODEN SEPARATORS, ARE SUBJECT TO ROTTING. THIS IS BROUGHT ABOUT BY THEIR CONTINUAL CONTACT WITH THE ACTIVE ACID, ESPECIALLY IF ANY FAULTY CONDITIONS EXIST WHICH WILL CAUSE THE ACID TO BECOME WARMER THAN NORMAL.

SEPARATORS ARE ALSO FREQUENTLY WORN THROUGH, IF THE ELEMENTS ARE LOOSELY FITTED INTO THE JARS. THAT IS, IF THE ELEMENTS HAVE A CHANCE TO BE JARRED AROUND, THE RESULTING FRICTION BETWEEN PLATES WILL IN A SHORT TIME RUB A HOLE THROUGH A SEPARATOR AND THEREBY CAUSE THE CELL TO BE SHORT CIRCUITED. BUCKLED PLATES, YOU WILL REMEMBER, WILL ALSO CAUSE WORN SPOTS IN SEPARATORS. IN FIG. 7 AND 8 SOME BADLY WORN WOODEN SEPARATORS ARE SHOWN.

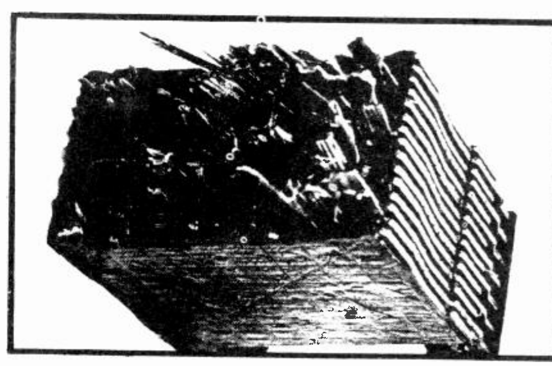

FIG. 8
Rotted Separators.

"TREEING"

ANOTHER PECULIAR CHARACTERISTIC OF WOODEN SEPARATORS IS KNOWN AS "TREEING". THIS NAME IS GIVEN TO A GROWTH OF FOREIGN MATERIALS, WHICH SOMETIMES TEND TO BUILD UP ON THE SEPARATORS AND WILL IN TIME RESULT IN A SHORT CIRCUIT.

WHENEVER WOODEN SEPARATORS SHOW THE SLIGHTEST DEFECTS, AFTER A CELL HAS BEEN DISMANTLED, YOU SHOULD NEVER HESITATE ABOUT REPLACING THEM WITH NEW ONES. DUE TO THE LOW COST OF WOODEN SEPARATORS, ONE IS NEVER JUSTIFIED IN REBUILDING A CELL AND DEPENDING UPON OLD SEPARATORS TO STAND UP UNDER THE RESPONSIBILITY, WHICH IS PLACED UPON THEM.

VARIOUS PATENTED SEPARATORS, SUCH AS RUBBER, ETC., ARE NOT AS SUSCEPTIBLE TO SUCH A RAPID BREAK-DOWN, AS IS THE CASE WITH WOODEN SEPARATORS.

THE MOST COMMON TROUBLE FOUND IN WOODEN CASES

NOW A WORD ABOUT THE TROUBLES FOUND IN BATTERY CASES. WOODEN CASES ARE SUBJECT TO ROTTING, WHICH IS DUE TO THE ACTION OF SPILT ACID UPON THE WOOD. THIS CONDITION CAN BE PREVENTED IF THE OUTSIDE OF THE CASE IS WASHED WITH A SODA OR AMMONIA SOLUTION ABOUT 3 TIMES A YEAR AND THEN FOLLOWED BY A COAT OF ACID RESISTING BATTERY PAINT. HOWEVER, WHEN IT IS ALREADY TOO LATE AND THE CASE IS ROTTED TO SUCH AN EXTENT THAT IT IS ALREADY FALLING APART, THEN THE ONLY LOGICAL REMEDY IS TO REPLACE IT WITH A NEW ONE.

THE MOST COMMON TROUBLE FOUND IN COMPOSITION CASES

RUBBER BATTERY CASES ARE SUBJECT TO SPREADING AT THE ENDS, WHICH IS CAUSED WHEN A BATTERY IS HELD IN PLACE TOO RIGIDLY BY MEANS OF OVER-TIGHT HOLD DOWN CLAMPS. IN FIG. 9 YOU WILL SEE A BATTERY WHICH IS HELD IN POSITION WITH HOLD-DOWN CLAMPS OR BOLTS.

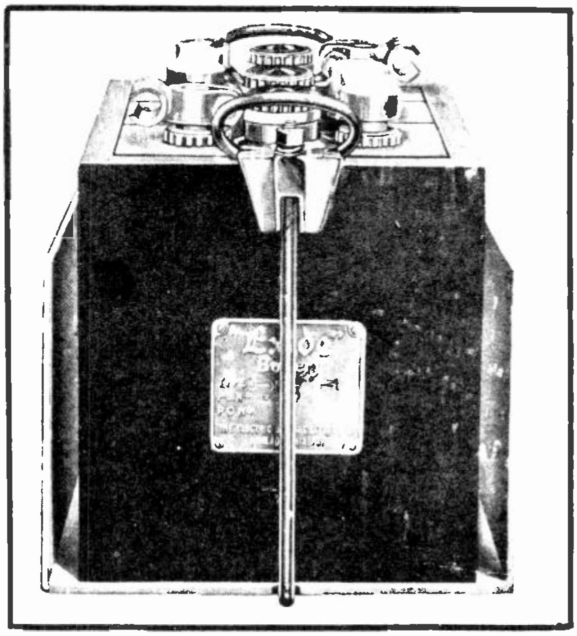

FIG. 9
Battery Held in Place With Bolts.

SOMETIMES SUCH A SPREAD CASE CAN BE PRESSED BACK INTO ITS NORMAL SHAPE AGAIN BY MEANS OF THE APPLICATION OF HEAT, AFTER WHICH IT IS ALLOWED TO COOL IN ITS RE-SET POSITION.

IF THE CONDITION OF THE CASE IS SUCH THAT IT WILL NOT PERMIT THIS OPERATION, THEN IT IS NECESSARY TO REPLACE IT WITH A NEW ONE.

THE HIGH RATE DISCHARGE TESTER

SO FAR, THE ONLY BATTERY TESTING INSTRUMENTS WITH WHICH YOU HAVE BEEN MADE FAMILIAR WERE THE VOLTMETER AND THE HYDROMETER. HOWEVER, TO DETERMINE BATTERY TROUBLES, WE ALSO FIND IT NECESSARY TO USE OTHER INSTRUMENTS. AMONG THESE USEFUL INSTRUMENTS, WE FIRST FIND THE HIGH RATE DISCHARGE TESTER.

BY LOOKING AT FIG. 10, YOU WILL NOTICE THAT THIS INSTRUMENT CONSISTS OF TWO SHARP METALLIC PRONGS, WITH A WOODEN HANDLE. THESE TWO PRONGS ARE ELECTRICALLY CONNECTED TOGETHER NEAR THEIR CENTER BY MEANS OF A HEAVY PIECE OF NICHROME WIRE. IN FACT, THIS HEAVY WIRE IS FREQUENTLY IN THE FORM OF A RIGID RIBBON.

JUST ABOVE THIS CONNECTING WIRE, YOU WILL SEE A SMALL VOLTMETER, SO MOUNTED THAT WHEN YOU GRIP THE HANDLE, YOU CAN SEE THE DIAL OF THE METER VERY EASILY. IF YOU WILL FOLLOW CAREFULLY, YOU WILL IMMEDIATELY SEE WHY

THIS INSTRUMENT IS SO VALUABLE FOR BATTERY TESTING PURPOSES.

THE REASON FOR MAKING A HIGH RATE DISCHARGE TEST

WHEN WE MERELY TEST THE CELL VOLTAGE WITH AN ORDINARY VOLTMETER, THE CELL IS NOT BEING PUT UNDER ANY LOAD. FOR THIS REASON, ANY DEFECT, SUCH AS A POORLY WELDED JOINT, LOW CAPACITY (SHEDDED) PLATES, ETC., WILL NOT NECESSARILY BE INDICATED BY THE CONVENTIONAL VOLTMETER READING. WE FIND, HOWEVER, THAT BY USING THE HIGH RATE DISCHARGE TESTER AND FIRMLY JABBING ITS POINTS INTO THE TWO TERMINALS OF A SINGLE CELL, THEN THE CELL WILL BE DISCHARGING AT A COMPARATIVELY HIGH RATE (ABOUT 150 TO 200 AMPS.)

FIG. 10
A High Rate Discharge Tester.

THIS HIGH RATE OF DISCHARGE IS DUE TO THE FACT THAT THE NICHROME BAND SERVES SOMEWHAT AS A SHORT ACROSS THE PRONGS BUT YET THE RESISTANCE OF THIS WIRE IS SUCH SO THAT A 100% SHORT CIRCUIT WILL NOT BE PRODUCED ACROSS THE CELL.

THE REQUIRED READINGS OF THE HIGH RATE DISCHARGE TEST

BECAUSE OF THE HIGH RATE OF DISCHARGE DURING THIS TEST, IT IS IMPERATIVE THAT WE DO NOT CONTINUE IT FOR TOO LONG A TIME. WHILE THIS DISCHARGE IS GOING ON, THE ATTACHED VOLTMETER IS WATCHED AND IF THE READING IS NOT BELOW 1.75 VOLTS AND THE READINGS OF THE VARIOUS CELLS DO NOT VARY BY MORE THAN 0.1 VOLTS, THEN THE BATTERY IS MECHANICALLY CORRECT.

SHOULD THERE, ON THE OTHER HAND, BE A POORLY WELDED JOINT, LOW CAPACITY CELL, ETC., WHEN THIS TEST IS MADE, THEN THE VOLTMETER WILL IMMEDIATELY INDICATE A READING LOWER THAN THAT REQUIRED FOR A NORMAL CELL.

FOR EXAMPLE, LET US SUPPOSE THAT ONLY AN ORDINARY VOLTMETER TEST IS TAKEN OF THE CELL. IN THIS CASE, AN EXTREMELY SMALL AMOUNT OF CURRENT IS ONLY CALLED UPON TO FLOW THROUGH THE HIGH RESISTANCE WINDING OF THE METER, SO THAT A READING WILL BE OBTAINED. DUE TO THIS VERY LOW CURRENT FLOW, A POORLY FITTED JOINT WILL VERY OFTEN PERMIT THIS SMALL AMOUNT OF CURRENT TO FLOW THROUGH IT WITHOUT PRESENTING ANY NOTICEABLE EFFECTS.

SHOULD THIS SAME JOINT, HOWEVER, BE FORCED TO PERMIT A HEAVY CURRENT TO FLOW THRU IT, IT WILL NOT STAND UP UNDER THE BIG LOAD AND THEREFORE, THIS CONDITION WILL QUICKLY MAKE ITSELF KNOWN WHEN THE HIGH RATE DISCHARGE TEST IS MADE.

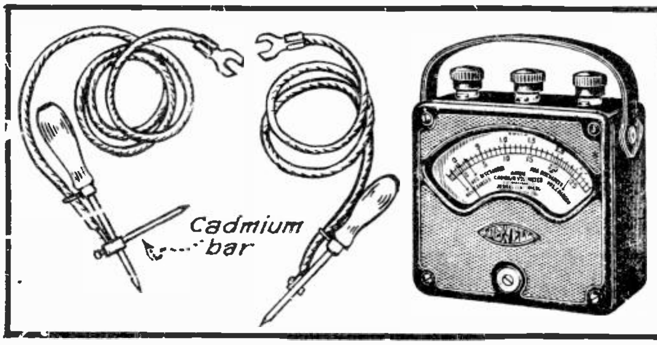

FIG. 11
The Cadmium. Test Voltmeter & Leads.

THE CADMIUM TEST VOLTMETER

WITH ALL THE TESTS, WHICH WE ARE ABLE TO MAKE SO FAR, WE CANNOT AS YET DETERMINE WHETHER IT IS THE POSITIVE GROUP OR THE NEGATIVE GROUP, WHICH IS AT FAULT IN A DEFECTIVE CELL. THEREFORE, LET US NOW PROCEED AND SEE HOW WE CAN DISTINGUISH THE SHORT COMINGS OF EITHER OF THE PLATE GROUPS, WITHOUT ACTUALLY HAVING TO FIRST DISASSEMBLE THE CELL.

TO DO THIS JOB, WE USE AN INSTRUMENT, WHICH IS KNOWN AS THE CADMIUM TEST VOLTMETER AND IT WILL GIVE SATISFACTORY RESULTS, PROVIDED THAT IT IS USED PROPERLY. THE METER IS GENERALLY SUPPLIED WITH AN UPPER AND LOWER SCALE AND IN THIS CASE, THE LOWER SCALE CAN BE USED FOR READING VOLTAGES OF VARIOUS ELECTRICAL UNITS, AS LONG AS THEIR VOLTAGE DOES NOT EXCEED 28 VOLTS. THE UPPER SCALE IS USED FOR READING VOLTAGES UP TO 2.8 VOLTS AND IT IS THIS SCALE, IN WHICH WE ARE FOR THE PRESENT CHIEFLY INTERESTED.

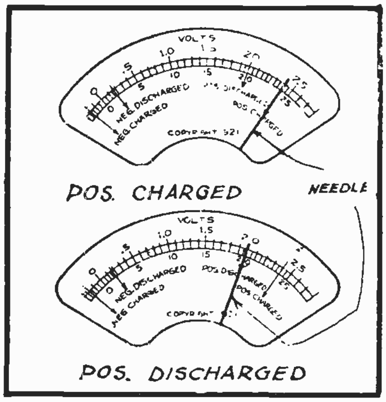

FIG. 12
Cadmium Test Voltmeter-Charged & Discharged Positive Group.

THE TEST LEADS

TWO TEST POINTS, WITH WOODEN HANDLES, ARE CONNECTED TO THE METER BY MEANS OF LONG, FLEXIBLE, INSULATED WIRES. ONE OF THESE TEST POINTS HAS A STICK OF CADMIUM ATTACHED TO IT IN SUCH A MANNER, SO THAT THE CADMIUM STICK IS AT THE RIGHT ANGLES TO THE TEST POINT, AS YOU WILL OBSERVE IN FIG. 11.

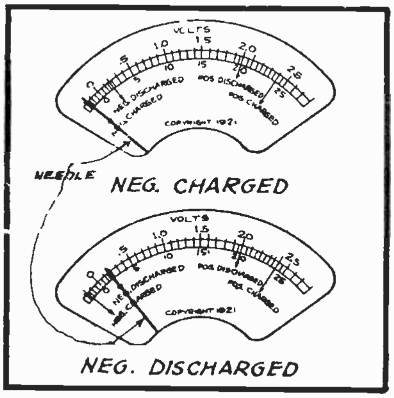

FIG. 13
Charged & Discharched Negative Group.

THE TEST POINT, WHICH HAS THE CADMIUM ATTACHED TO IT, IS CONNECTED TO THE TERMINAL OF THE METER WHICH IS LABELED 2.5V. THE OTHER TEST POINT IS CONNECTED TO THE TERMINAL OF THE METER, WHICH IS LABELED WITH AN (+) SIGN.

WITH OUR CONNECTIONS TO THE METER THUS MADE, WE ARE READY TO MAKE SOME TESTS. HOWEVER, TO OBTAIN RESULTS WITH THIS INSTRUMENT, THE BATTERY MUST EITHER BE UNDERGOING THE PROCESS OF A CHARGE OR ELSE A DISCHARGE. THAT IS, WE MUST MAKE THESE TESTS WHILE THE BATTERY IS CONNECTED TO THE CHARGING LINE OR ELSE ACTUALLY WORKING BY CAUSING A CURRENT FLOW.

TESTING THE POSITIVE PLATE GROUP

GENERALLY WE MAKE THIS TEST WHILE THE BATTERY IS BEING CHARGED AND WE PROCEED BY INSERTING THE CADMIUM STICK INTO THE ELECTROLYTE, BEING CAREFULY, HOWEVER, THAT IT DOES NOT COME IN CONTACT WITH ANY OF THE PLATES. AS SOON AS THE CADMIUM STICK HAS BEEN IMMERSED FOR A FEW SECONDS, WE TOUCH THE OTHER TEST POINT TO THE POSITIVE POST OF THE CELL.

WHILE WE ARE DOING THIS, WE TAKE NOTE OF THE READING ON THE SCALE OF THE METER AND IF WE FIND THAT THE NEEDLE COMES TO REST AT THE POINT LABELED "POS. CHARGED", WHICH IS REALLY EQUIVALENT TO 2.4 VOLTS, THEN WE

KNOW THAT THE POSITIVE GROUP OF THAT PARTICULAR CELL IS CHARGED. THIS IS ILLUSTRATED IN FIG. 12.

SHOULD WE, HOWEVER, MAKE THIS SAME TEST AND ONLY OBTAIN A READING OF 2.3 VOLTS, THEN THE POSITIVE PLATE GROUP IS 3/4 CHARGED; A VOLTAGE OF 2.2 VOLTS WOULD INDICATE THAT THE POSITIVE GROUP IS ½ CHARGED; A READING OF 2.1 VOLTS WOULD TELL US THAT THEY ARE ONLY ¼ CHARGED; AND 2.0 VOLTS WOULD MEAN THAT THE POSITIVE GROUP IS DISCHARGED.

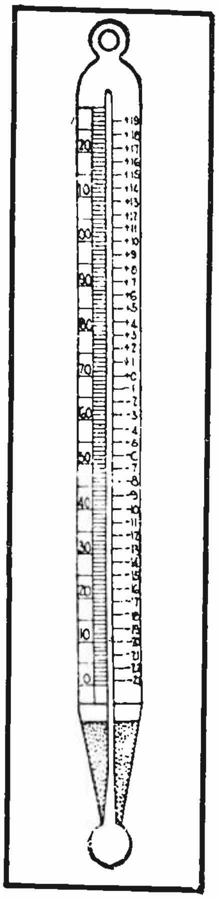

FIG. 14
A Correction Thermometer.

TESTING THE NEGATIVE PLATE GROUP

IN ORDER TO TEST THE NEGATIVE PLATE GROUP IN A SIMILAR MANNER, WE LEAVE THE CADMIUM STICK WITHIN THE ELECTROLYTE, JUST AS WE ALREADY HAVE IT BUT WE BRING OUR OTHER TEST POINT IN CONTACT WITH THE NEGATIVE POST OF THE CELL. NOW WE WATCH THE METER AND IF WE FIND THE READING TO BE 0.175 VOLTS (TO THE LEFT OF ZERO OR THE POINT MARKED "NEG. CHARGED") WE KNOW THAT THE NEGATIVE PLATE GROUP IS FULLY CHARGED. THIS IS ILLUSTRATION IN FIG. 13.

SHOULD WE, HOWEVER, FIND THE READING TO BE 0, THEN THE NEGATIVE GROUP IS ONLY ½ CHARGED AND SHOULD THE READING BE AROUND 0.15 OR 0.18 VOLTS TO THE RIGHT OF ZERO THEN THE NEGATIVE GROUP IS COMPLETELY DISCHARGED.

WITH A TEST, SUCH AS THIS, WE CAN DETERMINE WHICH PARTICULAR PLATE GROUP IS CAUSING ANY CELL FROM REACHING A FULLY CHARGED CONDITION WHILE ON THE CHARGING LINE.

WHAT THE READINGS MEAN

LET US SEE, FOR EXAMPLE JUST WHAT SUCH READINGS INDICATE IF WE USE THEM TOGETHER, SO AS TO OBTAIN THE ACTUAL VOLTAGE OF A CELL. ASSUMING THAT THE CADMIUM TEST FOR THE POSITIVE GROUP INDICATES 2.4 VOLTS AND THE TEST FOR THE NEGATIVE GROUP OF THE SAME CELL INDICATES A VOLTAGE OF -0.17, THEN THE ACTUAL VOLTAGE OF THE CELL WOULD BE 2.4 ADDED TO 0.17 OR 2.57 VOLTS, WHILE STILL ON THE CHARGING LINE.

ON THE OTHER HAND, IF THE READINGS WERE ONLY 2.0 VOLTS FOR THE POSITIVE GROUP AND +0.15 FOR THE NEGATIVE GROUP, THEN OUR ACTUAL CELL VOLTAGE WOULD ONLY BE THE DIFFERENCE BETWEEN 2.0 AND 0.15 OR 1.85 VOLTS WHILE ON THE CHARGING LINE. THIS, OF COURSE, WOULD BE A DISCHARGED CELL. WITH SEPARATE READINGS THUS OBTAINED, IF WE FIND THE POSITIVE GROUP VOLTAGE TEST NORMAL AND THE NEGATIVE GROUP VOLTAGE TEST BELOW NORMAL, WE KNOW THAT THE LOW CELL VOLTAGE IS DUE TO A FAULTY NEGATIVE PLATE GROUP AND VICE VERSA.

THE ACTION OF SULPHATED BATTERIES WHEN ON THE CHARGING LINE

WE HAVEN'T YET CONSIDERED HOW SOME OF THESE FAULTY BATTERIES ACT ON THE CHARGING LINE, SO THIS IS OUR NEXT STEP. YOU WILL REMEMBER THAT IN OUR DISCUSSION OF SULPHATED PLATES, YOU WERE TOLD THAT LEAD SULPHATE PRODUCED CONSIDERABLE ELECTRICAL RESISTANCE. WITH THIS IN MIND, CONSIDER FOR A SECOND WHAT HAPPENS WHEN AN EXCESSIVELY HIGH CHARGING RATE IS FORCED THRU

SUCH A BATTERY, WHICH IS AFFLICTED WITH PLATES COVERED WITH A HIGH RESISTANCE LEAD SULPHATE COATING.

SUCH A CONDITION WILL CAUSE THE BATTERY TO BECOME HOT BECAUSE WHENEVER CURRENT IS FORCED TO FLOW THROUGH A CONDUCTOR OF CONSIDERABLE RESISTANCE, THE CONDUCTOR WILL BECOME HOT. BESIDES THIS, THE SULPHATE COATING ONLY ALLOWS A LIMITED SPACE OF THE PLATE AREA TO BE EFFECTIVE AND THIS WILL ALSO REDUCE THE CAPACITY OF THE PLATES IN REGARDS TO THEIR ABILITY TO CARRY A CURRENT AND THEREFORE, THIS ACTION WILL ALSO PRODUCE HEAT.

FROM THESE FACTS, IT IS OBVIOUS THAT SULPHATED BATTERIES WILL HEAT WHILE ON THE CHARGING LINE, EVEN THOUGH THE CHARGING RATE IS LOW ENOUGH SO THAT THE TEMPERATURE OF THE AVERAGE BATTERIES WILL NOT RISE ABOVE NORMAL. THE QUESTION NOW ARISES AS TO WHAT TEMPERATURE LIMIT WE SHOULD PERMIT A BATTERY TO REACH AND ALSO WHAT ACTION WE SHALL TAKE TO PREVENT A BATTERY FROM BECOMING OVER HEATED.

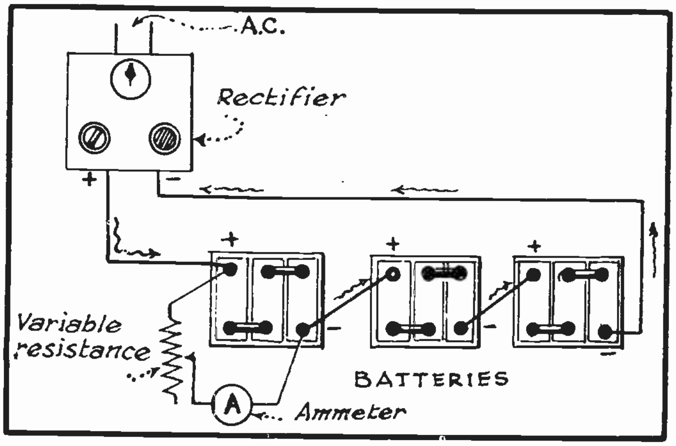

FIG. 15

Reducing the Charging Rate Thru a Heating Battery on a Series Circuit.

CONSIDERING BATTERY TEMPERATURES

IN BATTERY WORK, WE CONSIDER A TEMPERATURE OF 70° F. AS THE NORMAL TEMPERATURE, HOWEVER, BATTERY TEMPERATURES WILL NATURALLY VARY DUE TO ATMOSPHERIC CONDITIONS, THE AMOUNT OF CURRENT PASSING THRU THE BATTERY, ETC. THE DANGER POINT IS REACHED AT ABOUT 110° F. AND A BATTERY SHOULD NEVER BE PERMITTED TO RISE TO A TEMPERATURE ABOVE 110° F.

THE THERMOMETER

SO YOU SEE, WHEN A SULPHATED BATTERY IS ON THE CHARGING LINE, OR FOR THAT MATTER ANY BATTERY, WE MUST GUARD AGAINST EXCESSIVE TEMPERATURES. IN ORDER TO DETERMINE THE TEMPERATURE OF ANY CELL WHILE CHARGING, WE SIMPLY INSERT A THERMOMETER, SUCH AS THE ONE SHOWN IN FIG. 14, INTO THE ELECTROLYTE. AS SOON AS THE TEMPERATURE READING IS THUS OBTAINED, WE WILL REMOVE THE THERMOMETER FROM THE ELECTROLYTE AND ACT ACCORDINGLY, AS YOU WILL NOW BE SHOWN.

PREVENTING A BATTERY FROM OVERHEATING IN A SERIES CIRCUIT

LET US ASSUME THAT A CERTAIN BATTERY, WHICH IS CONNECTED IN A SERIES CHARGING CIRCUIT, SUCH AS IN FIG. 15, IS BECOMING OVER-HEATED, WHEREAS THE REST OF THE BATTERIES ON THE CHARGING LINE ARE STILL AT A PERFECTLY SAFE TEMPERATURE. IT IS OBVIOUS THAT IN THIS CASE, WE WOULD NOT REDUCE THE CHARGING RATE OF THE ENTIRE SYSTEM BECAUSE THIS WOULD SLOW UP THE CHARGING OPERATION OF THE WHOLE ARRANGEMENT AND THIS IS UNNECESSARY, AS WELL AS A WASTE OF TIME.

THEREFORE, IF WE DO NOT WISH TO REMOVE THE HEATING BATTERY FROM THE LINE ALTOGETHER AND PERMIT IT TO COOL BEFORE CONTINUING ITS CHARGE, ALL THAT MUST BE DONE IS TO CONNECT A RESISTANCE UNIT ACROSS IT, AS SHOWN IN FIG. 15. IT IS ALSO A GOOD POLICY TO CONNECT A SEPARATE AMMETER IN SERIES WITH THE VARIABLE RESISTANCE, FOR IN THIS WAY YOU WILL KNOW JUST HOW MUCH CURRENT IS FLOWING THROUGH THE RESISTANCE.

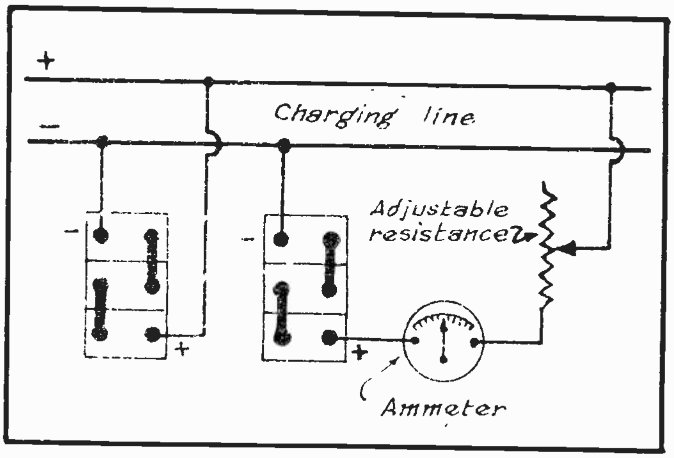

FIG. 16
Reducing the Charging Rate Thru a Heating Battery on a Parallel Circuit.

THE PURPOSE OF THE RESISTANCE

BY CONNECTING THE RESISTANCE IN THIS WAY, OR AS WE SHOULD SAY, IN PARALLEL WITH THE HEATING BATTERY, THE CHARGING CURRENT CAN DIVIDE AT THE BATTERY. THAT IS, PART OF IT WILL FLOW THROUGH THE BATTERY AND PART OF IT WILL FLOW THROUGH THE RESISTANCE BUT ALL OF IT WILL FLOW THROUGH THE REST OF THE BATTERIES.

THE PURPOSE OF THE SEPARATE AMMETER

THE PURPOSE OF THE SEPARATE AMMETER IS THIS: IF WE ONLY HAD THE RESISTANCE CONNECTED ACROSS THE HOT BATTERY, WE WOULDN'T KNOW WHAT PORTION OF THE CURRENT IS FLOWING THROUGH THE RESISTANCE AND WHAT PORTION IS FLOWING THROUGH THE BATTERY. HOWEVER, BY MEANS OF THE SEPARATE AMMETER, WE CAN TELL HOW MUCH OF THE CURRENT IS FLOWING THROUGH THE RESISTANCE AND, THEREFORE, WE CAN READILY TELL HOW MUCH IS FLOWING THROUGH THE HOT BATTERY BY SIMPLY SUBTRACTING THE READING OF THE SEPARATE AMMETER FROM THE READING OF THE CHARGER'S AMMETER. THAT IS, IF 3 AMPS. ARE FLOWING THROUGH THE RESISTANCE THEN 6 MINUS 3 OR 3 AMPS. ARE FLOWING THROUGH THE HOT BATTERY, PROVIDING THAT THE CHARGER IS "PUTTING OUT" 6 AMPS. THE OTHER BATTERIES, HOWEVER, WILL RECEIVE THEIR FULL QUOTA OR 6 AMPS. BECAUSE THE PARALLEL PATHS OF THE FIRST BATTERY, JOIN AT THE NEGATIVE TERMINAL OF THE SAME BATTERY.

BY HAVING THE RESISTANCE UNIT VARIABLE, THAT IS, ADJUSTABLE, YOU CAN REGULATE THE CURRENT FLOW THROUGH THE HOT BATTERY.

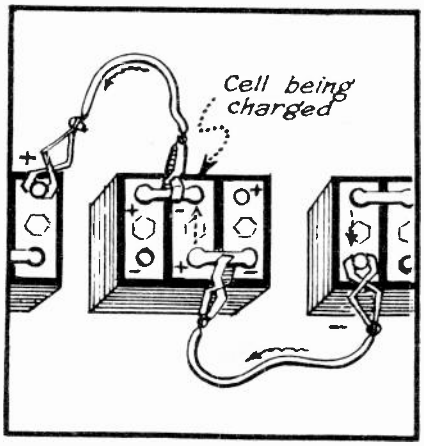

FIG. 17
Charging a Single Cell.

PREVENTING A BATTERY FROM OVER-HEATING IN A PARALLEL CIRCUIT

IN CASE THAT YOU ARE OPERATING A PARALLEL CHARGER INSTEAD OF A SERIES CHARGER, THEN YOU CONNECT THE AMMETER AND RESISTANCE IN SERIES WITH THE HOT BATTERY, AS SHOWN IN FIG. 16. HERE THE CHARGING CURRENT WILL COME FROM THE (+) BUSS BAR AND THENCE THROUGH THE RESISTANCE UNIT, AMMETER, BATTERY, AND BACK TO THE (–) BUSS BAR OF THE CHARGING LINE. BY CONTROLLING THE AMOUNT OF RESISTANCE, THE CHARGING RATE THROUGH THE HEATED BATTERY CAN LIKEWISE

BE CONTROLLED. THE NORMAL BATTERY, HAVING NO RESISTANCE CONNECTED TO IT, WILL, THEREFORE, RECEIVE ITS FULL AMOUNT OF CHARGING CURRENT.

CHARGING ONE CELL IN A SERIES CIRCUIT

SOMETIMES WHEN YOU ONLY WISH TO CHARGE ONE CELL OF A BATTERY, AS MAY BE THE CASE WHEN ALL THE OTHER CELLS ARE PERFECT BUT THE ONE CELL HAVING HAD TO BE REBUILT BECAUSE OF SOME FAULT, THEN YOU CAN CHARGE THIS ONE CELL AS SHOWN IN FIG. 17, WHEN A SERIES CHARGING CIRCUIT IS BEING USED.

CHARGING ONE CELL IN A PARALLEL CIRCUIT

TO CHARGE ONE CELL OF A BATTERY WHEN A PARALLEL CHARGING CIRCUIT IS USED, YOU CAN CONNECT THE CELL TO THE CHARGING LINE, AS SHOWN IN FIG. 18 WITH AN AMMETER AND VARIABLE RESISTANCE IN SERIES.

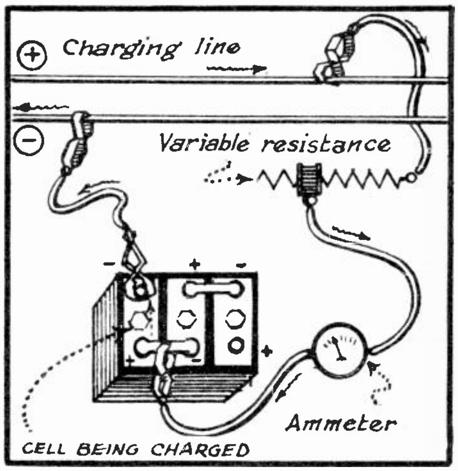

FIG. 18
Charging a Single Cell on a Parallel Charging Circuit.

CYCLING BATTERIES

IN THE EARLIER PART OF THIS LESSON, YOU WERE TOLD THAT YOU WOULD BE SHOWN A METHOD OF BRINGING SULPHATED BATTERIES BACK TO A MORE ACTIVE SERVICE. IF THE STATE OF SULPHATION IS NOT TOO BAD, WE RESORT TO THE PROCESS KNOWN AS CYCLING BUT IN EXTREME CASES OF SULPHATED PLATES, EITHER NEW PLATES OR ELSE A NEW BATTERY WILL BE REQUIRED.

TO CYCLE A BATTERY, WE FIRST CHARGE IT AT A SLOW RATE UNTIL ITS STATE OF CHARGE WILL COME UP TO AS NEARLY A FULLY CHARGED CONDITION AS POSSIBLE. THEN WE DISCHARGE IT AT A CONTROLLED RATE BY MEANS OF SOME KIND OF A RESISTANCE. THE RATE OF DISCHARGE SHOULD BE ABOUT 2 OR 3 AMPERES PER POSITIVE PLATE PER CELL. THAT IS, WE CAN DISCHARGE AN 11 PLATE BATTERY AT THE RATE OF ABOUT 15 AMPS.

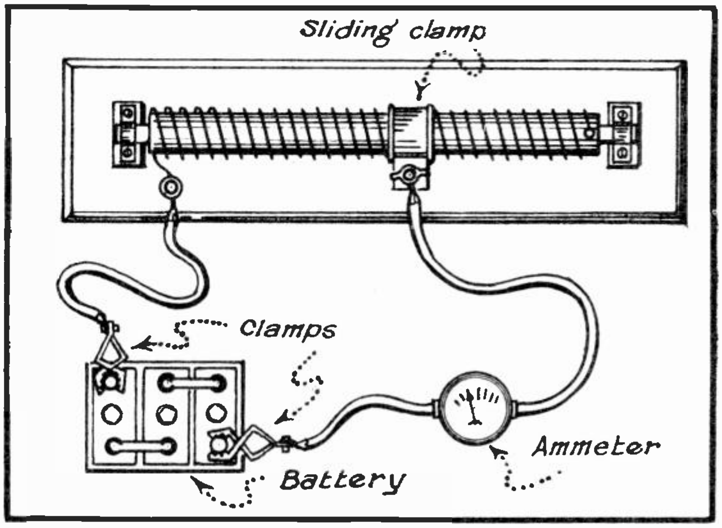

FIG. 19
Discharging a Battery by Means of a Variable Resistance Unit.

CONTROLLING THE RATE OF DISCHARGE

TO CONTROL THE RATE OF DISCHARGE, SEVERAL DEVICES CAN BE USED. A MOST COMMON ONE IS SHOWN IN FIG. 19 AND IN THIS CASE, A VARIABLE RESISTANCE UNIT, WITH AN AMMETER IN SERIES IS CONNECTED ACROSS THE TERMINALS OF THE BATTERY. THIS WILL OFFER A COMPLETE CIRCUIT SO THAT THE BATTERY WILL DISCHARGE ITSELF. THIS SIMPLE RESISTANCE UNIT, SIMPLY CONSISTS OF A $1\frac{1}{4}''$

PIPE WHICH IS COVERED WITH ASBESTOS AND WRAPPED WITH #14 IRON WIRE, THE TURNS BEING SPACED SO AS NOT TO TOUCH EACH OTHER. THE RATE OF DISCHARGE IS REGULATED BY MOVING A SLIDING CONTACT TO THE REQUIRED POSITION, SO THAT THE CORRECT AMOUNT OF RESISTANCE (IRON WIRE) WILL BE INCLUDED IN THE CIRCUIT.

WE PERMIT THE BATTERY TO CONTINUE DISCHARGING IN THIS WAY, UNTIL THE VOLTAGE OF EACH CELL REACHES A POINT OF ABOUT 1.6 OR 1.7 VOLTS, BUT NEVER LOWER. THE BATTERY IS THEN DISCONNECTED FROM THE RESISTANCE AND THEN AGAIN CONNECTED TO THE CHARGING LINE.

THIS PROCESS OF CHARGING AND DISCHARGING IS CONTINUED UNTIL THE BATTERY WILL SUBMIT TO BEING FULLY CHARGED AND ALSO HOLDING ITS CHARGE. IT MAY TAKE THREE OR FOUR OF THESE CYCLES (CHARGES & DISCHARGES) TO GET RID OF MOST OF THE LEAD SULPHATE COATING, WHICH WAS ON THE PLATES. NEW BATTERIES OR BATTERIES PROVIDED WITH NEW PLATES, MUST ALSO BE CYCLED IN THIS WAY BEFORE THEY ARE PUT INTO ACTIVE SERVICE.

THE CORRECTION THERMOMETER

LET US NOW CONSIDER ANOTHER IMPORTANT USE OF THE THERMOMETER, WHICH WAS SHOWN YOU IN FIG. 14. NOTICE THAT TO THE RIGHT OF THE TEMPERATURE GRADUATIONS, A COLUMN OF FIGURES IS ARRANGED, THE ZERO FIGURE BEING EVEN WITH THE 70° MARK. THEN AT INTERVALS OF EVERY THREE DEGREES ABOVE 70°, YOU WILL SEE THE FIGURES +1, +2, +3, ETC; WHERES BELOW 70°, YOU WILL SEE THE FIGURES -1, -2, -3, ETC. SPACED EQUALLY OR AT INTERVALS OF 3 DEGREES.

THESE FIGURES ARE USED FOR MAKING TEMPERATURE CORRECTIONS WHEN HYDROMETER READINGS ARE TAKEN. THE REASON FOR THIS IS THAT THE HYDROMETER WAS DESIGNED AND CALIBRATED TO READ CORRECTLY AT A NORMAL TEMPERATURE OF 70°F. CONSEQUENTLY, AT TEMPERATURES ABOVE OR BELOW 70°F, THE HYDROMETER READINGS WILL BE IN ERROR.

TO USE THIS CORRECTION THERMOMETER, YOU FIRST TEST THE SPECIFIC GRAVITY OF THE ELECTROLYTE IN THE CONVENTIONAL MANNER AND THEN AFTER RETURNING THE TESTED ELECTROLYTE TO THE CELL FROM WHICH IT WAS WITHDRAWN, YOU INSERT THE THERMOMETER INTO THE ELECTROLYTE. IF THE THERMOMETER READING SHOULD BE 100°F., YOU WILL FIND THE NUMBER +10 RIGHT NEXT TO IT. THIS MEANS THAT IN ORDER TO OBTAIN A CORRECT SPECIFIC GRAVITY READING, 10 POINTS WILL HAVE TO BE ADDED TO THE ACTUAL HYDROMETER READING. THAT IS, IF THE HYDROMETER READING IS 1.250 AT A TEMPERATURE OF 100°F., THEN THE CORRECT SPECIFIC GRAVITY IS 1.250+10 POINTS, WHICH EQUALS 1.260.

WHEN THE TEMPERATURE OF THE ELECTROLYTE IS BELOW 70° F. SAY FOR INSTANCE 40°F., THEN WE MUST SUBTACT 10 POINTS FROM THE HYDROMETER READING. THIS WOULD MEAN THAT IF THE HYDROMETER READING IS 1.250 AT 40°F, THEN THE CORRECT SPECIFIC GRAVITY IS 1.250 MINUS 10 POINTS OR 1.240. IN OTHER WORDS, FOR EVERY THREE DEGREES ABOVE 70°F., ONE POINT IS ADDED TO THE HYDROMETER READING AND FOR EVERY THREE DEGREES BELOW 70° F., ONE POINT IS SUBTRACTED FROM THE HYDROMETER READING, IN ORDER TO OBTAIN A CORRECT VALUE FOR THE SPECIFIC GRAVITY.

FROM THIS EXPLANATION YOU WILL SEE HOW IT IS POSSIBLE TO OBTAIN AN ABSOLUTELY ACCURATE SPECIFIC GRAVITY READING REGARDLESS OF THE ELECTROLYTE'S TEMPERATURE AT THE TIME THE READING IS TAKEN.

CIRCUIT OF A TEN-BATTERY TUNGAR RECTIFIER

NO DOUBT, YOU ARE INTERESTED IN THE CONSTRUCTIONAL FEATURES OF A COMMERCIAL TUNGAR BATTERY CHARGER, SO IN FIG. 20 WE ARE SHOWING YOU THE INTERNAL WIRING FOR A TYPICAL TUNGAR RECTIFIER WHICH IS CAPABLE OF HANDLING TEN BATTERIES AT ONE TIME.

WITH THE SPECIAL SWITCH IN THE CLOSED POSITION, THE A.C. LINE IS CONNECTED ACROSS THE PRIMARY WINDING OF THE CHARGER'S TRANSFORMER AT TERMINALS 1, 2, 3 AND 4 WHILE THE D.C. PART OF THE CIRCUIT IS ALSO COMPLETED AT THE SAME ACROSS TERMINALS 5 AND 6.

A STEP-UP IN VOLTAGE IS OBTAINED AT THE SECONDARY WINDING OF THE TRANSFORMER BUT THE MANY POINTS AT WHICH TAPS ARE TAKEN OFF THIS WINDING, MAKES A VARIETY OF LOWER SECONDARY VOLTAGES AVAILABLE. FOR INSTANCE, THAT PORTION OF THE SECONDARY WINDING INCLUDED BETWEEN ITS RIGHT END AND THE TAP NEXT TO IT FURNISHES A LOW VOLTAGE WITH WHICH TO HEAT THE FILAMENT OF THE TUNGAR BULB OR TUBE.

THE VARIOUS CONTACT BUTTONS OF THE DIAL SWITCH, WHICH ARE NUMBERED FROM 1 TO 15 IN CONSECUTIVE ORDER AND CONNECTED TO THE TAPS OF THE SECONDARY WINDING WHICH ARE CORRESPONDINGLY NUMBERED, OFFER A MEANS WHEREBY THE EFFECTIVE PLATE VOLTAGE AT THE TUNGAR BULB CAN BE REGULATED SIMPLY BY CHANGING THE POSITION OF THE DIAL SWITCHES CONTROL ARM. THE CHARGING CURRENT IS INCREASED AS THE PLATE VOLTAGE UPON THE BULB IS INCREASED BY MEANS OF THE DIAL SWITCH.

THE TUNGAR BULB ITSELF HAS A FILAMENT AND A PLATE AS ITS ACTIVE ELEMENTS AND THUS FUNCTIONS AS A CONVENTIONAL HALF-WAVE RECTIFIER. ITS CONSTRUCTION, HOWEVER, IS SUCH THAT IT CAN PASS A NORMAL DIRECT CURRENT OF ABOUT 6 AMPERES.

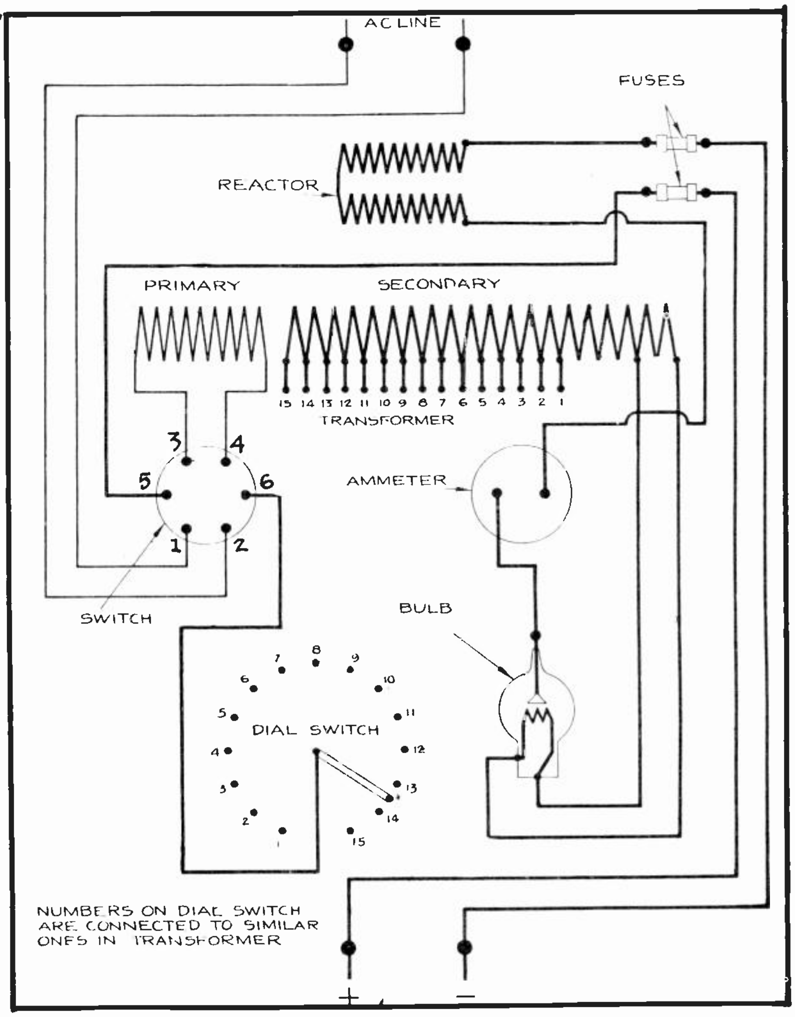

FIG. 20

Wiring Diagram of a Tungar Battery Charging Set.

THE AMMETER IS CONNECTED IN SERIES WITH THE D.C. CIRCUIT SO AS TO INDICATE THE CHARGING CURRENT AND THE REACTOR IS NOTHING MORE THAN A SPECIAL FILTER CHOKE, USED TO ASSIST IN OBTAINING A MORE UNIFORM CHARGING

CURRENT.

UPON COMPLETING THIS GROUP OF STORAGE BATTERY LESSONS, YOU SHOULD NOW HAVE A GOOD PRACTICAL KNOWLEDGE OF THIS TYPE OF BATTERY FROM A STANDPOINT OF BOTH CONSTRUCTION AND SERVICING.

EVEN THOUGH YOU MAY NOT INTEND TO ACTUALLY ENGAGE IN THE BATTERY BUSINESS, YOU SHOULD NEVERTHELESS FIND THESE BATTERY LESSONS TO BE OF VALUE TO YOU. AFTER ALL, THE STORAGE BATTERY PLAYS AN IMPORTANT PART IN YOUR CHOSEN FIELD AND BY HAVING THIS INFORMATION, YOUR GENERAL KNOWLEDGE OF THE SUBJECT IS EXPANDED.

Examination Questions

Answered August 9/1940

LESSON NO. 34

RB-1712

1. - HOW DOES A HARDENED COATING OF LEAD SULPHATE AFFECT A CELL AND ITS PLATES?

2. - WHAT IS MEANT BY THE TERM BUCKLED PLATES? HOW MAY THIS CONDITION BE CAUSED AND WHAT WOULD YOU DO IF YOU HAD TO CORRECT SUCH A FAULTY CONDITION?

3. - HOW WILL AN EXCESSIVE AMOUNT OF SHEDDING AFFECT A CELL?

4. - AT ABOUT WHAT TEMPERATURE WILL A DISCHARGED BATTERY FREEZE? AT ABOUT WHAT TEMPERATURE WILL A FULLY CHARGED BATTERY FREEZE?

5. - IF YOU SHOULD DISASSEMBLE A CELL, WOULD YOU PUT THE SAME WOODEN SEPARATORS BACK INTO THE CELL?

6. - DESCRIBE A HIGH RATE DISCHARGE TESTER? WHY IS IT USED?

7. - WHAT IS THE OBJECT OF MAKING A CADMIUM VOLT TEST? CAN THIS TEST BE MADE AND ACCURATE RESULTS OBTAINED IF THE BATTERY IS STANDING IDLE?

8. - WHAT IS THE HIGHEST TEMPERATURE, WHICH A BATTERY SHOULD BE ALLOWED TO REACH? DRAW A SIMPLE DIAGRAM SHOWING HOW YOU WOULD PREVENT A BATTERY FROM OVER-HEATING WHILE ON A SERIES CHARGING CIRCUIT.

9. - WHY ARE BATTERIES OFTEN CYCLED?

10. - WHY IS THE CORRECTION THERMOMETER USED?

RADIO - TELEVISION

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

NATIONAL SCHOOLS

Established 1905

Los Angeles, California

LESSON NO. 35

RADIO - PHONOGRAPH COMBINATIONS
TONE CONTROLS

As we have said so many times before, "Radio is never at a standstill." This is one of the chief reasons why radio is so fascinating for the man who likes to do things and who is always looking forward to see new developments take place. As, we look back over the years, we find that the radio receiver in its early stages was indeed a crude affair both as to appearance and performance.

The first radio improvements were practically all confined to bettering performance and very little attention was devoted to improving appearance or ease of operation. In fact, the early radio developments were made for the benefit of those people who knew something about the technical phases of radio, rather than for the general public. This is the one big reason why the radio fans of yesterday were entirely different to what we know then today. These former radio fans were eager to tinker with the "works" of their radio receiver but not so today, for now the radio enthusiasts are content with making themselves comfortable in an easy chair, to tune in a good program and then to relax and enjoy the entertainment.

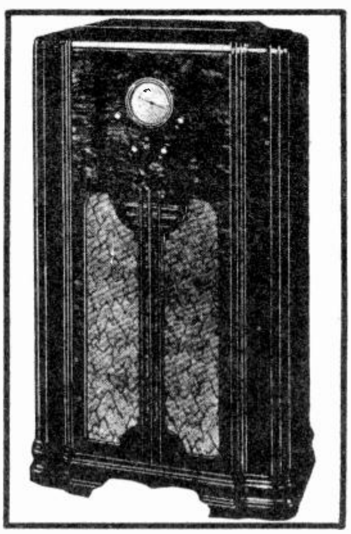

FIG. 1
Radio-Phonograph Combination.

During all these later years of radio progress however, designers and manufacturers devoted a great deal of effort toward not only improving radio performance but they have also succeeded remarkably well in producing receivers of beautiful appearance, which will equal that of the highest quality furniture and furthermore, so few controls remain that a small child can now successfully operate these powerful present day receivers.

Naturally, with all of these advanced designs, many improvements were incorporated and in this lesson, it is our aim to acquaint you with many of these later developments and in addition, we are also going to show how modern radio receiver's can be applied in the home for other types of entertainment besides just plain radio reception.

Radio-Phonograph Combinations

A factory built receiver of this type is shown you in Fig. I and with this arrangement, it is possible for the owner to listen either to radio broadcast programs or to the recordings of his own phonograph records -- either type of program being reproduceo by the radio loud speaker.

Factory built radio-phonograph combinations, such as pictured in Fig. I, are of course quite a bit more expensive than a plain radio receiver. This is due to the additional equipment needed for the reproduc-

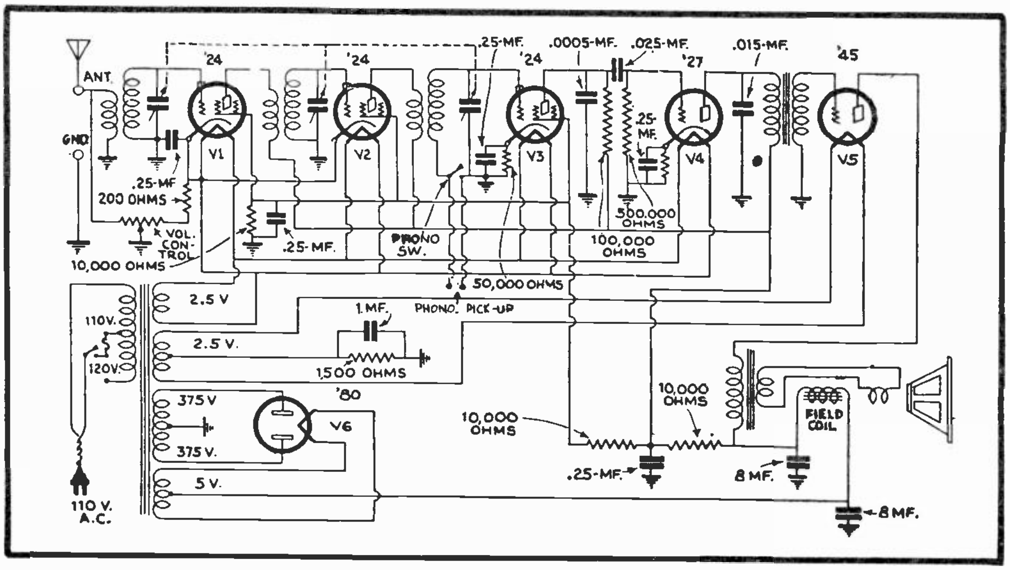

FIG. 2

A Midget Receiver With a Phonograph Pick-up Connection.

tion of phonograph records and also the the fact that the cabinet work of the combination set is generally more expensively designed. No doubt, it is on account of the additional cost of the combination set that we do not see more of them in the average home. Nevertheless, the unit forms an ideal combination, so that one can have entertainment of his own choosing, as well as that being transmitted by broadcast stations.

The owner of such a set can get a great deal of enjoyment by playing his favorite phonograph records upon which are recorded the work of famous artists. Furthermore, a well designed radio-phonograph reproducer will provide a higher type of tone quality from these recordings as will the average type of phonograph and so you can see that not only is the radio-phonograph combination convient but it is also efficient.

The top of the receiver cabinet illustrated in Fig. I is designed to be raised on its hinges so as to expose the turntable and the miscellaneous phonograph attachments when recordings are to be played.

It so happens that many people already possess a phonograph at the

TIME THAT THEY ADD A RADIO RECEIVER TO THEIR SOURCE OF ENTERTAINMENT AND THIS IS YOUR BIG OPPORTUNITY. THE THING TO DO HERE IS TO MAKE IT POSSIBLE FOR THE OWNER TO REPRODUCE HIS RECORDS WITH HIS NEW RADIO BY STILL USING THE PHONOGRAPH AS PART OF THE MECHANISM. YOU ARE GIVEN FULL INFORMATION IN THIS LESSON AS TO HOW TO DO THIS PROFITABLE WORK.

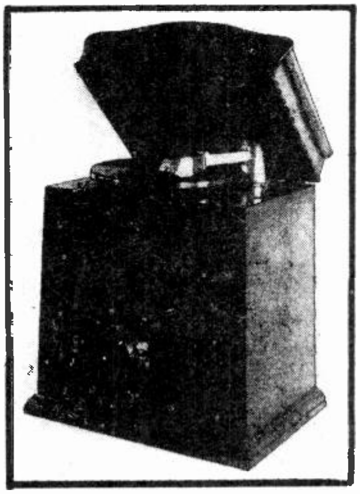

FIG. 3
Midget Radio Phono. Combination.

AS FAR AS THE RECEIVER CIRCUITS OF THE RADIO-PHONOGRAPH COMBINATIONS ARE CONCERNED, YOU WILL FIND THEM TO BE PRACTICALLY THE SAME AS THAT OF THE AVERAGE TYPE OF RADIO RECEIVERS. THAT IS, THEY CONSIST OF THE CONVENTIONAL TUNED AND R.F. AMPLIFYING STAGES, A DETECTOR AND AN AUDIO AMPLIFIER

RADIO-PHONOGRAPH CIRCUIT OF THE MIDGET TYPE

FOR THE SAKE OF SIMPLICITY AND SO THAT YOU WON'T HAVE TOO MANY CIRCUITS TO TRACE OUT, WE ARE SHOWING YOU IN FIG. 2 A CIRCUIT DIAGRAM OF A MIDGET RECEIVER IN WHICH A PHONOGRAPH PICK UP CIRCUIT IS INCORPORATED. A PHOTOGRAPH OF THIS SAME MIDGET TYPE RADIO-PHONOGRAPH IS SHOWN YOU IN FIG. 3 AND IN THIS LATTER ILLUSTRATION, YOU ARE LOOKING AT THE RECEIVER WHILE THE COVER IS BEING HELD OPEN SO AS TO EXPOSE THE TURNTABLE WITH THE RECORD, AS WELL AS THE PICKUP UNIT.

NOW RETURNING TO THE CIRCUIT DIAGRAM OF THIS RECEIVER IN FIG2, YOU WILL NOTE THAT IN THIS PARTICULAR CASE, TWO STAGES OF TUNED R.F. AMPLIFICATION PRECEDE A POWER DETECTOR AND THE DETECTOR STAGE IS FOLLOWED BY ONE STAGE OF RESISTANCE - CAPACITY COUPLED AUDIO AMPLIFICATION AND A SINGLE TYPE -45 TUBE IS USED IN THE FINAL OR POWER STAGE. THEN OF COURSE, WE HAVE THE CUSTOMARY POWER PACK AND SPEAKER COUPLING.

THE MOST IMPORTANT THING FOR YOU TO NOTICE AT THIS TIME IS THE LOCATION FOR THE PHONOGRAPH PICK-UP UNIT CONNECTIONS. AS YOU WILL NOTE IN FIG. 2, A SWITCH IS INSTALLED IN THE GRID CIRCUIT OF THE DETECTOR TUBE AND THE TERMINALS FOR THE PHONOGRAPH PICK UP UNIT ARE CONNECTED ACROSS THESE TWO SWITCH TERMINALS. WITH THIS SWITCH CLOSED, THE GRID CIRCUIT FOR THE DETECTOR IS COMPLETE SO THAT CUSTOMARY RADIO RECEPTION WILL BE OBTAINED.

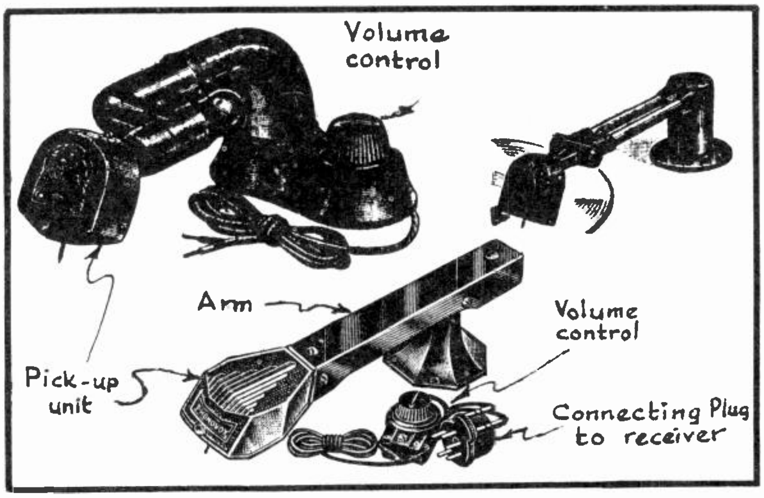

FIG. 4
Three Types of Phonograph Pick-ups.

BY OPENING THIS SAME SWITCH, IT IS CLEAR

THAT THIS GRID CIRCUIT WILL NOW BE COMPLETED THROUGH THE PHONOGRAPH PICK-UP UNIT.

THE PICK-UP UNIT

THREE TYPES OF COMMONLY USED PHONOGRAPH PICK-UPS ARE SHOWN IN FIG.4. THE UNIT AT THE UPPER LEFT HAS THE VOLUME CONTROL BUILT DIRECTLY INTO THE ASSEMBLY WHILE THE UNIT AT THE UPPER RIGHT REQUIRES THE VOLUME CONTROL TO BE LOCATED EITHER AT THE RECEIVER OR SOME OTHER SUITABLE POINT. THE UNIT AT THE LOWER CENTER OF FIG. 4 HAS THE VOLUME CONTROL ATTACHED BY A CABLE SO THAT IT CAN BE MOUNTED WHEREVER DESIRED.

BEFORE CONTINUING WITH THE DETAILS REGARDING THE CONSTRUCTIONAL FEATURES OF THESE PICK UP UNITS, AS WELL AS THEIR OPERATING PRINCIPLES, IT IS ADVISABLE TO FIRST TELL YOU SOMETHING ABOUT THE PHONOGRAPH RECORD UPON WHICH THE OPERATION OF THE PICK UP UNIT IS IN A LARGE MEASURE DEPENDENT.

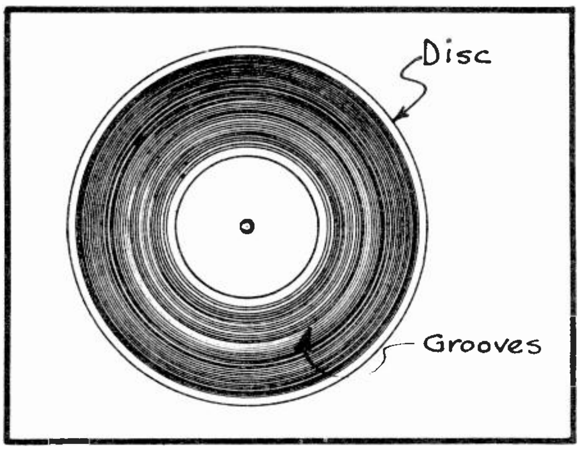

FIG. 5
The Phonograph Record.

AS YOU PROBABLY ALREADY KNOW, THE FLAT SURFACE OF THE CONVENTIONAL DISC TYPE PHONOGRAPH RECORD HAS A SPIRAL SHAPED GROOVE CUT INTO IT. THIS GROOVE STARTS NEAR THE CENTER OF THE RECORD AND GRADUALLY WORKS ITS WAY TOWARD THE CIRCUMFERENCE OR RIM OF THE RECORD. IN FIG. 5 THIS GROOVE IS ILLUSTRATED FOR YOU IN A RATHER EXAGGERATED MANNER SO AS TO MAKE THIS POINT CLEAR.

ACTUALLY, THIS SPIRAL GROOVE IS NOT UNIFORM IN THAT SMALL WAVES ARE CUT ALONG THE SIDES OF THE GROOVE SOMEWHAT AS ILLUSTRATED IN FIG.6, WHERE YOU ARE LOOKING AT A MAGNIFIED SECTION OF A RECORDED SURFACE. THESE WAVES CORRESPOND TO THE AUDIO FREQUENCIES OF THE SOUNDS WHICH WERE PRODUCED IN THE STUDIOS AT THE TIME OF RECORDING. WE MIGHT SAY THAT THESE WAVES "MODULATE" THE GROOVE OR THAT THE GROOVE IS "MODULATED" BY THEM.

FOR THE PRESENT, THIS IS ALL THAT YOU NEED TO KNOW REGARDING THE RECORD ITSELF. IN ANOTHER SECTION OF THE COURSE, THE PROCESS OF RECORDING IS TREATED IN DETAIL.

NOW FOR THE MECHANISM OF THE PICK UP UNIT.

THE ELECTROMAGNETIC PHONOGRAPH PICK-UP

THE CONSTRUCTIONAL DETAILS OF AN ELECTROMAGNETIC PHONOGRAPH PICK UP ARE SHOWN IN FIG. 7. IN APPEARANCE, IT IS QUITE SIMILAR TO A BALANCED ARMATURE TYPE SPEAKER UNIT. THE OPERATING PRINCIPLES OF THIS PICK UP DEVICE ARE, HOWEVER, DIFFERENT FROM ANY OF THOSE SO FAR GIVEN YOU.

REGARDING THE CONSTRUCTION OF THE PICK UP UNIT, WE HAVE FIRST A PERMANENT MAGNET, WHICH IS BENT INTO THE SHAPE OF A HORSESHOE AND A "U" SHAPED POLE PIECE IS CONNECTED TO EACH OF ITS EXTREMETIES.

In Fig. 7, you are looking at the pick up unit from the front and here you can see how the light armature is pivoted at its lower end between the pole pieces. A small piece of metal projects to each side of the armature at this point, thus making it "T" shaped and in our illustration, these projections are perpendicular to the paper and can therefore not be seen very clearly. One of these is in front and the other in the back. A rubber sleeve is slipped over them and is clamped between the lower portion of the pole pieces, thus permitting the armature to vibrate from right to left with its pivot at the lower end.

At the center portion, a coil surrounds the armature and the ends of this coil are connected across the input of the A.F. amplifier. Now if we should apply a vibrating force from right to left at the needle point, it is logical that the armature will rock on its pivot correspondingly.

Due to the fact that the armature is of a metal alloy structure, it is no more but natural that it should have a resonance frequency of its own. In the best modern pickups, this resonance point usually lies between frequencies of 3000 and 4000 cycles and so in order to prevent an excessive response at these frequencies, it is necessary to damp the system. This is generally accomplished by means of rubber buffers, which are applied to the free end of the armature. (These are mounted on the upper portion of the pole pieces as shown in Fig. 7.) These buffers at the same time also serve to center the armature in the magnetic air gap.

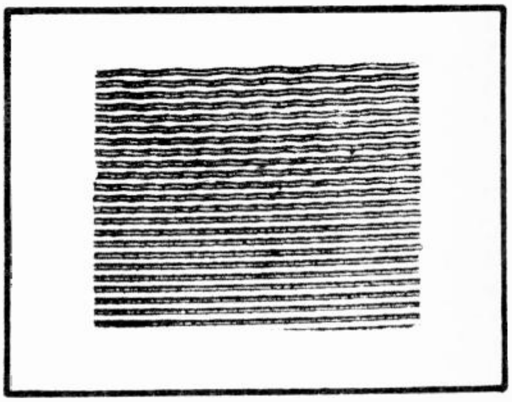

FIG. 6
The Modulated Groove.

Not only does this buffer system affect the resonant frequency but it damps the higher frequencies more than it does the lower ones, thus bringing out the lower tones in proportion to the higher ones. The effective range of the best modern electromagnetic pickups is from about 100 to 5000 cycles, which corresponds to the usual range of the phonograph record.

In some of the expensive electromagnetic pickup units, damping is accomplished through the use of a heavy oil, which is contained within a chamber and against whose resistance the armature must vibrate.

REPRODUCING SOUND FROM THE RECORDS

The pickup unit is mounted on the end of a pivoted arm so that its needle may ride in the groove of the record as the record rotates about its center on a turntable. Some pick up assemblies are equipped with an adjustable counterweight by means of which the needle pressure upon the record can be adjusted.

As the turn table rotates the record, the sharp pointed needle of the pickup unit must follow the spiral groove in the surface of the record. The groove, you will recall, has been modulated in the form of deviations to either side of the groove and therefore these irregularities will

CAUSE THE PICKUP NEEDLE TO VIBRATE FROM SIDE TO SIDE IN DIRECT RELATION TO THESE IRREGULAR IMPRESSIONS IN THE GROOVE OF THE RECORD.

THE ARMATURE OF THE PICKUP MUST VIBRATE FROM SIDE TO SIDE IN STEP WITH ITS NEEDLE AND IN DOING SO, THE FLUX (LINES OF FORCE) IN THE AIR GAP OF THE PERMANENT MAGNET VARIES CORRESPONDINGLY. THIS VARIATION IN THE PICKUP'S MAGNETIC FIELD REACTS UPON ITS COIL SO AS TO INDUCE VOLTAGE CHANGES IN IT, WHICH ARE THE EXACT ELECTRIC REPRESENTATION OF THE WAVE GROOVE OF THE RECORD, WHICH MOVES PAST THE PICKUP NEEDLE, THEREBY ACTUATING THE ARMATURE OF THE PICKUP.

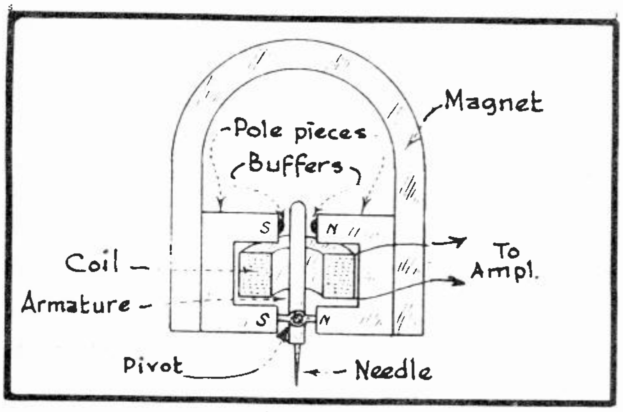

FIG. 7
Construction of the Electro Magnetic Phonograph Pick-up.

SINCE THESE VOLTAGE CHANGES ACROSS THE PICKUP COIL ARE THE EXACT ELECTRICAL REPRODUCTION OF THE VARIATIONS IN THE GROOVES OF THE RECORD WHICH IN TURN CORRESPOND TO THE AUDIO FREQUENCIES WHICH WERE RECORDED, WE CAN READILY APPLY THESE VOLTAGE CHANGES ACROSS THE GRID OF A VACUUM TUBE AND THUS BY THE CONVENTIONAL STEPS OF AUDIO FREQUENCY AMPLIFICATION OPERATE A SPEAKER UNIT WITH A GREAT DEAL OF FORCE. THE SPEAKER MUST THEN REPRODUCE THE SOUNDS WHICH WERE ORIGINALLY RECORDED ON THE RECORD.

A TYPICAL VOLUME CONTROL FOR A PHONOGRAPH

IN THE UPPER ILLUSTRATION OF FIG. 8, YOU WILL SEE HOW THE ELECTROMAGNETIC PICKUP UNIT IS REPRESENTED IN THE FORM OF A RADIO SYMBOL AND HOW IT IS CONNECTED TO THE FIRST OR INPUT TUBE OF AN AUDIO AMPLIFIER. THIS ILLUSTRATION ALSO SHOWS YOU HOW THE VOLUME CAN BE CONTROLLED BY MEANS OF A POTENTIOMETER, WHICH IS CONNECTED ACROSS THE ENDS OF THE PICKUP COIL.

THIS SAME ARRANGEMENT CAN BE USED WHEN COUPLING A A PHONOGRAPH PICK-UP TO AN A.F. AMPLIFIER OF THE PUBLIC ADDRESS TYPE, OR TO THE AUDIO AMPLIFIER OF A RADIO RECEIVER AND IN THE LATTER CASE, THE INPUT TUBE CAN BE EITHER THE DETECTOR OR ELSE THE FIRST AUDIO TUBE.

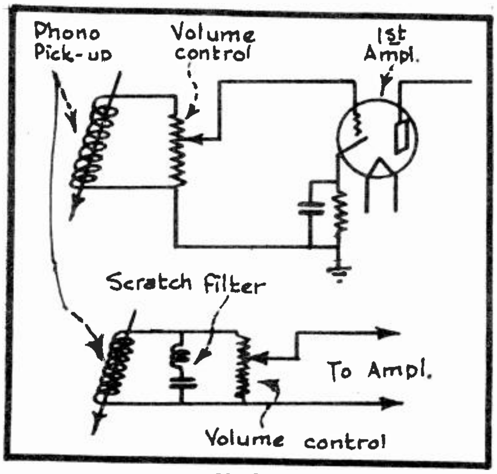

FIG. 8
Controlling Vol. With a Pick-up Unit and Reducing "Needle Scratch."

NOTICE ESPECIALLY HOW THE END TERMINALS OF THE VOLUME CONTROL POTENTIOMETER ARE CONNECTED ACROSS THE ENDS OF THE PICKUP'S COIL—IN THIS WAY BEING CONNECTED IN PARALLEL WITH THE COIL.

WITH THE CONNECTIONS THUS MADE, THE VOLTAGES WHICH ARE GENERATED ACROSS THE ENDS OF THE PICKUP COIL WILL ALSO BE AVAILABLE ACROSS THE ENDS OF THE POTENTIOMETER'S RESISTANCE ELEMENT. THEN BY CONNECTING ONE END OF THE POTENTIOMETER TO THE "GRID RETURN" END OF THE CIRCUIT WHILE THE

CONTROL ARM TERMINAL OF THE SAME UNIT IS CONNECTED TO THE GRID OF THE TUBE, VARYING AMOUNTS OF THE POTENTIOMETER'S RESISTANCE ELEMENT CAN BE USED IN ORDER TO APPLY THE SIGNAL VOLTAGES ACROSS THE GRID CIRCUIT OF THE TUBE. IN OTHER WORDS, THE VOLTAGE DROP WHICH IS DEVELOPED ACROSS THE RESISTANCE ELEMENT INCLUDED BETWEEN THE ARM AND THE GRID RETURN END IS APPLIED TO THE GRID CIRCUIT.

THE GREATER THE RESISTANCE VALUE INCLUDED BETWEEN THESE TWO POINTS, THE GREATER WILL BE THE SIGNAL VOLTAGE IMPRESSED UPON THE GRID CIRCUIT AND THE VOLUME WILL INCREASE ACCORDINGLY. BY ADJUSTING THE POSITION OF THE POTENTIOMETER ARM ON ITS RESISTANCE ELEMENT, WE THUS HAVE AN EFFECTIVE MEANS FOR CONTROLLING THE VOLUME.

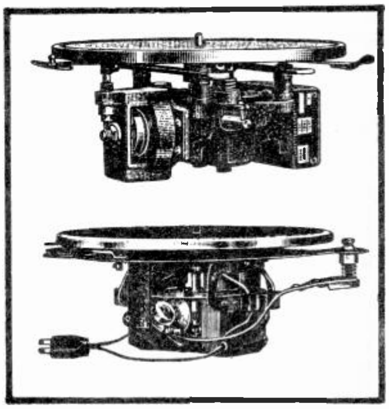

FIG. 9
Electric Phono. Turntable.

NEEDLE SCRATCH

QUITE OFTEN, A DISAGREEABLE SCRATCHING SOUND IS NOTICED DURING THE REPRODUCTION OF A RECORD. WE COMMONLY CALL THIS NEEDLE SCRATCH AND IT IS PRIMARILY CAUSE BY THE ADDED IRREGULARITIES WHICH HAVE BEEN INTRODUCED UPON THE SURFACE OF THE RECORD BY HIGH NEEDLE PRESSURES AND THE NECESSARY ABRASSIVE CHARACTERISTIC OF THE RECORD ITSELF, WHICH IS REQUIRED TO QUICKLY WEAR THE PICKUP NEEDLE DOWN TO A GOOD FIT FOR THE GROOVE. IN THE LOWER ILLUSTRATION OF FIG. 8, ONE OF THE METHODS IS SHOWN WHEREBY SOME OF THESE EXTRANEOUS NOISES CAN BE REDUCED. HERE A RESONANT CIRCUIT, CONSISTING OF A SERIES CONNECTED INDUCTANCE AND A CONDENSER IS SHUNTED ACROSS THE PICKUP COIL AND IT IS TUNED TO THE MOST BOTHERSOME NOISE FREQUENCY,, THEREBY PREVENTING THIS UNDESIRABLE FREQUENCY FROM BEING AMPLIFIED.

RECENT ADVANCEMENTS IN RECORD AND PICKUP CONSTRUCTION HAVE REDUCED SURFACE SCRATCH MATERIALLY TO WHAT WE HAD TO CONTEND WITH SEVERAL YEARS AGO.

THE TURNTABLE

FOR ROTATING THE RECORD, THE GENERAL PRACTICE IS TO DRIVE A TURNTABLE BY MEANS OF A SMALL ELECTRIC MOTOR, HOWEVER, A MECHANICAL TYPE MOTOR, IN WHICH AN UNWINDING SPRING PROVIDES THE MOTIVE FORCE, CAN ALSO BE USED. YOU ARE SHOWN TWO OF THE MANY TYPES OF ELECTRICALLY OPERATED IN FIG. 9.

THE POWER FOR OPERATING THIS TYPE OF ELECTRIC TURNTABLE IS OBTAINED FROM LINES SUPPLYING THE LIGHTING CURRENT TO THE BUILDING AND THE MOTOR UNIT IS THEN INSTALLED IN A CABINET, WITH ONLY THE TURNTABLE PROTRUDING UPON WHICH TO PLACE THE RECORD. THE TWO STANDARD SPEEDS AT WHICH THESE TURNTABLES REVOLVE ARE 33 1/3 R.P.M. (REVOLUTIONS PER MINUTE) AND 78 R.P.M. THE 78 R.P.M. RECORDS ARE THE STANDARD FOR HOME USE.

WITH THE PHONOGRAPH RECORD PLACED IN POSITION ON THE ROTATING TURNTABLE AND WITH THE NEEDLE OF THE PHONOGRAPH PICKUP RIDING IN THE GROOVES OF THE RECORD, YOU WILL READILY SEE THAT THE AUDIO FREQUENCY VOLTAGES,

WHICH ARE GENERATED WITHIN THIS PICKUP, WILL BE IMPRESSED UPON THE GRID CIRCUIT OF THE DETECTOR TUBE OF OUR RECEIVER IN FIG. 2. THESE AUDIO FREQUENCY CHANGES WILL THEN BE AMPLIFIED BY THE DETECTOR TUBE AND THE FOLLOWING AUDIO AMPLIFYING STAGES UNTIL THEY ARE FINALLY IMPRESSED ACROSS THE SPEAKER'S VOICE COIL AND CONVERTED INTO SOUND. IN THE CASE OF THE RECEIVER OF FIG. 2, THE VOLUME CONTROL FOR THE REPRODUCTION OF RECORDS WILL HAVE TO BE ON THE PHONOGRAPH PICKUP, FOR NO PROVISION IS MADE IN THE CIRCUITS OF THE RECEIVER.

THE REGULAR RECEIVER VOLUME CONTROL IN THIS CASE CANNOT BE USED FOR CONTROLLING THE VOLUME OF PHONOGRAPH MUSIC BECAUSE IT AFFECTS ONLY THE R.F. STAGES AND THESE ARE INOPERATIVE DURING THE REPRODUCTION OF PHONOGRAPH RECORDINGS. WITH THE PHONOGRAPH PICK-UP IN OPERATION, THE RECEIVER'S VOLUME CONTROL SHOULD BE TURNED TO THE "OFF" POSITION.

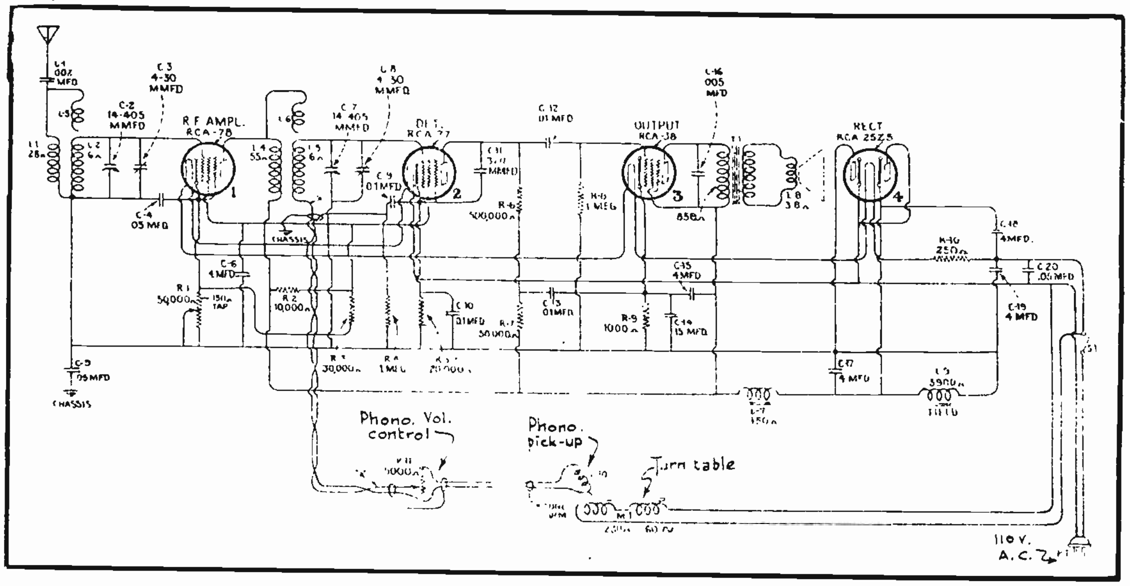

FIG. 10
The Four Tube Receiver.

A FOUR TUBE RADIO-PHONOGRAPH RECEIVER

IN FIG. 10 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF A FOUR TUBE RECEIVER WHICH WILL OFFER EITHER RADIO OR PHONOGRAPH ENTERTAINMENT. ALTHOUGH THE 25Z5 TUBE IS EMPLOYED IN THIS RECEIVER, YET THE CIRCUIT ARRANGEMENT OF THIS PARTICULAR RECEIVER IS SUCH THAT THIS TUBE FUNCTIONS ONLY AS A "VOLTAGE DOUBLER" WHEN CONNECTED TO A 110 VOLT A.C. LIGHTING SUPPLY AND DOES NOT OFFER PROVISIONS FOR OPERATING THE SAME RECEIVER FROM A D.C. SUPPLY.

THE WINDINGS FOR THE ELECTRIC MOTOR, WHICH IS USED TO DRIVE THE TURNTABLE OF THIS RECEIVER, IS CONNECTED DIRECTLY ACROSS THE 110 VOLT A.C. CIRCUIT WHENEVER SWITCH S-1 IS IN THE CLOSED POSITION. THE NATURE OF THIS MOTOR IS SUCH, HOWEVER, THAT IT WILL NOT COMMENCE TO OPERATE UNLESS THE TURNTABLE IS GIVEN A QUICK TWIRL WITH THE HAND SO AS TO CAUSE IT TO REVOLVE IN A CLOCKWISE DIRECTION.

THE VOLUME CONTROL FOR PHONOGRAPH REPRODUCTION CONSISTS OF THE 5000 OHM POTENTIOMETER R-11, WHICH IS CONNECTED ACROSS THE COIL OF THE PICK- UP

UNIT. ONE END TERMINAL OF THIS POTENTIOMETER IS CONNECTED TO THE CONTROL GRID OF THE DETECTOR TUBE WHILE THE ARM TERMINAL OF THE POTENTIOMETER IS CONNECTED TO THE CATHODE CIRCUIT OF THE DETECTOR TUBE. THIS WILL SERVE TO ACTUALLY CONNECT THE PICKUP ASSEMBLY ACROSS THE GRID CIRCUIT OF THE DETECTOR TUBE.

THE ENTIRE CABLE OF THE PICKUP IS ENCLOSED IN A BRAIDED METAL SHIELD WHICH IS GROUNDED TO THE METAL RECEIVER CHASSIS IN ORDER TO AVOID INTERFERENCE PICKUP.

FOR RADIO RECEPTION, THE VOLUME CONTROL FOR THE PHONOGRAPH PICKUP IS SET TO ITS "OFF" OR MINIMUM VOLUME POSITION, AT WHICH TIME THE GRID RETURN CIRCUIT OF THE DETECTOR STAGE WILL BE COMPLETED DIRECT WITHOUT ANY OF THE RESISTANCE OF R11 BEING INCLUDED IN IT.

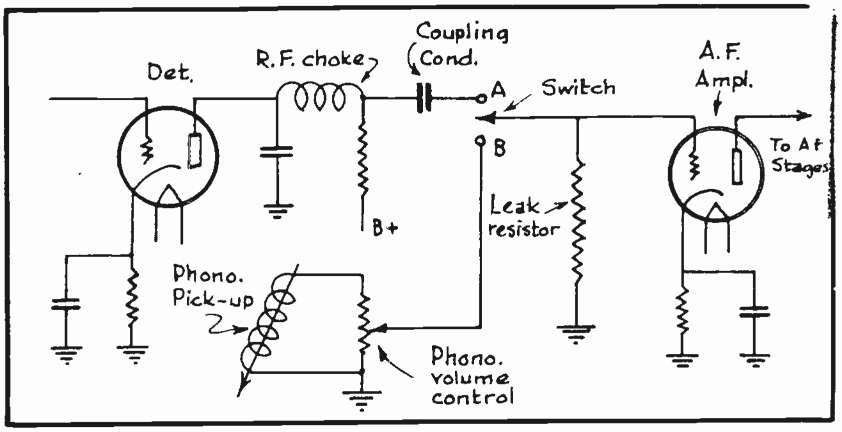

FIG. 11

Phonograph Input to 1st A.F. Tube

THE RECEIVER IS THEN OPERATED IN THE CONVENTIONAL MANNER AND THE VOLUME FOR RADIO RECEPTION IS CONTROLLED BY MEANS OF THE 50,000 OHM POTENTIOMETER R1, WHICH IS CONNECTED IN THE CATHODE CIRCUIT OF THE R.F. TUBE.

FOR THE REPRODUCTION OF PHONOGRAPH RECORDINGS, THE RECEIVER'S 50,000 OHM CONTROL POTENTIOMETER IS TURNED JUST FAR ENOUGH TO THE "ON" POSITION SO AS TO CLOSE THE SWITCH S-1 WITH WHICH IT IS MECHANICALLY CONNECTED. THE TURNTABLE IS THEN GIVEN A SLIGHT TWIRL TO START IT AND THE NEEDLE OF THE PICKUP UNIT IS PLACED AT THE STARTING END OF THE RECORDING GROOVE THE SAME AS FOR ANY ORDINARY PHONOGRAPH. POTENTIOMETER R-11 IS THEN ADJUSTED FOR THE VOLUME DESIRED.

ORDINARILY, NO RADIO SINGALS SHOULD GET THROUGH THE RECEIVER TO CAUSE INTERFERENCE WITH THE PHONOGRAPH MUSIC, AS LONG AS R-1 IS NEARLY IN ITS "OFF" POSITION. HOWEVER, IN THE EVENT THAT SOME STRONG LOCAL STATION SHOULD CAUSE TROUBLE IN THIS RESPECT, THEN THE RECEIVER CAN BE DETUNED BY TURNING THE TUNING CONTROL ONE WAY OR ANOTHER SLIGHTLY SO AS TO ELIMINATE THE BOTHERSOME STATION.

PHONOGRAPH INPUT TO A.F. STAGE

SO FAR, YOU WERE ONLY SHOWN HOW TO COUPLE A PHONOGRAPH PICKUP TO THE DETECTOR STAGE OF A RECEIVER. FIG. 11, HOWEVER, ILLUSTRATES HOW THE PICKUP UNIT MAY BE WORKED INTO THE FIRST A.F. TUBE OF A RECEIVER WHEN RESISTANCE -- CAPACITY COUPLING IS USED BETWEEN THE DETECTOR AND FIRST A.F. STAGE.

WITH THE SWITCH CLOSED TO POSITION "A", THE RADIO CIRCUIT WILL BE COMPLETE, WHILE THE PHONOGRAPH INPUT CIRCUIT IS AT THE SAME TIME INTERRUPTED. THEREFORE, CUSTOMARY RADIO RECEPTION WILL TAKE PLACE. HOWEVER, WHEN THE SWITCH IS CLOSED TO POSITION "B", THE RADIO CIRCUIT WILL BE INTERRUPTED AND THE PHONOGRAPH PICKUP TOGETHER WITH ITS VOLUME CONTROL WILL BE CONNECTED ACROSS THE GRID CIRCUIT OF THE A.F. AMPLIFIER TUBE. RADIO RECEPTION WILL THEREFORE CEASE AND THE A.F. SIGNAL VOLTAGES WHICH ARE GENERATED ACROSS THE PHONOGRAPH PICKUP COIL WILL BE APPLIED TO THE GRID OF THE FIRST A.F. TUBE FOR FURTHER AMPLIFICATION.

PHONOGRAPH CONNECTIONS FOR TRANSFORMER COUPLED A.F. STAGE

FIG. 12 SHOWS YOU HOW THE PHONOGRAPH PICKUP MAY BE CONNECTED TO THE RECEIVER CIRCUITS IN THE EVENT THAT TRANSFORMER COUPLING IS USED BETWEEN THE DETECTOR AND FIRST A.F. STAGE. IN THIS CASE, THE COIL OF THE PICKUP, TOGETHER WITH ITS VOLUME CONTROL POTENTIOMETER, IS CONNECTED ACROSS THE PRIMARY WINDING OF THE A.F. TRANSFORMER WHENEVER THE SWITCH IS PLACED IN THE PHONOGRAPH POSITION, THAT IS, CONTACTING POINT "B".

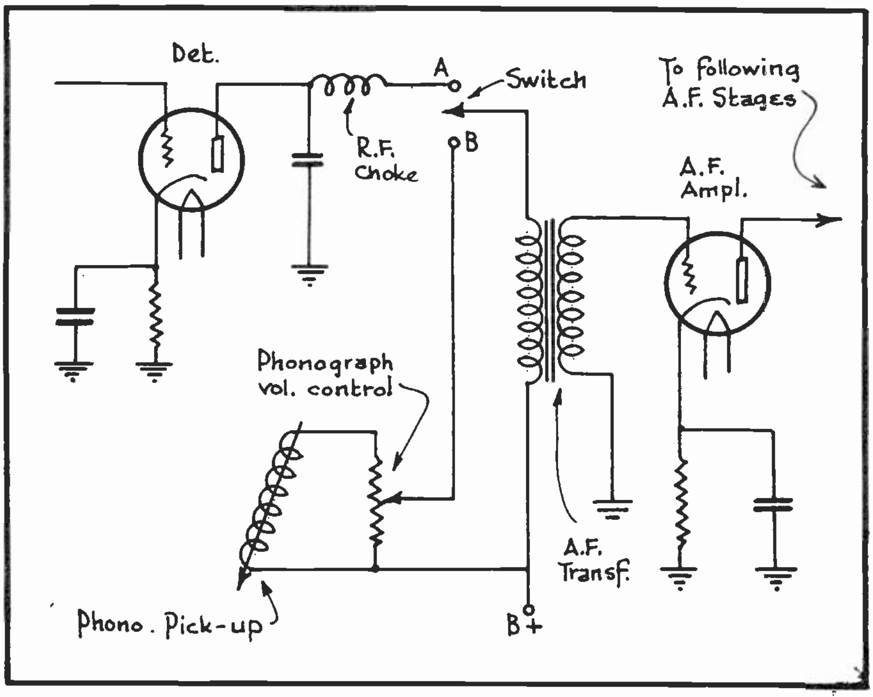

FIG. 12
Phonograph Input To Transformer Coupled A.F. Stage.

THE A.F. SIGNAL VOLTAGES, WHICH ARE GENERATED IN THE PICKUP COIL, WILL AT THIS TIME BE APPLIED ACROSS THE PRIMARY WINDING OF THE A.F. TRANSFORMER AND THEN PASSED ONTO THE SECONDARY WINDING OF THIS TRANSFORMER BY INDUCTION TO BE FINALLY IMPRESSED UPON THE GRID OF THE A.F. TUBE TO BE FURTHER AMPLIFIED. NOTICE THAT IN THIS SYSTEM, THE TURNS RATIO OF THE A.F. TRANSFORMER WILL OFFER A CONSIDERABLE STEP UP IN THE VOLTAGE GENERATED BY THE PICKUP WITH WHICH TO ACTUATE THE GRID OF THE A.F. TUBE.

PHONOGRAPH CONNECTION TO A DUPLEX DIODE-TRIODE

FIG. 13 SHOWS YOU HOW TO WORK A PHONOGRAPH PICKUP UNIT INTO A TYPE 2A6 DUPLEX DIODE TRIODE WHEN USING THIS TUBE AS A SECOND DETECTOR AND FIRST A.F. AMPLIFIER IN A SUPERHETERODYNE RECEIVER.

HERE YOU WILL SEE THAT THE PHONOGRAPH PICKUP, TOGETHER WITH ITS VOL-

UME CONTROL, IS CONNECTED ACROSS THE PRIMARY WINDING OF AN A.F. TRANSFORMER (PHONOGRAPH INPUT TRANSFORMER) WHICH SERVES TO COUPLE THE PHONOGRAPH UNIT TO THE RECEIVER CIRCUITS. THE SECONDARY WINDING OF THIS TRANSFORMER IS CONNECTED THROUGH A PLUG-IN TYPE TWIN JACK ACROSS THE ENDS OF THE .25 MEGOHM RESISTOR WHICH SERVES AS THE GRID LEAK FOR THE TRIODE SECTION OF THE 2A6 TUBE.

THE CONNECTIONS, WHEN MADE IN THIS WAY, PERMIT THE A.F. SIGNAL VOLTAGES AS GENERATED BY THE PHONOGRAPH PICKUP TO BE STEPPED UP BY THE COUPLING TRANSFORMER BEFORE BEING APPLIED ACROSS THE GRID CIRCUIT OF THE 2A6 TUBE'S TRIODE OR A.F. SECTION.

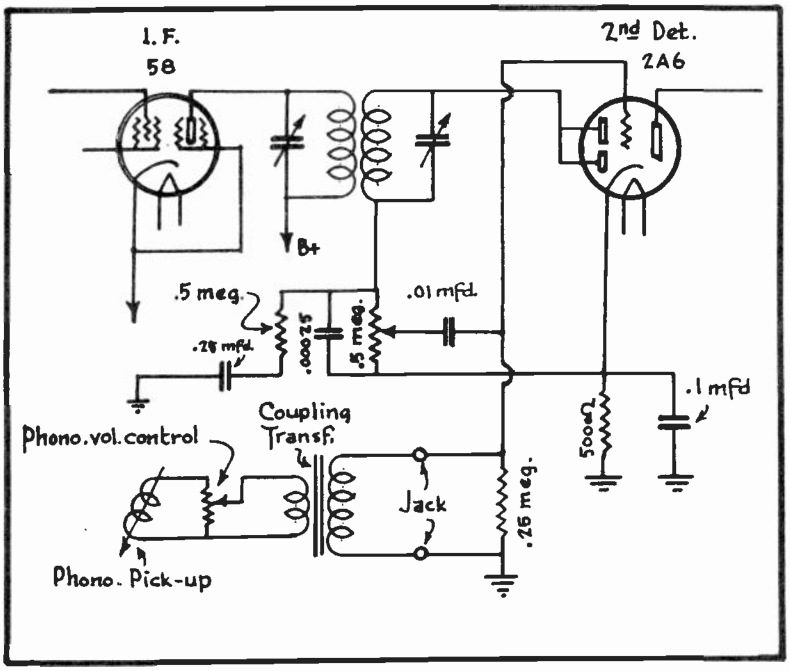

FIG. 13
Phonograph Pick-up Into a Duplex Diode-Triode.

PHONOGRAPH PICKUP UNITS CAN BE PURCHASED EITHER WITH A HIGH IMPEDANCE RATING OR A LOW IMPEDANCE RATING. SOME PICKUP UNITS ARE MANUFACTURED WITH VARIOUS IMPEDANCE RATINGS RANGING FROM 3 UP TO 10,000 OHMS. IN THE LOW IMPEDANCE GROUP RATINGS OF 200; 500 AND 700 OHMS ARE QUITE POPULAR WHILE IN THE HIGH IMPEDANCE GROUP, RATINGS OF 2000; 2500; 4000 AND 8500 OHMS ARE FREQUENTLY USED.

WHEN USING A HIGH IMPEDANCE PHONOGRAPH PICKUP, IT IS THE COMMON PRACTICE TO CONNECT THE PICKUP UNIT, TOGETHER WITH ITS VOLUME CONTROL, DIRECTLY INTO THE RECEIVER CIRCUIT WITHOUT USING ANY SPECIAL COUPLING TRANSFORMER. WHENEVER A LOW IMPEDANCE PICKUP IS USED, HOWEVER, THEN IT IS A BETTER PRACTICE TO COUPLE THE PICKUP ASSEMBLY TO THE RECEIVER BY MEANS OF A PHONOGRAPH INPUT TRANSFORMER. THIS CAN BE EXPLAINED IN THE FOLLOWING WAY:

FIRST, THE LOW IMPEDANCE PICKUP DOES NOT GENERATE AS GREAT AN A.F. SIGNAL VOLTAGE AS DOES THE HIGH IMPEDANCE PICKUP AND SO THE STEP UP RATIO OF THE TRANSFORMER WILL AID TO BOOST THE VOLTAGE BEFORE APPLYING IT TO THE GRID OF THE FIRST TUBE TO AMPLIFY THE SIGNAL. FURTHERMORE, THE GRID CIRCUIT OF THE AVERAGE RECEIVER A.F. STAGE INTO WHICH THE PICKUP UNIT IS TO OPERATE, IS OF A RATHER HIGH IMPEDANCE VALUE AND SO IF A LOW IMPEDANCE PICKUP IS FORCED TO WORK DIRECTLY INTO A HIGH IMPEDANCE GRID CIRCUIT, CONSIDERABLE VOLUME AND TONE QUALITY WILL BE SACRIFICED. IN OTHER WORDS, WE HAVE A CONDITION HERE SIMILAR TO THAT WHERE THE LOW IMPEDANCE VOICE COIL OF A DYNAMIC SPEAKER MUST BE PROPERLY MATCHED TO THE RELATIVELY HIGH IMPEDANCE OF THE POWER TUBE'S PLATE CIRCUIT IF BEST RESULTS ARE TO BE EXPECTED.

SO ALTOGETHER, WHAT THE PHONOGRAPH INPUT TRANSFORMER REALLY ACCOMP-

LISHES IS TO PROPERLY MATCH THE IMPEDANCE OF THE PHONOGRAPH PICKUP TO THE RECEIVER CIRCUIT INTO WHICH IT IS TO OPERATE, WHILE AT THE SAME BOOSTING THE PICKUP SIGNAL VOLTAGE TO A HIGHER VALUE BEFORE APPLYING IT TO THE RECEIVER CIRCUIT.

INSTALLING A PHONOGRAPH ATTACHMENT ON AN EXISTING RECEIVER

SOME PEOPLE ALREADY HAVE A REGULAR PHONOGRAPH, AS WELL AS A CONVENTIONAL TYPE OF RADIO RECEIVER AND HAVE A DESIRE TO REPRODUCE THEIR PHONOGRAPH RECORDS THROUGH THE SPEAKER OF THE RADIO RECEIVER. YOU MAY AT SOME TIME HAVE OCCASSION TO PERFORM SUCH A JOB AND SHOULD THEREFORE FIND THE FOLLOWING EXPLANATION TO BE OF SPECIAL INTEREST.

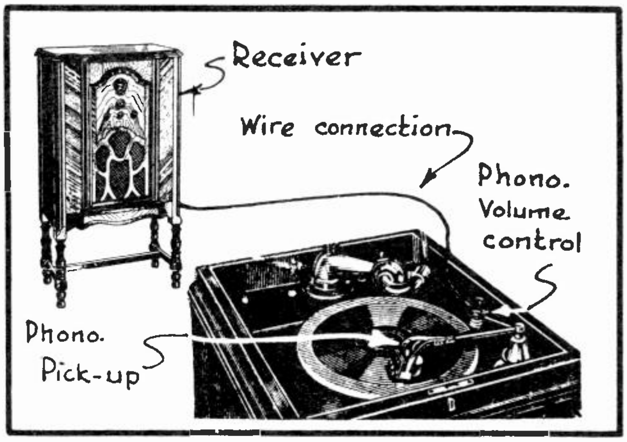

FIG. 14
Using a Phonograph With a Separate Receiver.

FIG. 14 WILL GIVE YOU A GENERAL IDEA OF HOW THIS CAN BE DONE. NOTICE THAT WITH THIS PARTICULAR TYPE OF PICKUP UNIT, THE ORIGINAL TONE ARM OF THE PHONOGRAPH NEED NOT BE DISTURBED. ALSO NOTICE THAT THE VOLUME CONTROL FOR THE PHONOGRAPH ATTACHMENT IS MOUNTED CONVENIENTLY ON THE PHONOGRAPH.

IN SOME EXISTING RECEIVERS, THE VOLUME CONTROL IS INSTALLED IN THE AUDIO STAGES AND IN SUCH A CASE, NO ADDITIONAL VOLUME CONTROL NEED BE ADDED AT THE TIME OF INSTALLING A PHONOGRAPH PICKUP ASSEMBLY -- THE RECEIVER'S VOLUME CONTROL CAN CONTROL THE VOLUME FOR PHONOGRAPH REPRODUCTION AS WELL. HOWEVER, MOST RECEIVERS, ESPECIALLY THOSE OF LATER DESIGN, HAVE THE VOLUME CONTROL INSTALLED IN THE R.F. STAGES AND UNDER THESE CONDITIONS, IT BECOMES NECESSARY THAT AN ADDITIONAL VOLUME CONTROL BE PROVIDED FOR PHONOGRAPH REPRODUCTION AT THE TIME OF INSTALLING THE PICKUP.

IN ORDER TO OBTAIN THE BEST RESULTS FROM THIS PHONOGRAPH ATTACHMENT, WHENEVER AN ADDITIONAL VOLUME CONTROL IS REQUIRED, IS TO USE A PICKUP UNIT WHICH ALREADY HAS THE VOLUME CONTROL INCORPORATED IN IT OR ELSE WITH THE TWO PARTS SOLD TOGETHER AS A UNIT. THE REASON FOR THIS IS THAT THE MANUFACTURER PROVIDES A VOLUME CONTROL WHICH IS BEST SUITED FOR THE PARTICULAR PICKUP IN QUESTION.

THERE WILL BE NO NEED FOR US TO AGAIN GO INTO THE DETAILS CONCERNING THE CONNECTIONS BETWEEN THE PICKUP AND THE RECEIVER CIRCUITS BECAUSE THIS HAS ALREADY BEEN COVERED IN THIS LESSON. WE MIGHT ADD AT THIS TIME, HOWEVER, THAT BY OPERATING THE PICKUP INTO THE GRID CIRCUIT OF THE RECEIVER'S DETECTOR STAGE, ONE GETS THE BENEFIT OF THE AMPLIFICATION OFFERED BY THE DETECTOR TUBE IN ADDITION TO THAT OF THE A.F. AMPLIFIER.

THE TWO WIRES WHICH CONNECT THE PICKUP TO THE RECEIVER ARE CABLED TOGETHER AND GENERALLY ALREADY FURNISHED IN THIS FORM WITH THE PICKUP BY THE MANUFACTURER.

TONE CONTROLS

NOW LET US TURN OUR ATTENTION TO THE MATTER OF TONE CONTROLS. AS YOU ALREADY KNOW, PEOPLE HAVE DIFFERENT TASTES AS TO TONE QUALITY AND EVEN IF THE DESIGNING ENGINEERS SHOULD PRODUCE A RECEIVER WHICH TO THEM HAS EXCEPTIONAL GOOD TONE QUALITY, YET THERE WOULD BE SOME LISTENERS WHO WOULD COMPLAIN OF THE TONES BEING TOO HIGH OR TOO LOW PITCHED. THEREFORE, THE LOGICAL THING TO DO, IN ORDER TO PLEASE EVERYBODY'S SENSE OF HEARING, IS TO PROVIDE A CONTROL ON THE RECEIVER, WHICH THE INDIVICUAL CAN ADJUST SO THAT THE PRODUCED SOUNDS TO HIM WILL BE MOST PLEASING. WE CALL SUCH DEVICES "TONE CONTROLS."

TONE CONTROL WITH GANGED BY-PASS CONDENSERS

VARIOUS CIRCUIT ARRANGEMENTS HAVE BEEN WORKED OUT TO ACCOMPLISH THIS PURPOSE AND ONE SYSTEM IS ILLUSTRATED FOR YOU IN FIG. 15. HERE YOU WILL SEE THAT THREE BY-PASS CONDENSERS HAVE ONE OF THEIR SIDES MUTUALLY CONNECTED TO THE PLATE END OF THE INPUT PUSH-PULL TRANSFORMER'S PRIMARY WINDING. THE OTHER SIDE OF ALL THREE OF THESE BY-PASS CONDENSERS ARE CONNECTED TO SEPARATE CONTACT TERMINALS AND A GROUNDED BLADE IS SO ARRANGED THAT WHEN IT IS ROTATED FROM THE LEFT TOWARD THE RIGHT, IT WILL FIRST GROUND ONE OF THESE BY-PASS CONDENSERS. AT THE SECOND POSITION OF THIS BLADE, TWO BY-PASS CONDENSERS WILL BE GROUNDED AT THE SAME TIME AND IN THE LAST POSITION, ALL THREE CONDENSERS WILL HAVE ONE OF THEIR SIDES GROUNDED.

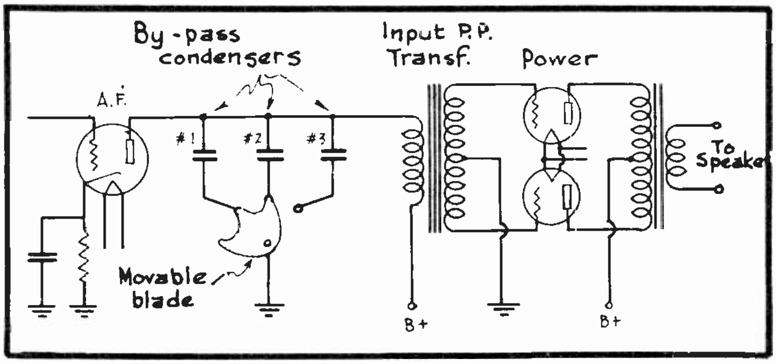

FIG. 15
Example of one Type of Tone Control.

NOW THEN, WITH CONDENSER #1 OF FIG. 15 CONNECTED TO GROUND BY WAY OF THE SWITCH BLADE, THE AUDIO FREQUENCIES IN THE PLATE CIRCUIT OF THIS A.F. TUBE WILL HAVE TWO PATHS AVAILABLE, - NAMELY, THAT THROUGH THE PRIMARY WINDING OF THE INPUT PUSH-PULL TRANSFORMER AND THAT OFFERED BY CONDENSER #1. FROM YOUR EARLY RADIO PRINCIPLES, YOU WILL RECALL THAT THE PRIMARY WINDING OF THIS TRANSFORMER HAS CONSIDERABLE INDUCTANCE AND THEREFORE IT HAS NATURAL TENDENCIES TO OPPOSE THE FLOW OF ALTERNATING CURRENT, ESPECIALLY THAT OF HIGHER FREQUENCIES. A CONDENSER, ON THE OTHER HAND, HAS A NATURAL TENDENCY TO PASS ALTERNATING CURRENTS AND THE HIGHER THE FREQUENCY OF THESE CURRENTS, THE EASIER IT WILL BE FOR THEM TO PASS THRU THE CONDENSER. SO THIS CHARACTERISTIC IS JUST EXACTLY OPPOSITE TO THAT OF INDUCTANCE AND AS A RESULT, THE HIGHER AUDIO FREQUENCIES WILL BE FORCED TO TAKE THE PATH OF LEAST OPPOSITION THEREBY PASSING TO GROUND THROUGH CONDENSER #1 INSTEAD OF THROUGH THE PRIMARY WINDING OF THE TRANSFORMER.

FOR THIS REASON, IT IS CLEAR THAT THE HIGHER AUDIO FREQUENCIES ARE NOT PRESENT IN THE TRANSFORMER WINDING AND CAN THEREFORE NOT BE AMPLIFIED. THE ABSENCE OF THESE HIGHER FREQUENCIES HAS A TENDENCY TO MAKE THE LOWER FREQUENCIES MORE EFFECTIVE OR MORE PRONOUNCED, WITH THE RESULT THAT THE SOUNDS REPRODUCED BY THE SPEAKER ARE NOW LOWER IN PITCH.

WITH THE SWITCH BLADE OF FIG. 15 IN THE SECOND POSITION, TWO BY-PASS CONDENSERS WILL NOW BE CONNECTED IN PARALLEL AND AT THE SAME TIME SHUNTED ACROSS THE PRIMARY OF THE TRANSFORMER. THIS SERVES TO INCREASE THE CAPACITY, SO THAT A STILL GREATER PERCENTAGE OF THE HIGHER AUDIO FREQUENCIES WILL BE BY-PASSED AROUND THE TRANSFORMER. THUS WITH A WIDER BAND OF THE HIGHER AUDIC FREQUENCIES NOW ABSENT FROM THE TRANSFORMER, THE SPEAKER TONES WILL APPEAR STILL LOWER IN PITCH.

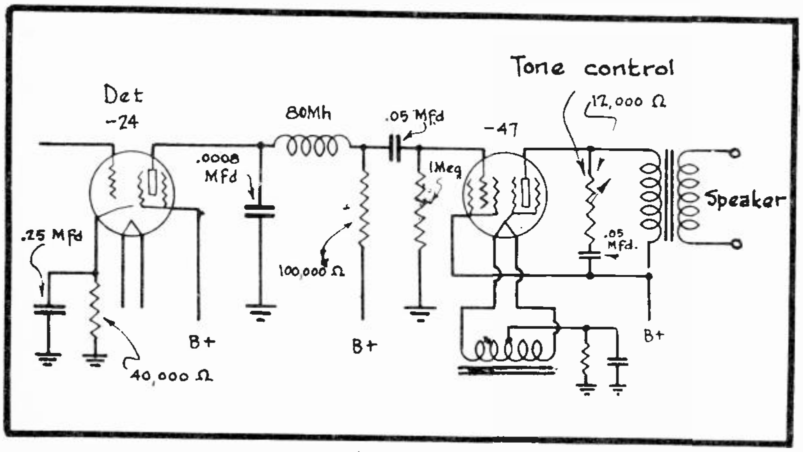

FIG. 16
Tone Control Across Output of Pentode Tube.

FINALLY, WITH THE SWITCH BLADE OF THE TONE CONTROL IN THE THIRD POSITION, ALL THREE OF THE CONDENSERS WILL BE CONNECTED IN PARALLEL AND SHUNTED ACROSS THE PRIMARY WINDING. THIS WILL INCREASE THE CAPACITY STILL MORE, RESULTING IN A STILL GREATER LOSS OF THE HIGHER FREQUENCIES AND THE TONE QUALITY AS REPRODUCED BY THE SPEAKER WILL NOW BE AT ITS LOWEST PITCH.

A TONE CONTROL FOR A SINGLE-TUBE POWER STAGE

ANOTHER METHOD OF PROVIDING A TONE CONTROL IS ILLUSTRATED FOR YOU IN FIG. 16. IN THIS CASE, THE TONE CONTROL CONSISTS OF A 12,000 OHM RHEOSTAT WHICH IS CONNECTED IN SERIES WITH A .05 MFD. FIXED CONDENSER AND THESE TWO UNITS ARE TOGETHER SHUNTED AROUND THE PRIMARY WINDING OF THE OUTPUT TRANSFORMER.

IF THIS RHEOSTAT IS TURNED TO ONE EXTREME POSITION, SO THAT ALL OF THE RESISTANCE IS INSERTED INTO THIS SHUNT CIRCUIT, THEN THE IMPEDANCE THROUGH THE TONE CONTROL CIRCUIT IS QUITE HIGH. FOR THIS REASON A CONSIDERABLE PORTION, — IN FACT, PRACTICALLY ALL OF THE HIGHER AUDIO FREQUENCIES WILL FLOW THROUGH THE PRIMARY WINDING OF THE OUTPUT TRANSFORMER, SO THAT THESE WILL BE INDUCTIVELY TRANSFERRED TO THE SPEAKER. AS THE RHEOSTAT KNOB IS TURNED SO AS TO DECREASE ITS RESISTANCE, THE IMPEDANCE THROUGH THE TONE CONTROL WILL BECOME LESS AND IF ITS IMPEDANCE TO THE HIGHER AUDIO FREQUENCIES IS PROPORTIONATELY LESS THAN THAT OFFERED BY THE PRIMARY OF THE OUTPUT TRANSFORMER, A CERTAIN PERCENTAGE OF THE HIGHER FREQUENCIES WILL BE BY-PASSED THROUGH THE .05 MFD. CONDENSER, THEREBY BEING PREVENTED FROM

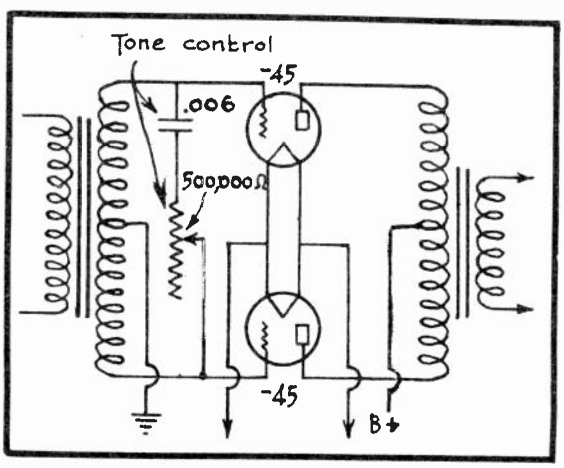

FIG. 17
Tone Control Connected Across Grids of the Push-Pull Power Stage.

BEING TRANSFERRED TO THE SPEAKER. THUS IT IS CLEAR THAT AS THE RHEOSTAT KNOB IS TURNED TOWARDS THE POSITION OF LEAST RESISTANCE, AN INCREASING PERCENTAGE OF THE HIGHER FREQUENCIES WILL BE BY-PASSED AROUND THE TRANSFORMER, WITH THE RESULT THAT THE SPEAKER TONES WILL BECOME LOWER IN PITCH.

TONE CONTROLS CONSISTING OF A RHEOSTAT CONNECTED IN SERIES WITH A FIXED CONDENSER ARE AT THE PRESENT TIME THE MOST POPULAR TYPE. HOWEVER, THERE ARE VARIOUS WAYS IN WHICH THIS COMBINATION CAN BE USED EFFECTIVELY. FOR, EXAMPLE, A TONE CONTROL OF THIS TYPE COULD ALSO BE USED IN THE CIRCUIT OF FIG. 15, SO AS TO REPLACE THE THREE-CONDENSER AND BLADE COMBINATION. IN OTHER WORDS, IN THIS CASE, ONE END OF THE RHEOSTAT COULD BE CONNECTED TO THE PLATE OF THE A.F. TUBE AND THE FREE END OF THE CONDENSER TO GROUND.

TONE CONTROL CONNECTED IN PUSH-PULL STAGE

STILL ANOTHER TONE CONTROL CONNECTION IS SHOWN YOU IN FIG. 17. HERE WE AGAIN HAVE THE RHEOSTAT-CONDENSER COMBINATION BUT IN THIS PARTICULAR CASE, THEIR VALUES ARE SOMEWHAT DIFFERENT. THAT IS, A 500,000 OHM RHEOSTAT IS USED TOGETHER WITH A .006 MFD. FIXED CONDENSER AND THE COMBINATION IS CONNECTED ACROSS THE GRIDS OF THE PUSH-PULL POWER STAGE. IN THIS WAY, THE TONE CONTROL SERVES AS A SHUNT AROUND THE SECONDARY WINDING AND WITH THE RHEOSTAT OFFERING MAXIMUM RESISTANCE, THE HIGHER FREQUENCIES WILL NOT BE BY-PASSED AND CONSEQUENTLY THEY WILL BE IMPRESSED UPON THE GRIDS OF THESE TUBES SO AS TO BE FURTHER AMPLIFIED. THE SPEAKER SOUNDS WILL THEREFORE BE OF A HIGHER PITCH.

WITH THE RHEOSTAT OFFERING MINIMUM RESISTANCE, THE HIGHER FREQUENCIES WILL BE BY-PASSED THROUGH THE .006 MFD. CONDENSER AND THEREFORE THEY CANNOT BE IMPRESSED UPON THE GRIDS OF THE TWO POWER TUBES AND SO AT THIS TIME, THE SPEAKER SOUNDS WILL BE LOWER IN PITCH.

FROM THE EXAMPLES GIVEN, YOU SHOULD HAVE A SOUND UNDERSTANDING OF TONE CONTROLS AND AS YOU COME IN CONTACT WITH DIFFERENT TYPES OF TONE CONTROL CIRCUITS, YOU SHOULD NOT HAVE ANY DIFFICULTY IN ANALYZING THEIR PRINCIPLES OF OPERATION. IN REGARDS TO THE VALUES GIVEN THE PARTS FOR THE CONTROL CIRCUIT, YOU WILL FIND QUITE AN ASSORTMENT FROM WHICH TO CHOOSE.

MANUFACTURERS DIFFER CONSIDERABLY IN THIS RESPECT AND A GREAT DEAL DEPENDS UPON THE RANGE OF TONE CONTROL, WHICH THE MANUFACTURER WANTS THE SET OWNER TO HAVE AT HIS COMMAND. IN OTHER WORDS, SOME TONE CONTROLS WILL ENABLE AN ADJUSTMENT TO BE MADE FROM A VERY LOW PITCH TO A VERY HIGH ONE, WHEREAS OTHERS DO NOT PERMIT CONTROL FROM ONE EXTREME TO THE OTHER BUT ONLY WITHIN A LIMITED RANGE. THE VALUES, WHICH WE HAVE GIVEN YOU IN THIS LESSON, ARE AVERAGE VALUES AND YOU WILL FIND THEM TO GIVE SATISFACTORY RESULTS.

YOU SHOULD FIND THE CONTENTS OF THIS LESSON NOT ONLY INTERESTING BUT IMPORTANT AS WELL. MANY SUGGESTIONS ARE GIVEN HEREIN, WHICH YOU CAN USE PROFITABLY, SUCH AS PERTAINING TO THE INSTALLATION OF RADIO-PHONOGRAPH COMBINATIONS, AND TONE CONTROLS. THERE ARE MANY PEOPLE WHO DESIRE SUCH MODERN ATTACHMENTS FOR THEIR RADIO AND SO IT IS UP TO YOU TO TAKE ADVANTAGE OF YOUR KNOWLEDGE ABOUT THIS WORK AND THUS EARN YOUR SHARE OF RADIO DOLLARS WHICH THIS TYPE OF WORK HAS TO OFFER.

Examination Questions

LESSON NO. 35

"Education is the foundation on which character is built. Unfortunately, some men do not realize the value of early training until late in life."

ans 4/9/40

1. - HOW DOES THE RADIO-PHONOGRAPH COMBINATION DIFFER FROM THE CONVENTIONAL TYPE OF RADIO RECEIVER?

2. - DESCRIBE THE CONSTRUCTIONAL FEATURES OF THE ELECTROMAGNETIC TYPE PHONOGRAPH PICK-UP.

3. - EXPLAIN THE OPERATING PRINCIPLES OF THE ELECTROMAGNETIC PHONOGRAPH PICK-UP.

4. - HOW CAN "NEEDLE SCRATCH" BE REDUCED?

5. - DRAW A CIRCUIT DIAGRAM WHICH ILLUSTRATES HOW A PHONOGRAPH PICK-UP CAN BE CONNECTED TO A RESISTANCE-CAPACITY COUPLED A.F. STAGE OF A RECEIVER.

6. - WHY ARE PHONOGRAPH INPUT TRANSFORMERS SOMETIMES USED?

7. - EXPLAIN HOW YOU WOULD GO ABOUT THE JOB OF MAKING PHONOGRAPH PROGRAMS POSSIBLE WHEN A CUSTOMER HAS AN INDIVIDUAL PHONOGRAPH AND A CONVENTIONAL RADIO RECEIVER.

8. - IF IN A RADIO-PHONOGRAPH COMBINATION, THE RECEIVER'S VOLUME CONTROL IS CONNECTED IN THE R.F. CIRCUITS OF THE RECEIVER, CAN THIS SAME VOLUME CONTROL BE USED TO REGULATE THE VOLUME WHILE PHONOGRAPH RECORDINGS ARE BEING REPRODUCED?

9. - WHY ARE TONE CONTROLS USED?

10. - DESCRIBE THE OPERATING PRINCIPLE OF A TONE CONTROL, ILLUSTRATING YOUR EXPLANATION WITH A SIMPLE DIAGRAM.

RADIO - TELEVISION

Practical Training

NATIONAL SCHOOLS

Established 1905

Los Angeles, California

J. A. ROSENKRANZ, Pres.

LESSON NO. 36

· SHORT WAVE RECEIVERS ·

THE RECEIVERS, WHICH YOU HAVE BEEN STUDYING ABOUT SO FAR, WERE ALL SPECIALLY DESIGNED TO RECEIVE SIGNALS WITHIN THE BROADCAST BAND. THE BROADCAST BAND, YOU WILL REMEMBER, INCLUDES THOSE FREQUENCIES BETWEEN 500 KC. AND 1500 KC. AND EXPRESSED IN WAVELENGTHS, THIS WOULD BE EQUIVALENT TO A RANGE OF FROM 600 METERS DOWN TO 200 METERS.

NOW WHEN WE DEAL WITH WAVELENGTHS LOWER THAN 200 METERS IN OUR RADIO WORK, WE ARE NO LONGER WORKING IN THE BROADCAST BAND BUT IN THAT BAND OF WAVELENGTHS AND FREQUENCIES WHICH WE SPEAK OF AS THE SHORT WAVE BAND.

THE SHORT WAVE BAND COVERS A MUCH GREATER RANGE OF WAVELENGTHS AND FREQUENCIES THAN DOES THE BROADCAST BAND. THE SHORT WAVE BAND IS GENERALLY CONSIDERED AS INCLUDING ALL OF THOSE WAVE LENGTHS, WHICH COME BETWEEN 14 AND 200 METERS.

EXPERIMENTS, HOWEVER, ARE BEING CONDUCTED SUCCESSFULLY AT WAVELENGTHS BELOW 14 METERS AND IN WHAT IS DESIGNATED AS BEING THE ULTRA-SHORT WAVE BAND.

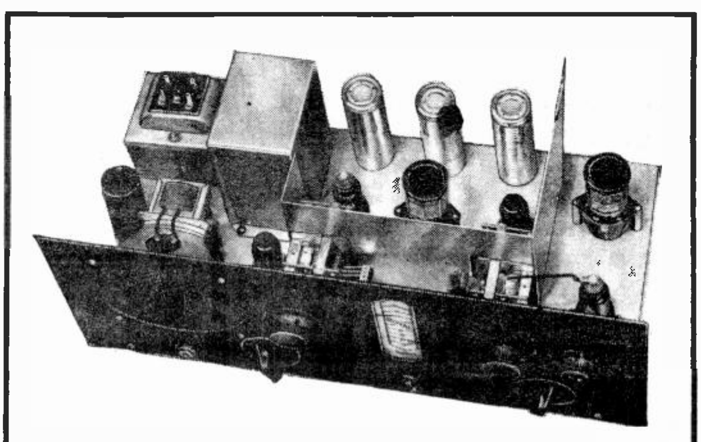

FIG. 1

Chassis of a Factory—Built Short Wave Receiver.

FIG. 2 SHOWS YOU A GRAPHICAL COMPARISON BETWEEN THE SHORT-WAVE BAND AND THE BROADCAST BAND AND YOU WILL NO DOUBT BE IMPRESSED WITH THE SMALL PORTION WHICH IS OCCUPIED BY THE BROADCAST BAND AS COMPARED TO THE SHORT WAVE BAND. THEN TOO, NOTICE IN THIS ILLUSTRATION THAT THE FREQUENCY INCREASES RAPIDLY AS WE APPROACH THE LOWER WAVE LENGTHS. THAT

IS, THE LOWER THE WAVE LENGTH, THE GREATER WILL BE THE FREQUENCY AND THIS FACT IS MIGHTY IMPORTANT SO DON'T FORGET IT.

THE FREQUENCIES INCLUDED IN THIS SHORT WAVE BAND, AS SHOWN IN FIG.2, EXTEND FROM 1500 KC. UP TO 20,000 KC. -- AND IT IS DUE TO THESE HIGHER FREQUENCIES THAT SUCH MARVELOUS RESULTS CAN BE OBTAINED ON LONG DISTANCE RECEPTION. YOU HAVE PROBABLY ALREADY HEARD OF MANY INSTANCES WHERE A SMALL TWO OR THREE-TUBE SHORT WAVE RECEIVER HAS PICKED UP STATIONS CLEAR ACROSS A CONTINENT OR OCEAN OR EVEN BOTH. THINK OF IT, RECEIVING MESSAGES BY RADIO OVER A DISTANCE OF THOUSANDS OF MILES WITH A RECEIVER, WHICH IS EVEN SMALLER THEN MANY OF THE PORTABLE TYPE BROADCAST RECEIVERS. IN FACT, THERE ARE EVEN ONE OR TWO-TUBE SHORT WAVE RECEIVERS, WHICH ARE CAPABLE OF "BRINGING IN" FOREIGN STATIONS WITH FAIR REGULARITY.

YOU ARE ALREADY FAMILIAR WITH THE FACT THAT WHEN IT COMES TO BROADCAST RECEPTION, WE WOULDN'T GET VERY FAR BY USING A ONE, OR TWO-TUBE RECEIVER BUT NOT SO IN SHORT WAVEWORK. NO DOUBT YOU ARE NOW BEGINNING TO WONDER JUST WHY SUCH REMARKABLE PERFORMANCE IS POSSIBLE AT THE SHORTER WAVE LENGTHS SO BEFORE ENTERING INTO A DISCUSSION ON THE CONSTRUCTION OF SHORT WAVE RECEIVERS LET US FIRST INVESTIGATE SOME OF THE INTERESTING AND IMPORTANT PHENOMENA ENCOUNTERED IN THE PROPAGATION OF THESE SHORTER WAVES. YOU SEE, BY FIRST BECOMING MORE FAMILIAR WITH THE ACTIONS OF THESE WAVES YOU WILL MORE CLEARLY SEE THROUGH THE PROBLEMS CONFRONTING US IN THE CONSTRUCTION OF THE RECEIVERS FOR THIS TYPE OF COMMUNICATION.

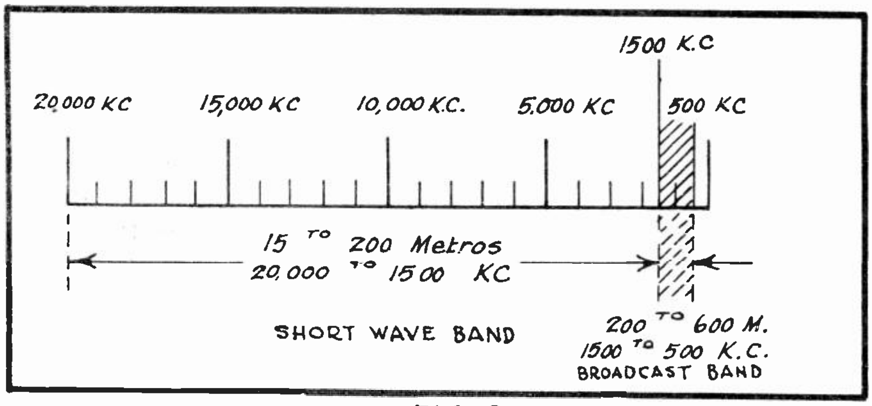

FIG. 2
Comparison of Broadcast and Short Wave Bands.

WAVE REFLECTION AT HIGH FREQUENCIES

NOW IF YOU WILL LOOK AT FIG. 3, YOU WILL SEE TWO RECEIVING STATIONS RECEIVING SIGNALS FROM THE SAME TRANSMITTER. THE TRANSMITTER, AS YOU ALREADY LEARNED, RADIATES ITS RADIO WAVES IN ALL DIRECTIONS AND SOME OF THESE WAVES SPREAD OUTWARDS CLOSE TO THE EARTH'S SURFACE AND WE CALL THESE THE GROUND WAVES. IT SO HAPPENS THAT ALL KINDS OF GEOGRAPHICAL OBSTACLES SUCH AS TREES, BUILDINGS, MOUNTAINS ETC. ALL ABSORB A CERTAIN AMOUNT OF THIS SIGNAL ENERGY, SO THAT THE GROUND WAVE PRODUCES A WEAKER SIGNAL INTENSITY THE FARTHER AWAY IT GETS FROM THE TRANSMITTER AND FINALLY IT DIES OUT ALTOGETHER.

THE HIGHER THE TRANSMITTING FREQUENCY, THE GREATER WILL BE THE ABSORBING EFFECT UPON THE GROUND WAVE AND IT IS FOR THIS REASON THAT SHORT WAVE RECEPTION WAS FOR SOMETIME REGARDED AS IMPRACTICAL FOR LONG DISTANT COMMUNICATION. CONSEQUENTLY, ALL OF THE AMATEUR TRANSMITTERS WERE ASSIGNED TO THESE HIGHER FREQUENCIES OR SHORTER WAVE LENGTHS AND THE LONGER WAVE LENGTHS WERE RETAINED FOR COMMERCIAL USE. IT DIDN'T TAKE THESE AMATEUR

RADIO ENTHUSIASTS LONG, HOWEVER, TO DISCOVER THAT THEY COULD COVER A GREATER DISTANCE WITH LESS POWER ON THE SHORTER WAVE LENGTHS THAN WAS POSSIBLE AT THE LONGER OR BROADCAST WAVE LENGTHS.

THIS THEN, DEMONSTRATED THAT THE THEORIES OF WAVE PROPAGATION HAD NOT YET ALL BEEN WORKED OUT AND IT LED TO A GREAT DEAL OF ADDITIONAL RESEARCH UNTIL OUR PRESENT THEORIES OF WAVE REFLECTION HAD BEEN DISCOVERED. SO FOLLOW CLOSELY AND YOU WILL BE SHOWN HOW IT IS POSSIBLE TO RECEIVE SHORT WAVE SIGNALS AT GREAT DISTANCES, EVEN THOUGH THE GROUND WAVE "DIES OUT" RELATIVELY SOON. BY AGAIN LOOKING AT FIG. 3, YOU WILL NOTE THAT IN ADDITION TO THE GROUND WAVE, A CERTAIN PERCENTAGE OF THE WAVES RADIATED BY THE TRANSMITTER ANTENNA, "SHOOT" UPWARDS INTO SPACE AT A STEEP ANGLE AND WE CALL THIS THE SKY WAVE. THIS SKY WAVE, HOWEVER, DOES NOT CONTINUE ITS SKYWARD TRAVEL INDEFINITELY BUT IF OF HIGH FREQUENCY, IT IS REFLECTED BACK TO

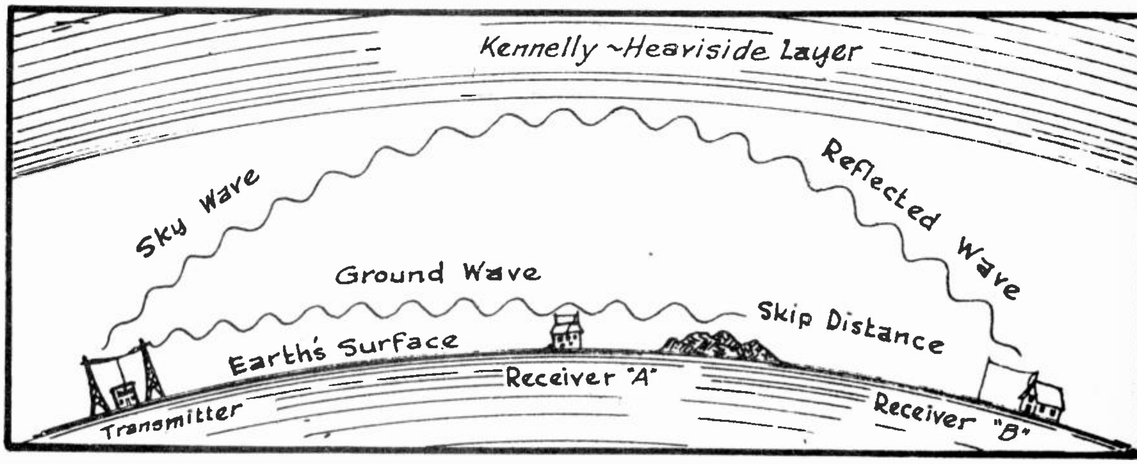

FIG. 3

Some Interesting and Important Wave Actions.

WARDS THE EARTH BY THE KENNELLY-HEAVISIDE LAYER IN MUCH THE SAME MANNER AS LIGHT IS REFLECTED BY A MIRROR.

NOW THE KENNELLY-HEAVISIDE LAYER IS A BLANKET OF IONIZED (DECOMPOSED) GAS MAKING UP THE AIR AND WHICH IN WINTER NIGHTS IS APPROXIMATELY 100 MILES ABOVE THE EARTH'S SURFACE. RECEIVING STATION "B" IN FIG. 3 IS NOT GETTING ANY OF THE GROUND WAVE, AS SHOWN, BUT RECEIVES ITS SIGNAL ENERGY BY WAY OF THE SKY WAVE, WHICH IS REFLECTED BACK TO EARTH BY THE KENNELLY HEAVISIDE LAYER AND WE CALL THIS PORTION OF THE WAVE, THE REFLECTED WAVE. SO REMEMBER, RECEIVING STATION "B" IN FIG. 3 DEPENDS UPON THE REFLECTED WAVE FOR ITS SIGNAL ENERGY AND NOT UPON THE GROUND WAVE. THIS EFFECT OF WAVE REFLECTION IS MORE PRONOUNCED WITH THE SHORTER WAVE LENGTHS THAN WITH THE LONGER ONES AND THEREFORE IS OF A GREAT HELP IN SHORT WAVE WORK BECAUSE IT ENABLES DISTANT RECEIVERS TO OPERATE WITH THE REFLECTED WAVE INSTEAD OF WITH THE RAPIDLY LOST GROUND WAVE.

SKIP-DISTANCE

STILL ANOTHER IMPORTANT POINT TO NOTICE IN FIG. 3 IS THAT ALONG THE EARTH'S SURFACE, BETWEEN THE ENDING OF THE GROUND WAVE AND THE POINT WHERE THE REFLECTED WAVE AGAIN REACHES THE EARTH, WE HAVE A SPACE IN WHICH THERE ARE NO WAVES CLOSE ENOUGH TO THE GROUND TO HAVE A SUITABLE EF fect upon a receiving antenna. This is a so-called "dead spot" for radio reception at one particular frequency and we refer to this interval as the SKIP DISTANCE.

A receiver located within this skip distance will not pick up signals at this one frequency except in rather rare cases, where a most powerful receiver is used and where other complex phenomena enter. In the daytime, this skip distance is about 200 miles at 40 meters and 800 miles at 20 meters. Then at a point beyond that where the reflected wave first strikes the earth, the signal energy again becomes weaker and weaker with an increase in distance. Above 300 meters, the skip distance is negligible.

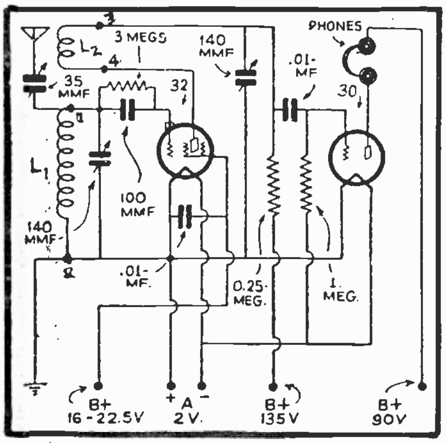

FIG. 4
2 Tube Short Wave Receiver.

From your studies of radio tubes, you will remember that HEAT caused electrons to be emitted from the filament. We have a similar condition in the Kennelly- Heaviside Layer, where the rays of the sun break up, the atmospheric molecules, so that a tremendous number of electrons are freed, thus causing a great deal of the electrical signal energy to be absorbed by this layer of ionized air. This means that now only a smaller percentage of the sky wave is reflected, which DECREASES the reception at distant points. At night, this heating effect upon the layer of ionized air is less pronounced, with the result that less absorption and greater reflection takes place at the Kennelly- Heaviside Layer, thereby INCREASING the reception at distant points.

This effect of the difference in night and day reception is most pronounced at short wavelengths but is also quite noticeable at the broadcast frequencies for here too, we are able to bring in distant stations better at night than during the daytime. Furthermore, during the daytime or warmer weather, the Kennelly-Heaviside Layer is closer to the earth than during cooler temperatures and for this reason, the skip distance for a given wave length is not as great during warmer temperatures than when the weather is cooler. At the same time, of course, the distance covered becomes greater with a decrease in atmospheric temperature.

This explanation of wave propagation will no doubt clear up any question, which you might have had in mind as to why the regularity of reception varies so much especially at the lower wavelengths. This information is important to you in that it will help you materially in figuring out the reasons for different peculiar effects, which are always encountered in short wave transmitting and reception.

THE SHORT-WAVE RECEIVER

Having investigated the nature of the shorter wave lengths, let us now proceed with the discussion of the construction of short wave receivers. In Fig. 4, you will see the circuit diagram of a simple battery type, two-tube short-wave receiver for headphone reception and upon inspecting

THIS CIRCUIT, YOU WILL OBSERVE THAT IT IS ESSENTIALLY THE SAME AS THAT OF AN ORDINARY TWO-TUBE BROADCAST RECEIVER FOR HEADPHONE RECEPTION, AND CONSISTS OF A DETECTOR AND ONE A.F. STAGE.

YOU SEE, EVEN THOUGH THESE SHORT WAVE RECEIVERS ARE REGARDED BY THE GENERAL PUBLIC AS BEING RATHER MYSTERIOUS IN THEIR CONSTRUCTION AND OPERATION WHEN COMPARED TO THE BROADCAST RECEIVER, YET IN REALITY, THE SAME PRINCIPLES ARE EMPLOYED IN BOTH OF THESE RECEIVERS. THIS NATURALLY MEANS THAT YOU HAVE NOTHING TO "UNLEARN" AND ALL OF THE RADIO PRINCIPLES, WHICH YOU HAVE LEARNED ABOUT BROADCAST RECEIVERS ARE GOING TO APPLY EQUALLY AS WELL TO SHORT-WAVE RECEIVERS.

THE ONLY ESSENTIAL DIFFERENCE BETWEEN THE OPERATION OF THE SHORT-WAVE RECEIVER AND THAT OF A BROADCAST RECEIVER IS THAT THE RADIO FREQUENCIES WITH WHICH THE SHORT WAVE RECEIVER MUST DEAL ARE MUCH HIGHER THAN THOSE HANDLED BY THE BROADCAST RECEIVER. THEREFORE, WE FIND THAT ALTHOUGH THE PARTS OF THESE TWO RECEIVERS ARE FUNDAMENTALLY THE SAME IN OPERATION, YET THEY MUST BE ESPECIALLY DESIGNED TO OPERATE AT HIGHER FREQUENCIES. SINCE THE RADIO FREQUENCIES ARE NOT USED IN THE A.F. STAGES OF A RECEIVER, IT IS OBVIOUS THAT THE DIFFERENCES BETWEEN THE BROADCAST AND SHORT-WAVE RECEIVER EXIST ONLY IN THE R.F. AND DETECTOR STAGES.

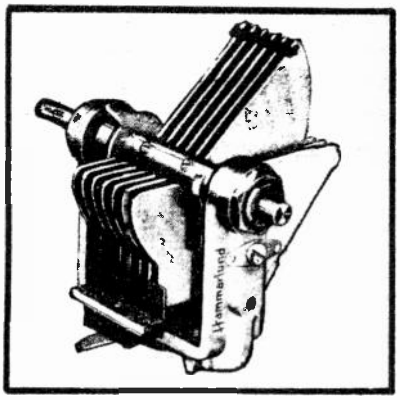

FIG.5
Tuning Condenser for Short Wave Receiver.

SHORT-WAVE CONDENSERS

IN YOUR STUDIES OF TUNED RADIO FREQUENCY CIRCUITS, YOU LEARNED THAT THE FREQUENCY, TO WHICH THE TUNED CIRCUIT RESPONDED, WAS DEPENDENT UPON THE CAPACITY OF THE TUNING CONDENSER AND THE INDUCTANCE OF THE COIL, WHICH WAS USED WITH THE GIVEN CONDENSER. FURTHERMORE, YOU ALSO FOUND THAT IF THE CAPACITY OF THE TUNING CONDENSER WAS REDUCED OR ELSE THE INDUCTANCE OF THE COIL REDUCED, THE TUNED CIRCUIT WOULD RESPOND TO HIGHER FREQUENCIES. THEN IF THIS CONDITION IS CARRIED STILL FARTHER, SO THAT THE CAPACITY OF THE TUNING CONDENSER AND THE INDUCTANCE OF THE COIL ARE BOTH DECREASED, THE TUNED CIRCUIT WILL RESPOND TO STILL HIGHER FREQUENCIES AND THIS IS JUST EXACTLY WHAT WE DO IN SHORT WAVE RECEIVERS.

FOR EXAMPLE, IN FIG. 5, YOU WILL SEE A TYPICAL TUNING CONDENSER FOR USE IN A SHORT WAVE RECEIVER. NOTICE THAT IT CONSISTS OF FEWER PLATES THAN FOUND IN THE CONVENTIONAL TUNING CONDENSER FOR BROADCAST PURPOSES AND THAT THESE PLATES ARE MADE OF HEAVY STOCK, WITH CONSIDERABLE SEPARATION BETWEEN THEM. THIS MEANS THAT THE SHORT-WAVE TUNING CONDENSER HAS LESS MAXIMUM CAPACITY THAN THE BROADCAST TYPE TUNING CONDENSER.

DUE TO THE HIGH FREQUENCIES HANDLED BY THE SHORT-WAVE RECEIVER, WE ARE FOREVER FACED WITH THE PROBLEM OF PREVENTING THESE FLIGHTY CURRENTS FROM LEAVING THEIR INTENDED CIRCUIT OR PATH AND DARTING IN ALL DIRECTIONS TO ADJACENT PARTS WHENEVER THEY GET THE SLIGHTEST CHANCE. THEREFORE, TO REDUCE THE CHANCES FOR ANY SUCH UNDESIRABLE CURRENT LOSSES, HIGH GRADE INSULATION IS USED ON THE BETTER QUALITY SHORT-WAVE TYPE TUNING CONDENSERS.

NOW WHEN WE COME TO THE SUBJECT OF COILS FOR THE SHORT-WAVE RECEIVER,

A PECULIAR BUT MOST INTERESTING CONDITION ARISES. FOR INSTANCE, IN BROADCAST WORK, OUR TUNERS ONLY HAVE TO COVER THE BAND OF FREQUENCIES, WHICH LIE BETWEEN 500 AND 1500 Kc., THUS GIVING US A RANGE OF BUT 1000 Kc. TO COVER WITH THE TUNER IN ORDER TO PICK UP EVERY STATION WITHIN THE BROADCAST BAND. BUT SINCE THE SHORT WAVE BAND INCLUDES ALL FREQUENCIES BETWEEN 1500Kc. AND 20,000 Kc., IT IS OBVIOUS THAT HERE WE HAVE A FREQUENCY RANGE OF 18,500Kc. OR $18\frac{1}{2}$ TIMES AS WIDE A RANGE AS THE BROADCAST RECEIVER.

WHEN BUILDING A BROADCAST RECEIVER, IT IS A SIMPLE MATTER TO DESIGN A COIL, WHICH WILL WORK TOGETHER WITH A SINGLE TUNING CONDENSER, SO AS TO COVER THE BROADCAST RANGE OF 1000 Kc. BUT TRYING TO COVER THE ENTIRE SHORT WAVE BAND OR A RANGE OF 15,500 Kc. WITH A SINGLE COIL-CONDENSER COMBINATION ISN'T SUCH A SIMPLE PROBLEM. BECAUSE OF THIS, YOU WILL FIND MOST SHORT-WAVE RECEIVERS USING PLUG-IN TYPE R.F. COILS.

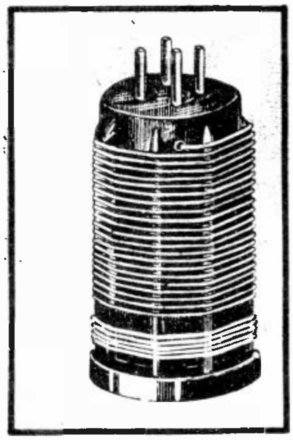

FIG. 6
A Plug-in Short Wave Coil

SHORT-WAVE COILS

A TYPICAL PLUG-IN TYPE SHORT WAVE COIL IS SHOWN YOU IN FIG. 6. NOTICE THAT THIS COIL IS WOUND ON A BAKELITE TUBING HAVING LONGITUDINAL BAKELITE RIBS ATTACHED TO IT. THE WINDING IS THEN WOUND AROUND THIS COIL FORM IN SUCH A MANNER THAT THE RIBS HOLD THE WINDING AWAY FROM THE MAIN BODY OF THE COIL FORM.

THIS METHOD OF CONSTRUCTION LIMITS THE AMOUNT OF THE COIL FORM WHICH ACTUALLY CONTACTS THE WINDING AND THIS REDUCES THE DIELECTRIC LOSSES OF THE COIL AND WHICH ARE ORDINARILY QUITE NOTICEABLE WHEN WORKING WITH THE HIGHER FREQUENCIES. ALSO NOTICE IN THE COIL OF FIG. 6 THAT THERE IS A SLIGHT AIR SPACE BETWEEN ADJACENT TURNS OF THE WINDING, SO THAT THE ADJACENT TURNS DO NOT TOUCH EACHOTHER -- WE THEN SAY THAT THE COIL IS SPACE WOUND.

ANOTHER INTERESTING FACT ABOUT COIL CONSTRUCTION FOR SHORT WAVE WORK IS THAT BEST RESULTS ARE GENERALLY OBTAINED WHEN THE COIL IS WOUND WITH BARE COPPER WIRE OR ELSE WITH PLAIN ENAMEL COATED COPPER WIRE RATHER THAN WITH COPPER WIRE WHICH HAS A CLOTH INSULATION, SUCH AS SILK OR COTTON. THE ENAMEL COATED COPPER WIRE IS THE MOST GENERALLY USED WIRE FOR SHORT WAVE RECEIVER COILS AND IN THIS CASE, THE ENAMEL COATING, AS WELL AS THE SPACING BETWEEN ADJACENT TURNS OF THE COIL OFFERS ADEQUATE INSULATION.

A RATHER LARGE WIRE SIZE IS ALSO GENERALLY USED FOR THE COIL WINDING WHICH IS INCLUDED IN THE TUNED CIRCUIT SO AS TO REDUCE THE RESISTANCE OF THE TUNED CIRCUIT AS MUCH AS POSSIBLE. THIS ADDS CONSIDERABLY TO THE EFFICIENCY OF THE RECEIVER BY REDUCING EXTRANEOUS LOSSES.

ALSO NOTICE THAT THE COIL FORM IN FIG. 6 HAS A STANDARD FOUR PRONG TUBE BASE ATTACHED TO IT. THE ENDS OF EACH OF THE COIL WINDINGS ARE CONNECTED TO THESE PRONGS WITHIN THE FORM, SO THAT BY PLUGGING THE COIL INTO A STANDARD FOUR PRONG (UX) TUBE SOCKET, WHOSE TERMINALS ARE PROPERLY WIRED TO THE RECEIVER CIRCUITS, WE HAVE A CONVENIENT MEANS OF INCLUDING OR REMOVING THIS PARTICULAR COIL FROM THE CIRCUIT SO THAT ANOTHER COIL CAN BE SUBSTITUTED FOR IT WHENEVER WE WISH TO TUNE OVER ANOTHER WAVE BAND.

IN FIG. 7, FOR INSTANCE, WE HAVE A SET OF FOUR PLUG-IN COILS AS USED BY MOST SHORT WAVE FANS TO COVER THE BAND FROM 15 TO 200 METERS. FOR EXAMPLE, WHEN USING A TUNING CONDENSER HAVING A CAPACITY RATING OF .00015 MFD., COIL #1 OF FIG. 7 WILL TUNE OVER THAT PORTION OF THE SHORT WAVE BAND EXTENDING FROM 16 TO 30 METERS, COIL #2 WILL COVER FROM 29 TO 58 METERS, COIL #3 FROM 54 TO 110 METERS AND COIL #4 FROM 103 TO 225 METERS.

THESE COIL FORMS CAN BE PURCHASED FROM MOST RADIO SUPPLY HOUSES EITHER WITH OR WITHOUT WINDINGS AND IN ADDITION TO THE RIBBED TYPE, PLAIN TUBING IS ALSO USED CONSIDERABLY FOR THIS PURPOSE.

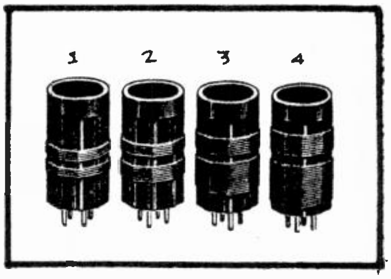

FIG. 7
Plug-in Coil Kit.

FOR ESPECIALLY EFFICIENT SHORTWAVE COILS, FORMS MADE OF ISOLANTITE ARE FREQUENTLY USED. ISOLANTITE LOOKS SOMEWHAT LIKE PORCELAIN AND IS A COMPARATIVELY NEW FORM OF INSULATION HAVING ESPECIALLY FINE DIELECTRIC PROPERTIES AND FOR CRITICAL USES IS RAPIDLY REPLACING FIBER, BAKELITE AND OTHER SIMILAR DIELECTRICS.

BY RETURNING TO FIG. 4 AGAIN, YOU WILL OBSERVE THAT GRID CONDENSER AND LEAK TYPE DETECTION IS USED TOGETHER WITH REGENERATION. THIS IS A COMMON PRACTICE IN THE MAJORITY OF SHORT WAVE RECEIVERS IN THAT THIS COMBINATION OFFERS GOOD SENSITIVITY WITH A MINIMUM NUMBER OF TUBES. THIS FEATURE OF COURSE MAKES POSSIBLE A SENSITIVE RECEIVER AT LOW COST.

IN THE CIRCUIT OF FIG. 4, TWO SINGLE 140 MMFD. (.00014 MFD.) VARIABLE CONDENSERS ARE USED, EACH WITH ITS INDIVIDUAL CONTROL. ONE OF THESE CONDENSERS IS CONNECTED ACROSS ONE OF THE WINDINGS L1 OF THE COIL FORM SO AS TO ACT AS A TUNING CONTROL, WHILE THE OTHER 140 MMFD. VARIABLE CONDENSER IS CONNECTED BETWEEN GROUND AND THE TICKLER L2 AND THUS SERVES AS A REGENERATION CONTROL.

THE 35 MMFD. CONDENSER, WHICH IS CONNECTED BETWEEN THE ANTENNA TERMINAL AND COIL L1 IN THE CIRCUIT OF FIG. 4 IS OF THE SEMI-VARIABLE TYPE. THAT IS, ITS CAPACITY CAN BE VARIED WITHIN CERTAIN LIMITS BY MEANS OF A BAKELITE SCREW DRIVER. ITS PURPOSE IS TO REDUCE THE EFFECTIVE LENGTH OF THE ANTENNA SO THAT THE ANTENNA CAN BE MADE TO MORE NEARLY RESONATE AT THE SIGNAL FREQUENCIES BEING RECEIVED AND IN THIS WAY SOMEWHAT INCREASES THE VOLUME AT WHICH THE SIGNALS ARE RECEIVED.

THE NUMBERS 1,2,3 AND 4 IN FIG. 4 INDICATE THE CORRESPONDING PRONGS AND SOCKET TERMINALS FOR THE PLUG-IN TYPE COIL WHICH IS ILLUSTRATED IN FIG. 8 AND WHICH IS TO BE USED IN THE CIRCUIT OF FIG. 4.

IN THE CONSTRUCTION OF SHORT WAVE RECEIVERS, STILL MORE CARE MUST BE EXCERISED IN THE MECHANICAL LAYOUT OF THE RECEIVER THAN WHEN BUILDING BROADCAST RECEIVERS. THE REASON FOR THIS IS THAT THE HIGHER FREQUENCIES ARE MORE DIFFICULT TO HANDLE AND HAVE A TENDENCY TO ENTER GROUND WHENEVER POSSIBLE. BESIDES THIS, EXTRANEOUS COUPLING BETWEEN PARTS ALSO OCCURS MORE READILY WHEN THE CIRCUITS ARE OPERATING AT HIGHER FREQUENCIES. BECAUSE OF THESE FACTS, IT BECOMES ADVISABLE WHEN CONSTRUCTING A SHORT-WAVE RECEIVER, TO ALLOW CONSIDERABLE SPACE BETWEEN COILS ETC., BETWEEN WHICH UNWANTED COUPLING IS LIKELY TO OCCUR AND TO ARRANGE THE PARTS TO REDUCE AS MUCH AS POSSIBLE ANY UNWANTED COUPLING.

FIG. 9 SHOWS YOU A TYPICAL EXAMPLE OF HOW THE PARTS ARE CORRECTLY ARRANGED ON THE DECK OF A METAL CHASSIS BASE FOR A THREE TUBE SHORT WAVE RECEIVER. IN THIS PARTICULAR CASE, THERE ARE THREE TUBES, A 58 R.F. AMPLIFIER, A 57 DETECTOR AND A 47 POWER AMPLIFIER AND THE CIRCUIT DIAGRAM FOR THIS SAME RECEIVER APPEARS IN FIG. 10.

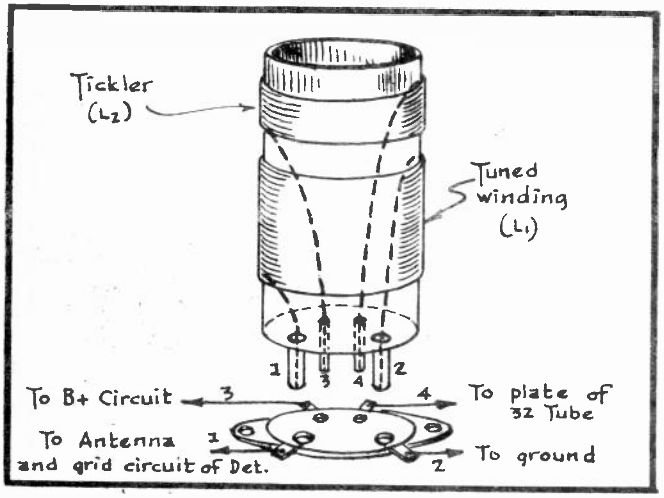

FIG. 8

Base & Socket Connections for Plug-in Coil.

SINCE TWO COILS ARE USED IN THIS PARTICULAR RECEIVER (ONE FOR THE R.F. STAGE AND--ONE FOR THE DETECTOR STAGE) NOTICE HOW WIDELY SEPARATED THEY ARE ON THE CHASSIS SO THAT PRACTICALLY NO INDUCTIVE COUPLING CAN EXIST BETWEEN THEM.

FURTHERMORE, YOU WILL ALSO SEE IN FIG. 9 THAT EACH OF THESE COILS IS MOUNTED IN AN ISOLANTITE SOCKET WHICH IS SLIGHTLY RAISED FROM THE CHASSIS DECK AND NO SHIELD CANS ARE USED AROUND THE COILS. BY KEEPING THE COILS AS FAR AS POSSIBLE FROM ANY METALLIC MASS, THERE WILL BE LESS DETUNING EFFECTS BY THE CAPACITY INTRODUCED BY SUCH GROUNDED METALLIC MASSES AND ALSO LESS TENDENCY FOR THE SIGNAL ENERGY TO STRAY INTO THESE GROUNDED OBJECTS SO AS TO REDUCE THE SIGNAL.

SINCE WINDINGS L2 AND L4 OF THE ANTENNA STAGE AND DETECTOR STAGE BOTH REQUIRE TUNING, THEY CAN BE TUNED SIMULTANEOUSLY BY A SINGLE CONTROL THE SAME AS IN THE CONVENTIONAL BROADCAST RECEIVER THROUGH THE USE OF A TWO-GANG SHORT WAVE TUNING CONDENSER.

IN ALL SHORT WAVE RECEIVERS, SPECIAL CARE SHOULD BE TAKEN TO MAKE THE CONTROL GRID WIRES AS SHORT AS POSSIBLE AND TO KEEP THEM WELL APART FROM ALL METAL STRUCTURE OF THE RECEIVER AS WELL AS FROM ALL OTHER WIRING. IN FACT, ALL CIRCUIT WIRING SHOULD BE RUN BETWEEN TERMINALS BY AS DIRECT A ROUTE AS POSSIBLE.

ALSO NOTICE IN FIG. 9 THAT THE R.F. AND DETECTOR TUBE ARE BOTH FULLY SHIELDED -- THE SHIELDING HAS SIMPLY BEEN PARTIALLY REMOVED IN THIS ILLUSTRATION SO AS TO SHOW THESE TWO TUBES MORE CLEARLY. FOR BEST RESULTS ON THE SHORT WAVES, IT IS ALSO

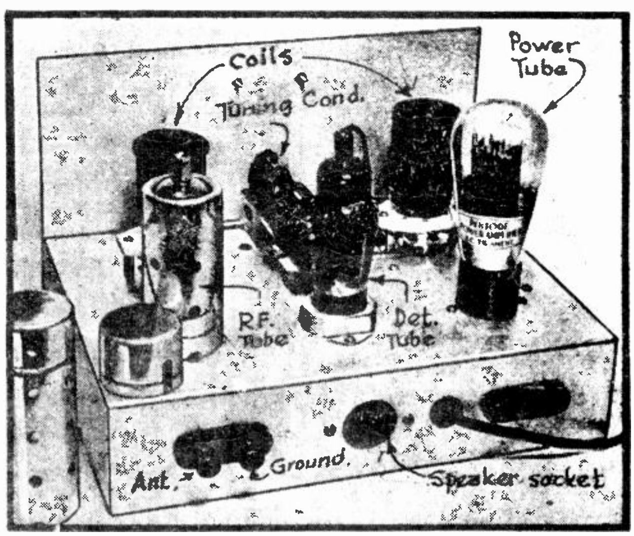

FIG. 9

Parts Arrangement for Short Wave Receiver.

ADVISABLE TO HOUSE THE ENTIRE RECEIVER IN A METALLIC SHIELD CAN.

WITH THE CIRCUIT DESIGN AS ILLUSTRATED IN FIG. 10, THE FILAMENT SUPPLY CAN BE FURNISHED BY A 2.5 VOLT FILAMENT TRANSFORMER CONNECTED TO THE 110 VOLT A.C. CIRCUIT AND THE 180 VOLT "B" SUPPLY CAN BE FURNISHED EITHER BY BATTERIES OR BY A POWER PACK.

THE COMPLETE PARTS LIST FOR THIS RECEIVER IS GIVEN YOU IN TABLE I.

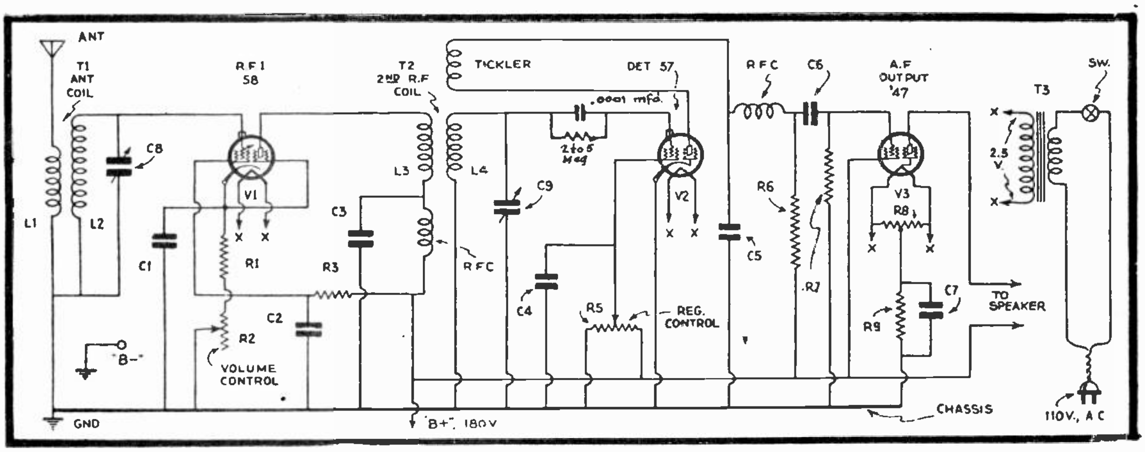

FIG. 10
Circuit Diagram of the Three Tube Receiver.

WHILE THE CONSTRUCTION OF THE ANTENNA STAGE COIL APPEARS IN FIG. 11 AND THE SECOND R.F. COIL IN FIG. 12.

LIST OF PARTS FOR THE RECEIVER OF FIG. 10

1—SET OF ANTENNA COILS AS DESCRIBED.
1—FILAMENT TRANSFORMER, WITH A 2.5 VOLT SECONDARY, T3.
1—5,000—OHM VOLUME CONTROL, R2.
1—100,000—OHM POTENTIOMETER, R5.
2—600—OHM RESISTORS, 1—WATT, R1, R9.
3—.1—MEG. RESISTORS, 1—WATT, R3, R6.
1—.5—MEG. RESISTOR, 1—WATT R7.
1—20—OHM CENTER—TAPPED RESISTOR, R8.
1—.006—MF. CONDENSER, C1.
1—.02—MF. CONDENSER, C2.
1—.1—MF. CONDENSER, C3.
1—.1—MF. CONDENSER, C4.
1—.001—MF. CONDENSER, C5.
1—.03—MF. CONDENSER, C6.
1—25—MF. DRY ELECTROLYTIC CONDENSER, C7.
1—TWO—GANG "TUNING" CONDENSER, 140—MMF., C8, C9.
2—R.F. CHOKES, 100 TURNS NO. 38 ENAMELED WIRE ON A SPOOL $\frac{1}{4}$—INCH IN DIAMETER AND $\frac{1}{4}$—INCH LONG.
1—SPECIAL PANEL AND CHASSIS.
2—TUBE SHIELDS.

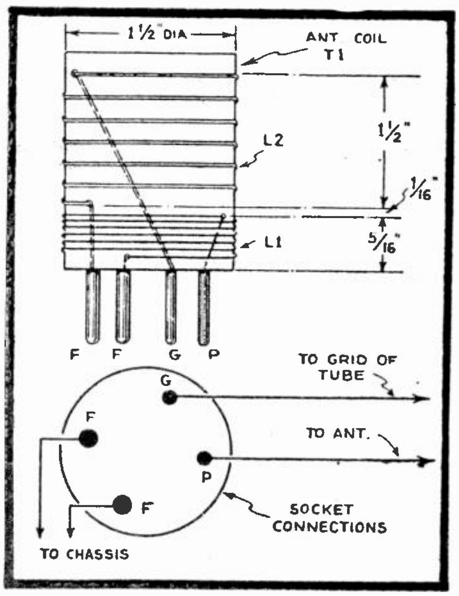

FIG. 11
The Antenna Stage Coil.

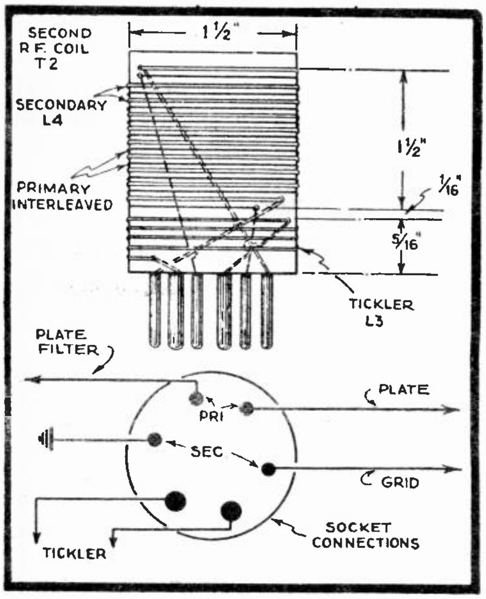

FIG.12

The Second R.F. Coil.

1-ANTENNA AND GROUND STRIP.
2-6-PRONG SOCKETS.
1-5-PRONG SOCKET.
1-4-PRONG SOCKET
1-4-PRONG ISOLANTITE SOCKET, TYPE FOR T1.
1-6-PRONG ISOLANTITE SOCKET, FOR T2.
1-THREE-WIRE CABLE.
1-POWER CABLE WITH PLUG.
1-0-100 VERNIAL DIAL.
1-"MAGNETIC" LOUD SPEAKER.

RETURNING TO FIG. 11, YOU WILL SEE THAT THE DIAMETER OF THE ANTENNA STAGE COIL FORM IS 1½" AND THAT IT HAS A FOUR PRONG BASE. THE CORRESPONDING CIRCUIT CONNECTIONS FOR THE BASE AND SOCKET ARE ILLUSTRATED DIRECTLY BELOW.

TO COVER THE SHORT WAVE BAND FROM 16 TO 200 METERS, FOUR OF THESE ANTENNA STAGE COILS ARE REQUIRED. THE CONSTRUCTIONAL DATA FOR THIS SET OF FOUR ANTENNA STAGE COILS IS AS FOLLOWS:

TO COVER THE 16 TO 31 METER BAND, THE TUNED WINDING L2 CONSISTS OF 6 1/3 TURNS OF #18 B&S ENAMELED WIRE, SPACE-WOUND TO COVER A WINDING LENGTH OF 1½" AS ILLUSTRATED IN FIG. 11. THE PRIMARY WINDING L1 FOR THIS SAME COIL CONSISTS OF 3 TURNS OF #30 B&S DOUBLE SILK COVERED WIRE WOUND 1/16" BELOW L2.

FOR THE 31 TO 55 METER BAND, L2 CONSISTS OF 11 5/6 TURNS OF #18 B&S ENAMELED WIRE, SPACE-WOUND TO COVER A WINDING LENGTH OF 1½" AND L1 CONSISTS OF 7 TURNS OF #30 B&S DOUBLE SILK COVERED WIRE WOUND 1/16" BELOW L2.

TO COVER THE 55 TO 104 METER BAND, COIL L2 CONSISTS OF 25 1/3 TURNS OF #18 B&S ENAMELED WIRE, SPACE-WOUND TO COVER A WINDING LENGTH OF 1½" AND L1 CONSISTS OF 13 TURNS

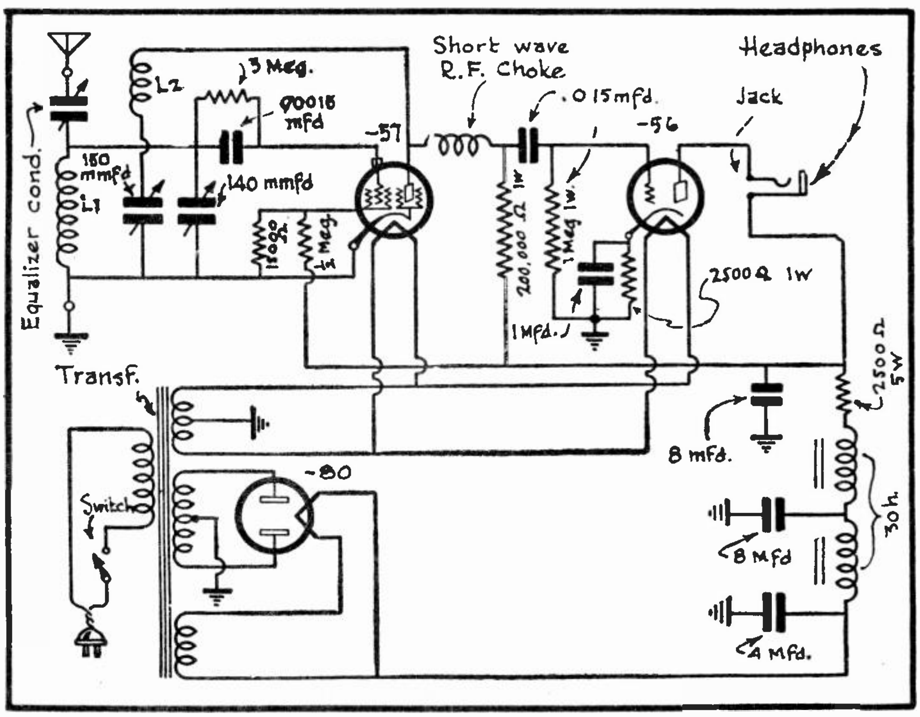

FIG. 13

Three Tube A.C. Short Wave Receiver.

OF #30 B&S DOUBLE SILK COVERED WIRE WOUND 1/16" BELOW L2.

FOR THE 104 TO 200 METER BAND, COIL L2 CONSISTS OF 55 TURNS OF #26 B&S ENAMEL WIRE AND L1 CONSISTS OF 15 TURNS OF #30 B&S DOUBLE SILK COVERED WIRE.

THE SECOND R. F. COIL SET ILLUSTRATED IN FIG. 12, YOU WILL NOTICE, IS ALSO WOUND ON A $1\frac{1}{2}$" DIAMETER FORM BUT THE FORM IN THIS CASE IS EQUIPPED WITH A SIX PRONG BASE. THE BASE AND CORRESPONDING SOCKET CONNECTIONS ARE SHOWN IN THE LOWER PORTION OF FIG. 12.

FOR EACH OF THE ANTENNA STAGE COILS SO FAR DESCRIBED, A CORRESPONDING SECOND R. F. COIL MUST BE USED AND THE CONSTRUCTIONAL DATA FOR THE FOUR NECESSARY SECOND R.F. COILS FOLLOWS:

TO COVER EACH OF THE FOUR BANDS ALREADY DESIGNATED, WINDING L4 OF THE SECOND R.F. COIL MUST BE AN EXACT DUPLICATE OF L2 FOR THE SAME WAVE BAND.

THE PRIMARY WINDING L3 FOR THE 16 TO 31 METER SECOND R.F. COIL CONSISTS OF 6 1/3 TURNS OF #30 B&S DOUBLE SILK COVERED WIRE INTERLEAVED BETWEEN THE TURNS OF SECONDARY L4 AS ILLUSTRATED IN FIG. 12, WHILE THE TICKLER COIL L3 IS WOUND AT ONE END OF L4 AND CONSISTS OF 3 TURNS OF #30 B&S DOUBLE SILK COVERED WIRE.

FOR THE 31 TO 55 METER BAND, THE PRIMARY L3 CONSISTS OF 11 5/6 TURNS OF #30 DOUBLE SILK COVERED WIRE INTERLEAVED BETWEEN THE TURNS OF L4 AND THE TICKLER IS WOUND WITH 6 TURNS OF #30 B&S DOUBLE SILK COVERED WIRE.

COIL L3 FOR THE 55 TO 104 METER BAND IS WOUND WITH 25 1/3 TURNS OF #30 B&S DOUBLE SILK COVERED WIRE INTERLEAVED BETWEEN THE TURNS OF L4, WHILE THE TICKLER IS WOUND WITH 9 TURNS OF #30 B&S DOUBLE SILK COVERED WIRE.

FOR THE 104 TO 200 METER BAND, COIL L3 IS WOUND WITH 36 TURNS OF #30 B&S DOUBLE SILK COVERED WIRE INTERLEAVED BETWEEN THE TURNS OF L4, WHILE THE TICKLER IS WOUND WITH 13 TURNS OF #30 B&S DOUBLE SILK COVERED WIRE.

RETURNING TO FIG. 10 YOU WILL OBSERVE THAT REGENERATION IN THIS CASE IS CONTROLLED BY VARYING THE SCREEN GRID VOLTAGE OF THE 57 DETECTOR TUBE BY MEANS OF THE POTENTIOMETER R5. THE MOST IMPORTANT FEATURE OF THIS TYPE OF REGENERATION CONTROL IS THAT IT DOES NOT EFFECT THE TUNING OF THE CIRCUIT AND FOR THIS REASON PERMITS BRINGING-IN THE SAME STATION AT THE SAME DIAL MARK AT ANY FUTURE TIME REGARDLESS OF THE REGENERATION CONTROL ARM'S POSITION.

A THREE-TUBE A.C. SHORT WAVE RECEIVER

IN FIG. 13 YOU ARE SHOWN THE CIRCUIT DIAGRAM OF AN A.C. OPERATED SHORT WAVE RECEIVER WHICH IS DESIGNED FOR HEADPHONE RECEPTION. THE VALUES FOR ALL OF THE PARTS ARE INDICATED DIRECTLY UPON THE DIAGRAM AND YOU WILL ALSO READILY NOTICE THAT REGENERATION IS IN THIS INSTANCE CONTROLLED BY THE 150 MMFD. CONDENSER WHICH IS CONNECTED BETWEEN THE TICKLER COIL L2 AND GROUND.

IN THIS RECEIVER, NO PRIMARY WINDING IS USED FOR THE ANTENNA INPUT

AND THE SIGNAL IS FED FROM THE ANTENNA, THROUGH THE SEMI-VARIABLE EQUALIZING CONDENSER DIRECTLY INTO THE TUNED WINDING L1 WHICH FORMS A PART OF THE DETECTOR CIRCUIT.

WINDING L1 CORRESPONDS TO THE TUNED SECONDARY WINDING OF THE CONVENTIONAL SHORT WAVE R.F. TRANSFORMER AND SINCE IT IS USED ONLY WITH THE TICKLER L2 AND NO PRIMARY WINDING, A FORM WITH A FOUR PRONG BASE CAN BE USED TO AFFECT THE PLUG-IN FEATURE.

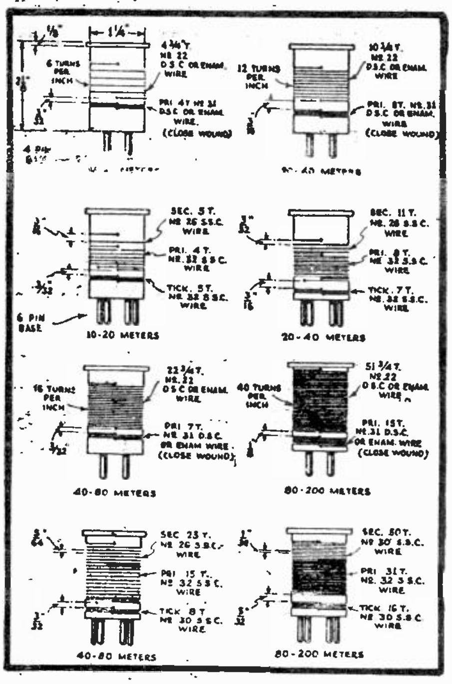

FIG. 14
Construction of Plug-in Coils.

IN FIG. 14 YOU WILL FIND COMPLETE SPECIFICATIONS FOR THE CONSTRUCTION OF PLUG-IN COILS OF THE TWO AND THREE WINDING VARIETY TO COVER THE SHORT-WAVE BAND FROM 10 TO 200 METERS WHEN USED WITH A .00014 MFD. TUNING CONDENSER. THE COIL FORM DIAMETER IN THIS INSTANCE, YOU WILL NOTICE, IS 1¼".

IN FIG. 14, THE VARIOUS ABREVIATIONS HAVE THE FOLLOWING MEANING: T = TURNS; D.S.C = DOUBLE SILK COVERED; S.S.C. = SINGLE SILK COVERED WIRE; PRI = PRIMARY WINDING; SEC. = SECONDARY OR TUNED WINDING; TICK = TICKLER WINDING.

THE DETECTOR IN THE CIRCUIT OF FIG. 13 FEEDS INTO A RESISTANCE-CAPACITY COUPLED A.F. STAGE IN WHICH A TYPE 56 TUBE IS USED AND THE WINDINGS OF THE HEADPHONES ARE THEN CONNECTED IN SERIES WITH THE PLATE CIRCUIT OF THIS LATTER TUBE -- THE PLUG-IN JACK FURNISHING THIS CONNECTION.

A BATTERY OPERATED RECEIVER

IN FIG. 15 WE HAVE A CIRCUIT DIAGRAM OF A TWO-TUBE BATTERY OPERATED SHORT WAVE RECEIVER EMPLOYING A 32 REGENERATIVE DETECTOR AND A TYPE 30 A.F. AMPLIFIER.

OBSERVE IN FIG. 15 THAT A POTENTIOMETER IS CONNECTED IN THE SCREEN GRID CIRCUIT OF THE DETECTOR TUBE SO THAT THE SCREEN GRID VOLTAGE OF THIS TUBE MAY BE VARIED IN ORDER TO CONTROL REGENERATION.

BY USING THE SAME SIZE R.F. COIL FORM AS ALREADY DESCRIBED RELATIVE TO THE CIRCUIT OF FIG. 10 IN THIS LESSON AND WITH A FOUR PRONG BASE, YOU CAN WIND COILS L1 AND L2 IN FIG. 15 TO CORRESPOND WITH COIL L4 AND ITS TICKLER IN THE CIRCUIT OF FIG. 10. NO PRIMARY WINDING WILL BE NEEDED FOR THE CIRCUIT ILLUSTRATED IN FIG. 15. YOU CAN ALSO USE THE DATA SUPPLIED IN FIG. 14.

ANOTHER INTERESTING FEATURE REGARDING THE CIRCUIT OF FIG. 15 IS THE METHOD OF COUPLING THE TYPE 30 TUBE TO THE OUTPUT SIDE OF THE DETECTOR. THE SECONDARY WINDING OF AN ORDINARY 3 TO 1 RATIO A.F. TRANSFORMER IN THIS CASE IS CONNECTED IN SERIES WITH THE PLATE CIRCUIT OF THE DETECTOR TUBE AND IN THIS WAY USED AS AN A.F. CHOKE TO REPLACE THE CUSTOMARY PLATE CIRCUIT RESISTOR AS USED WITH RESISTANCE -- CAPACITY COUPLING.

THEREFORE, THE A.F. SIGNAL VOLTAGES WHICH ARE DEVELOPED ACROSS THIS TRANSFORMER WINDING, ARE FORCED THROUGH THE .02 MFD. COUPLING CONDENSER AND APPLIED TO THE GRID OF THE 30 TUBE. THE TRANSFORMER'S PRIMARY WINDING IS NOT USED.

BY EMPLOYING THIS METHOD OF INTERSTAGE COUPLING, NOT SO MUCH D.C."B" VOLTAGE WILL BE LOST IN THE PLATE CIRCUIT AS IS THE CASE WHEN A PLATE CIRCUIT RESISTOR OF HIGH OHMIC VALUE IS USED HERE. FOR THIS REASON, A HIGHER "B" VOLTAGE CAN NOW BE IMPRESSED UPON THE PLATE OF THE DETECTOR TUBE. AT THE SAME TIME, THE HIGH INDUCTANCE OF THE TRANSFORMER WINDING OFFERS SUFFICIENT OPPOSITION TO THE A.F. SIGNAL VOLTAGES, WHICH ARE OF AN A.C. COMPONENT, SO AS TO FORCE THEM THRU THE COUPLING CONDENSER.

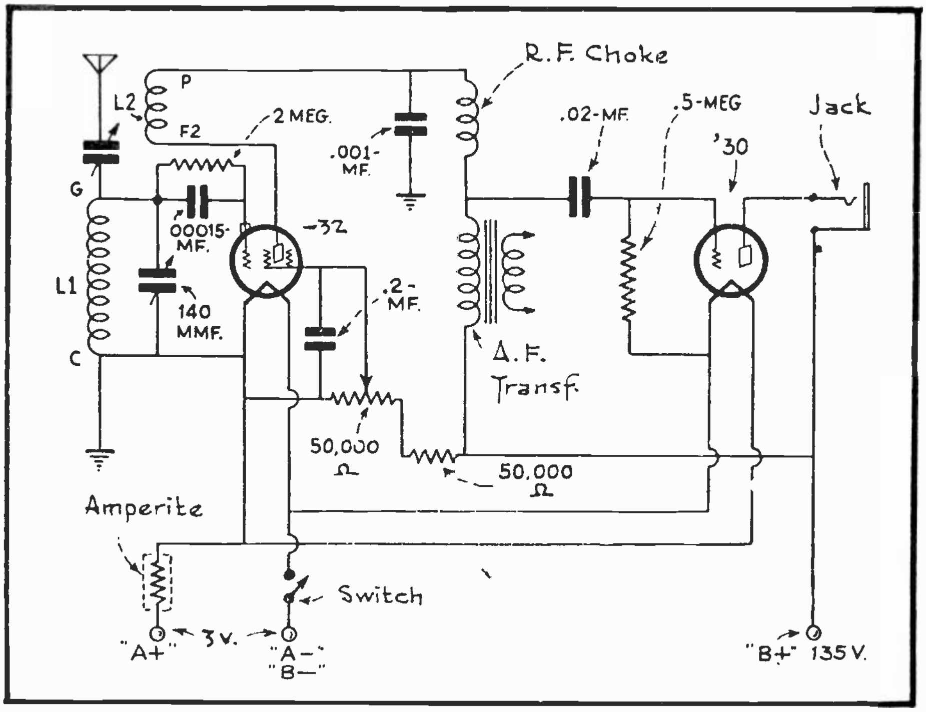

FIG. 15

Two Tube Battery Short Wave Receiver.

DUE TO THE CHOICE OF TUBES IN THE CIRCUIT OF FIG. 15, YOU CAN READILY SEE THAT THIS RECEIVER CAN BE OPERATED WITH AN "A" SUPPLY CONSISTING OF TWO SERIES -- CONNECTED DRY CELLS AND THREE SERIES-CONNECTED 45 VOLT "B" BATTERIES.

SHORT-WAVE ANTENNAS

IN ORDER TO OBTAIN THE BEST POSSIBLE RECEPTION AT THE SHORTER WAVE LENGTHS, IT IS NECESSARY TO USE A FIRST CLASS ANTENNA SYSTEM. THIS IS ESPECIALLY TRUE IF ONE DESIRES TO BRING IN DISTANT STATIONS.

ALTHOUGH A GOOD ANTENNA OF THE CONVENTIONAL INVERTED "L" TYPE, TOGETHER WITH A GOOD GROUNDING SYSTEM, WILL MAKE SHORT-WAVE RECEPTION POSSIBLE, YET THE SPECIALLY DESIGNED SHORT-WAVE ANTENNA, WHICH IS ILLUSTRATED IN FIG. 16, WILL OFFER SUPERIOR RESULTS.

NOT ONLY WILL THE ANTENNA OF FIG. 16 ASSIST IN ENABLING THE RECEIVER TO PERFORM WITH GREATER SENSITIVITY AND SELECTIVITY, BUT IT WILL AT THE SAME TIME REDUCE THE PICKUP OF EXTRANEOUS NOISES CAUSED BY ELECTRICAL INTERFERENCE DISTURBANCES.

AS YOU WILL NOTICE IN FIG. 16, THE ELEVATED PORTION OF THIS ANTENNA

CONSISTS OF TWO LENGTHS OF REGULAR ENAMEL COATED STRANDED COPPER ANTENNA WIRE FASTENED TO A COMMON ANTENNA INSULATOR (THE CENTER INSULATOR IN THE ILLUSTRATION.) THE TWO LENGTHS OF ANTENNA WIRE ARE THEN EXTENDED IN OPPOSITE DIRECTIONS, PARALLEL TO THE EARTH AND THE FAR ENDS FASTENED TO INDIVIDUAL ANTENNA INSULATORS WHICH ARE ANCHORED TO A SET OF MASTS OR OTHER FIRM SUPPORT. EACH OF THESE ANTENNA WIRE LENGTHS SHOULD BE 33 FT.

IT IS ADVISABLE THAT THIS ELEVATED PORTION OF THE ANTENNA BE EXTENDED OVER GROUND FREE FROM TREES, BUILDINGS ETC. AND THAT IT BE ELEVATED AT A HEIGHT OF ABOUT 45 FEET.

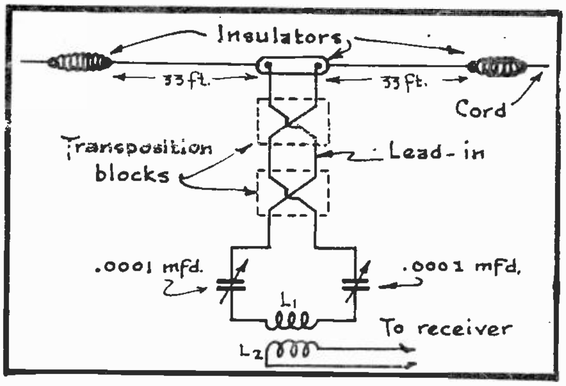

FIG. 16

The Special Antenna.

FROM THE INNERMOST ENDS OF EACH OF THESE ELEVATED WIRES, A LEAD-IN WIRE IS RUN TO THE RECEIVER — THE TWO LEAD-IN WIRES BEING RUN PARALLEL TO EACHOTHER BUT CROSSED OR TRANSPOSED AT INTERVALS OF 15". THE LEAD-IN MAY BE MADE WITH #14 B&S ENAMELED COPPER CONDUCTOR AND TRANSPOSITION BLOCKS MADE OF BAKELITE, PORCELAIN, OR ISOLANTITE MAY BE USED AS ILLUSTRATED IN FIG. 17, SO THAT THE LEAD-IN WIRES CAN BE CROSSED WITHOUT TOUCHING EACHOTHER. THESE TRANSPOSITION BLOCKS CAN BE PURCHASED READY-MADE FROM MOST RADIO SUPPLY CONCERNS.

THESE TWO LEAD-IN WIRES ARE THEN CONNECTED TO THE COUPLING, CONSISTING OF THE COIL L1 AND THE TWO .0001 MFD. VARIABLE CONDENSERS. COIL L1 MAY CONSIST OF ABOUT 12 TO 15 TURNS OF #22 B&S DOUBLE COTTON COVERED WIRE WOUND ON AN INSULATIVE TUBULAR FORM, WHOSE DIAMETER IS SLIGHTLY LARGER THAN THE DIAMETER OF THE COIL FORM USED IN THE ANTENNA STAGE OF THE RECEIVER. COIL L1 CAN THEN BE SLIPPED OVER THE ANTENNA STAGE COIL OF THE RECEIVER DESIGNATED AS L2 IN FIG. 16 AND THE DISTANCE BETWEEN THESE COILS VARIED TO PRODUCE THE DESIRED RESULTS.

DURING THE RECEPTION OF ANY PROGRAM, THE .0001 MFD. VARIABLE CONDENSERS IN THE ANTENNA CIRCUIT SHOULD BE ADJUSTED FOR BEST RECEPTION.

TUNING-IN SHORT-WAVE STATIONS

TO TUNE IN SHORT-WAVE PROGRAMS, REQUIRES GREATER SKILL THAN DOES THE TUNING IN OF BROADCAST PROGRAMS BECAUSE THE SHORT WAVE STATIONS COME IN AND GO OUT WHEN THE TUNING DIAL IS TURNED ONLY SLIGHTLY ONE WAY OR ANOTHER. BECAUSE OF THIS FACT, THE DRIVE OF THE DIAL AS USED ON SHORT WAVE RECEIVERS IS GEARED SO THAT CONSIDERABLE MOVEMENT OF THE DIAL KNOB PRODUCES VERY LITTLE MOVEMENT OF THE DIAL AND THE TUNING CONDENSER PLATES.

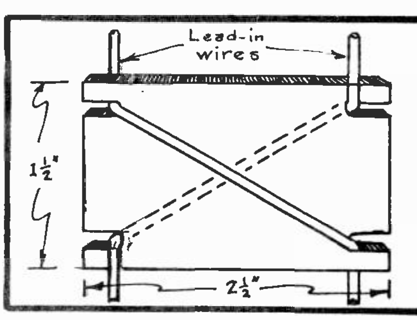

FIG. 17

The Transposition Block.

WHEN OPERATING A SHORT-WAVE RECEIVER

EMPLOYING A REGENERATIVE DETECTOR, IT IS THE COMMON PRACTICE TO FIRST TURN THE RECEIVER SWITCH ON SO AS TO PERMIT THE TUBES TO HEAT UP TO OPERATING EFFICIENCY AND THEN TO TURN UP THE REGENERATION CONTROL UNTIL A HISSING SOUND IS HEARD COMING FROM THE SPEAKER. THIS HISSING SOUND INDICATES THAT THE RECEIVER IS REGENERATING.

PROCEED TO TUNE-IN A STATION BY OPERATING THE TUNING CONTROL VERY SLOWLY UNTIL A STATION IS HEARD TO COME IN. SET THE DIAL TO THE POINT WHERE THE STATION COMES IN LOUDEST AND ADJUST THE REGENERATION CONTROL FOR THE DESIRED VOLUME. IF THE REGENERATION CONTROL IS TURNED ON TOO FAR, THEN THE CIRCUIT WILL COMMENCE TO OSCILLATE AND THIS CONDITION WILL BE INDICATED BY A SQUEALING SOUND BEING EMITTED FROM THE SPEAKER.

FOR MAXIMUM SENSITIVITY, THE REGENERATION CONTROL SHOULD BE TURNED ON AS FAR AS POSSIBLE WITHOUT CAUSING A SQUEAL.

HAVING COMPLETED THIS LESSON, YOU SHOULD NOW BE FAMILIAR WITH THE BASIC RPINCIPLES OF SHORT WAVE RECEPTION AS WELL AS WITH THE CONSTRUCTIONAL FEATURES OF RECEIVERS USED FOR THIS PURPOSE. LATER ON, HOWEVER, YOU WILL RECEIVE ADDITIONAL INSTRUCTION REGARDING THE MORE COMPLEX SHORT WAVE RECEIVERS, SHORT WAVE ADAPTERS AND CONVERTERS, ALL-WAVE RECEIVERS ETC. IN FACT, YOU WILL FIND NATIONAL TO OFFER YOU COMPLETE INSTRUCTION IN SHORT WAVE WORK, AS WELL AS IN ALL OTHER BRANCHES OF THE RADIO INDUSTRY.

"I will study and prepare myself, and maybe my chance will come."

—ABRAHAM LINCOLN.

Lincoln's chance came as it always comes if you are ready for it.

Study, well chosen reading, all efforts to improve one's self—to prepare for the opportunities which may come—are *always* worth while.

Examination Questions

LESSON NO. 36

> The secret of success is to set a goal and then study and work until that goal is reached. When you reach it then set another goal a little further ahead and study and work some more. - is that so? -

1. - WHAT ARE THE MOST ESSENTIAL DIFFERENCES BETWEEN THE CONSTRUCTION OF A BROADCAST RECEIVER AND A SHORT-WAVE RECEIVER?

2. - WHAT IS ONE OF THE REASONS WHY RADIO SIGNALS CAN BE RECEIVED AT GREATER DISTANCES BY MEANS OF SHORT WAVE TRANSMISSION THAN IF THESE SIGNALS WERE TRANSMITTED IN THE REGULAR BROADCAST BAND?

3. - WHAT IS MEANT BY THE TERM "SKIP-DISTANCE"?

4. - HOW DO SHORT WAVE COILS OR R.F. TRANSFORMERS DIFFER FROM THE CONVENTIONAL COIL OR R.F. TRANSFORMER AS USED IN THE BROADCAST RECEIVER?

5. - WHAT ARE SOME OF THE MORE IMPORTANT POINTS TO CONSIDER REGARDING THE PLACEMENT OF PARTS ON THE CHASSIS OF A SHORT WAVE RECEIVER?

6. - WHY IS THE PRINCIPLE OF REGENERATIVE DETECTION USED SO EXTENSIVELY IN SHORT WAVE RECEIVERS?

7. - DESCRIBE A GOOD ANTENNA SYSTEM WHICH IS ESPECIALLY SUITABLE FOR SHORT WAVE RECEPTION?

8. - WHY IS IT MORE DIFFICULT TO TUNE IN SIGNALS AT THE SHORTER WAVELENGTHS THAN IN THE REGULAR BROADCAST BAND?

9. - HOW DO SHORT WAVE TUNING CONDENSERS COMPARE WITH THE ORDINARY TYPE OF TUNING CONDENSERS AS USED IN BROADCAST RECEIVERS?

10. - DRAW A CIRCUIT DIAGRAM OF A SIMPLE BATTERY OPERATED SHORT WAVE RECEIVER.

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RADIO - TELEVISION

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

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LESSON NO. 37

Mathematics Applied to Radio

Up to the present time, you found your lessons to contain very little mathematics. They dealt practically exclusively with the principles governing the operation of different types of popular circuits, trouble-shooting and general radio construction work. Now that you have acquired this amount of foundational training, you are ready to go a step farther and that is to learn how these different types of circuits are DESIGNED. This naturally requires the use of a certain amount of mathematics and so we have prepared this particular lesson, so that you can "brush-up" on your mathematics if such is necessary, before we go ahead with its application to radio circuits.

By all means do not feel that just because mathematics is involved in the lessons to follow that your studies are going to become dry. The truth of the matter is that the PRACTICAL METHOD which National uses to apply these mathematical principles to Radio is going to be of great interest to you and you are going to learn a great deal from it.

To still further stimulate your interest, you will find that we have added variety to your following studies by including practical radio construction lessons at specific intervals among the lessons of a more technical nature.

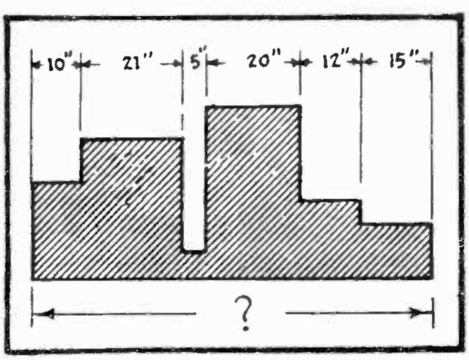

FIG. 1
Calculating Total Length of a Figure

It is advanced training as this which is going to carry you to the top of the Radio Industry, so we are depending upon you to do your utmost to master the studies to come. Remember, National always has the student's interest at heart.

PRACTICAL MATHEMATICS

Mathematics is the one tool, which is extensively used in practically every line of work. Of course, this does not necessarily mean that one need be a master mathematician in order to succeed in his chosen life's work but a good fundamental understanding of this subject will enable one to accomplish more than would be possible without its use.

In this lesson, it is our aim to give you just those fundamental mathematical facts which it is NECESSARY for you to know. Probably, most of the information given in this lesson is already well known to you but if not, read every part of it carefully, so that you will understand each point thoroughly. In the latter portion of this lesson, even those who have had a certain amount of mathematical training, will find some valuable suggestions.

ADDITION

The first arithmetical process, which we shall consider, is ADDITION. To illustrate this, let us look at Fig. 1. Here we have a casting, whose partial dimensions are all marked on the drawing. The problem now is to determine the total width of this casting and so we resort to the process of addition. That is, we must add together 10 inches, 21 inches, 5 inches, 20 inches, 12 inches and 15 inches. To do this, we arrange these figures in a vertical column as at (A) in Fig. 2 and draw a horizontal line below the column.

(A)	(B)	(C)
10	10	10
21	21	21
5	5	5
20	20	20
12	12	12
15	15	15
	3	83

FIG. 2

Now the right hand column of figures under (A) is the "units" column, whereas the left hand column of figures under (A) is the tens column and therefore, note that the single number 5 must be placed under the UNITS column. We begin by adding the figures in the right hand column under (A) from the bottom of this column toward the top as 5+2+0+5+1+0 and this is equal to 13. The 3 of this sum or result is placed directly under the column of figures, which was just added up but below the horizontal line as at (B) of Fig. 2.

The 1, which is still left of the number 13, is added to the left or tens column, so that by adding up the tens column, we have 1+1+2+2+1+ the extra 1, which is equal to 8 and we place this 8 directly below the column of figures just added and below the horizontal line. The result is as shown at (C) in Fig. 2 and thus we have 83 for an answer.

The answer obtained from the process of addition is called the TOTAL or SUM and since the numbers just added represent inches, our answer will also be expressed inches. That is, the total width of the casting in Fig. 1 is 83 inches. Remember, that you can only add units of the SAME KIND, that is to say, you cannot add inches to feet and obtain a correct answer. The inches would first have to be changed to feet or else the feet to inches.

Should you be adding electrical units, such as volts, for example, then all of the numbers, which you add together, must represent volts. Let us consider such a problem where the following voltages must be added together; 3; 47; 5,260; 10,297; and 347. The first step is to arrange these numbers in a vertical column as shown at (A) in Fig. 3, drawing the horizontal line below them and then carrying out the work with the follow

ING PROCESSES AS SHOWN IN STEPS (B), (C), (D) AND (E) OF FIG. 3.

(A)	(B)	(C)	(D)	(E)
3	3	3	3	3
47	47	47	47	47
5260	5260	5260	5260	5260
10297	10297	10297	10297	10297
347	347	347	347	347
4	54	954	5954	15,954 (SUM)

FIG. 3

THE TOTAL OR SUM OF THIS ADDITION THEN BECOMES 15,954 VOLTS. ALSO NOTE THAT THE PLUS SIGN (+) INDICATES ADDITION.

IF THE ADDITION PROBLEM WHICH YOU ARE WORKING, IS QUITE LONG AND YOU THEREFORE CARE TO CHECK THE ANSWER, SO AS TO BE SURE THAT IT IS CORRECT, THEN YOU DO THIS BY ADDING THE COLUMN OF FIGURES FROM THE TOP TOWARD THE BOTTOM BEGINNING WITH THE RIGHT HAND COLUMN AND THEN WORKING OUT EACH COLUMN IN THIS WAY, NOTING WHETHER OR NOT THE RESULTS OBTAINED AGREE WITH THOSE OBTAINED FROM THE ORIGINAL ADDITION.

SUBTRACTION

NOW LET US BRIEFLY CONSIDER THE PROCESS OF SUBTRACTION. IN THE CASE OF SUBTRACTION, WE TAKE AWAY SOME NUMBER FROM ANOTHER, IN ORDER TO FIND HOW MUCH IS LEFT. TO ILLUSTRATE THIS PROCESS, WE SHALL USE FIG. 4, WHERE WE HAVE A DRAWING OF A PIECE OF SHEET STEEL, WHICH IS TO BE CUT TO THE DIMENSIONS INDICATED.

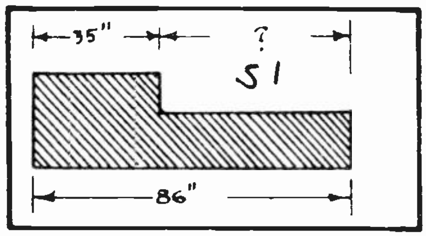

FIG. 4

An Example in Subtraction.

THE TOTAL LENGTH OF THIS MATERIAL IS GIVEN AS 86 INCHES AND THE LENGTH OF ONE SECTION IS INDICATED ON THE DRAWING TO BE 35 INCHES. SO IN ORDER TO FIND THE LENGTH OF THE SECTION LABELED WITH THE QUESTION MARK, WE SUBTRACT OR TAKE AWAY 35 INCHES FROM 86 INCHES.

TO CARRY OUT THIS PROCESS OF SUBTRACTION, WE PLACE THE SMALLER NUMBER UNDER THE LARGER NUMBER AS AT (A) OF FIG. 5, DRAWING A HORIZONTAL LINE BELOW THEM AS SHOWN.

	(A)	(B)	(C)	
(MINUEND)	86 IN.	86 IN.	86 IN.	
(SUBTRAHEND)	35 IN.	35 IN.	35 IN.	
		1	51 IN.	(DIFFERENCE)

FIG. 5

THE UPPER NUMBER IS CALLED THE MINUEND AND THE LOWER ONE THE SUBTRAHEND AS POINTED OUT AT (A). WE BEGIN OUR SUBSTRACTION IN THE RIGHT HAND COLUMN AS SHOWN AT (B), BY TAKING 5 AWAY FROM 6. THIS LEAVES A REMAINDER OF 1 AND SO WE PLACE THE 1 BELOW THE LINE, DIRECTLY UNDER THE COLUMN WITH WHICH WE JUST WORKED AS SHOWN AT (B). WE CAN NOW PROCEED BY WORKING WITH THE NEXT COLUMN OF FIGURES BY SUBTRACTING OR TAKING AWAY 3 FROM 8, WHICH LEAVES US A REMAINDER OF 5. OUR ANSWER OR DIFFERENCE THUS BECOMES 51 AS SHOWN AT (C) AND SINCE INCHES WERE SUBTRACTED FROM INCHES, THE ANSWER WILL ALSO BE EXPRESSED IN INCHES.

IN SUBTRACTION, THE SAME AS IN ADDITION, IT IS ONLY PERMISSIBLE TO SUBTRACT VALUES OF THE SAME KIND FROM EACHOTHER. IN OTHER WORDS, DOLLARS

COULD NOT BE SUBTRACTED FROM FEET ETC. THE MINUS SIGN (–) INDICATES THE PROCESS OF SUBTRACTION AND THE EXPRESSION GIVEN AT (C) OF FIG. 5 COULD ALSO BE WRITTEN AS 86–35=51, WHERE THE SIGN (=) SIGNIFIES EQUALS.

SOMETIMES, YOU WILL BE CONFRONTED WITH A PROBLEM, WHERE THERE ARE A GREATER NUMBER OF DIGITS (FIGURES) IN THE MINUEND AS THERE ARE IN THE SUBTRAHEND, SUCH AS WHEN SUBTRACTING 762 FROM 89,964. IN SUCH A CASE, WE ARRANGE THIS WORK AS:

```
 89964
  -762
 89202 (DIFFERENCE)
```

IF THE PROBLEM IS SUCH THAT WHEN SOME FIGURES IN THE MINUEND ARE LESS THAN THE FIGURE DIRECTLY UNDER THEM IN THE SUBTRAHEND, THEN WE DO THINGS A LITTLE DIFFERENT. FOR EXAMPLE, IF 863 IS TO BE TAKEN AWAY FROM 1952, WE ARRANGE THE WORK IN THE USUAL FORM OR AS AT (A) OF FIG. 6.

(A)	(B)	(C)	(D)
1952	1952	1952	1952
863	863	863	863
	9	89	1089 (DIFFERENCE)

FIG. 6

IN THE EXTREME RIGHT HAND COLUMN, IT IS OBVIOUS THAT 3 CANNOT BE TAKEN AWAY FROM 2, SO WE TAKE AWAY 1 FROM THE 5 IN THE MINUEND AND WE PLACE THIS 1 IN FRONT OF THE 2 SO AS TO RAISE THE VALUE OF THIS 2 TO 12 AND THUS BY TAKING 3 AWAY FROM 12, WE HAVE A REMAINDER OF 9 AS SHOWN IN STEP (B).

NOW WHEN WE COME TO THE NEXT COLUMN TOWARD THE LEFT, WE FIND THE 5 TO HAVE BEEN REDUCED TO 4 BECAUSE WE TOOK 1 AWAY FROM IT IN THE PRECEEDING STEP. THEREFORE, WE MUST TAKE 6 AWAY FROM 4, WHICH CANNOT BE DONE, SO WE BORROW 1 FROM THE 9 AND PLACE IT IN FRONT OF THE VALUE 4 AND THUS WE CAN SUBTRACT THE 6 FROM THE 14, WHICH LEAVES A REMAINDER OF 8 AS AT (C), THEREBY GIVING US A REMAINDER OF 89 SO FAR.

THE NEXT STEP IS TO SUBTRACT THE 8 FROM THE 9 BUT THE 9 HAS ALREADY BEEN REDUCED TO 8 BY THE 1 WHICH WAS BORROWED FROM IT DURING THE PREVIOUS STEP. HENCE, WE MUST SUBTRACT 8 FROM 8, WHICH LEAVES A REMAINDER OF ZERO (0). NOTHING IS TO BE TAKEN AWAY FROM THE 1 IN THE LEFT HAND COLUMN AND SO WE JUST BRING THIS 1 STRAIGHT DOWN BELOW THE LINE. THE DIFFERENCE OR ANSWER TO THIS PROBLEM THEN BECOMES 1089 AS SHOWN AT (D).

TO CHECK YOUR ANSWER OF A PROBLEM IN SUBTRACTION, YOU CAN ADD THE REMAINDER OR DIFFERENCE TO THE SUBTRAHEND AND THE RESULT SHOULD BE A NUMBER THE SAME AS THE MINUEND. FOR EXAMPLE, IN THE PRECEDING PROBLEM, WHERE 863 WAS SUBTRACTED FROM 1952, SO AS TO GIVE US A DIFFERENCE OF 1089, WE CAN CHECK THIS WORK BY ADDING 1089 AND 863, WHICH GIVES US A SUM OF 1952. THIS, YOU WILL NOTE, IS EQUAL TO OUR MINUEND.

MULTIPLICATION

THE NEXT ARITHMETICAL PROCESS WHICH WE SHALL CONSIDER, IS THAT OF MULTIPLICATION. THE PROCESS OF MULTIPLICATION IS IN A WAY A SHORTENED PROCESS OF ADDITION AND USED WHEN THE SUM OF A GROUP OF EQUAL NUMBERS IS TO BE FOUND. THAT IS, TO MULTIPLY A NUMBER, SIMPLY MEANS TO ADD IT TO ITSELF A CERTAIN NUMBER OF TIMES. FOR EXAMPLE, IF 8 IS TO BE ADDED TO ITSELF THREE TIMES, WE WOULD HAVE 8+8+8=24. THIS ANSWER IS THE SAME AS that obtained by multiplying 8 by 3, that is, 8 times 3 is also equal to 24.

Although in a simple problem as just given, it is perhaps as easy to obtain this answer of 24 either by addition or multiplication, yet when we have a problem where a number such as 36,478 must be added to itself 147 times, then this addition would become a long drawn-out and tedious process. The process of multiplication, on the other hand, offers a much quicker and easier solution.

The number, which is to be added to itself, is called the MULTIPLICAND and the number, which denotes how many times the multiplicand is added to itself, is called the MULTIPLIER. For example, 7 times 8 is equal to 56 and in this case, the number 7 is the multiplicand, 8 is the multiplier and the answer or PRODUCT, as it is properly called, is equal to 56. The sign for multiplication is (X) and so the simple problem, which was just given, can also be written as 7X8 = 56. This expression can be read as 7 times 8 equals 56 or 7 multiplied by 8 equals 56.

Let us begin with a simple multiplication problem, say multiplying 63 by 3. The first step is to write the problem in the form shown at (A) in Fig. 7. Note that the multiplier is placed below the multiplicand. We now multiply the 3 of the multiplicand by the multiplier, which gives us 3 times 3 or 9 and we place this 9 under the line as shown at (A). The next step is to multiply the 6 of the multiplicand by the multiplier and since 6 times 3 is equal to 18, we place this 18 below the line and in front of the 9 as at (B). Thus our answer or product is 189.

	(A)	(B)
Multiplicand	63	63
Multiplier	3	3
	9	189 (Product)

Fig. 7

If a certain number is to be multiplied by another number containing two or more figures, then the work is laid out as in Fig. 8. That is, if 3724 is to be multiplied by 307, we arrange the work as at (A) in Fig. 8.

(A)	(B)	(C)	(D)	(E)
3724	3724	3724	3724	3724
307	307	307	307	307
	26068	26068	26068	26068
		0000	0000	0000
			11172	11172
				1143268

Fig. 8

We now multiply the entire mulipicand by the 7 of our multiplier, writing the result of this process in the form shown at (B). This partial product is 26068 as shown. With this part of the work completed, we next multiply the multiplicand by the zero (0) of our multiplier and since zero times any number is equal to zero, we place these zeros under our first partial product as shown in step (C).

The following step consists of multiplying the multiplicand by the 3 of the multiplier and we place this partial product of 11172 under the row of zeros. Another horizontal line is then drawn below this last partial product.

The computation is then completed by adding together these partial products, thus giving us as our final answer for our problem, the product

1143268.

WHEN MULTIPLYING BY ZERO, AS IN THE PREVIOUS EXAMPLE, IT IS A COMMON PRACTICE NOT TO WRITE DOWN ALL OF THE ZEROS BUT TO JUST PUT DOWN THE FIRST ZERO AS INDICATED IN FIG. 9. THE PRODUCT OBTAINED FROM THE NEXT NUMBER OF THE MULTIPLIER OR 3 IN THIS CASE, IS THEN PLACED ON THE SAME LINE TO THE LEFT OF THIS ZERO.

```
   3724
    307
  26068
 111720 ← (THE ZERO)
1,143268
```

FIG. 9

ONE METHOD OF CHECKING A PROBLEM IN MULTIPLICATION IS TO INTERCHANGE THE MULTIPLICAND AND MULTIPLIER AND TO REPEAT THE PROCESS. A QUICK CHECK, HOWEVER, IS AS FOLLOWS:

(A) ADD THE DIGITS (FIGURES) IN THE MULTIPLICAND. IF THIS SUM IS A NUMBER COMPOSED OF MORE THAN 1 DIGIT, ADD THESE. CONTINUE IN THIS WAY UNTIL YOU FINALLY ARRIVE AT A NUMBER CONSISTING OF 1 DIGIT.

(B) ADD THE DIGITS OF THE MULTIPLIER IN THE SAME MANNER AS DESCRIBED IN NOTE (A)

(C) MULTIPLY TOGETHER THE FINAL NUMBERS OBTAINED FROM NOTES (A) AND (B) AND ADD THE DIGITS UNTIL A NUMBER OF ONE DIGIT IS FOUND.

(D) ADD THE DIGITS OF THE PRODUCT IN THE SAME MANNER AS OUTLINED IN NOTE (A). NOW COMPARE THE RESULTS OBTAINED IN NOTE (C) WITH THOSE OBTAINED IN NOTE (D). IF THEY ARE THE SAME, THEN THE WORK CHECKS, PROVING IT TO BE CORRECT.

TO ILLUSTRATE THIS CHECKING METHOD, LET US CHECK OUR PREVIOUS COMPUTATION, WHERE WE MULTIPLIED 3724 BY 307. BY ADDING THE DIGITS OF THE MULTIPLICAND, WE HAVE $3+7+2+4=16$ OR THE TWO DIGITS 1 AND 6, THEREFORE WE ADD THESE AND GET $6+1$ OR 7 AS THE SINGLE DIGIT AS PER RULE (A). BY ADDING THE DIGITS IN THE MULTIPLIER WE HAVE $3+0+7=10$ OR THE 1 AND 0. SINCE $1+0=1$, WE HAVE AS OUR SINGLE DIGIT SIMPLY 1 ACCORDING TO RULE (B).

AS PER RULE (C), WE MUST NOW MULTIPLY THE RESULTS OF NOTES (A) AND (B). THAT IS, $7 \times 1 = 7$. THIS DONE, WE ADD THE DIGITS IN THE PRODUCT OF OUR PREVIOUS COMPUTATION, WHENCE WE HAVE $1+1+4+3+2+6+8=25$. ADDING THIS 2 AND 5 TOGETHER, WE GET THE NUMBER 7, WHICH CHECKS WITH THE NUMBER 7 OF STEP (C). THUS WE HAVE PROVEN OUR CALCULATIONS TO BE CORRECT.

DIVISION

LET US NOW PROCEED WITH THE PROCESS OF DIVISION. BY DIVISION IS MEANT TO FIND HOW MANY TIMES SOME NUMBER IS CONTAINED IN ANOTHER OR ELSE IT CAN ALSO BE THE PROCESS OF SEPARATING A NUMBER INTO A GIVEN NUMBER OF EQUAL PARTS.

THE NUMBER, WHICH IS TO BE DIVIDED, IS CALLED THE DIVIDEND AND THE NUMBER BY WHICH THE DIVIDEND IS TO BE DIVIDED IS CALLED THE DIVISOR. THE RESULT OR QUOTIENT IS THE NUMBER WHICH DENOTES HOW MANY TIMES THAT THE DIVISOR IS CONTAINED IN THE DIVIDEND. FOR EXAMPLE, IF 40 IS TO BE DIVIDED BY 5, THEN THE DIVIDEND IS 40 AND THE DIVISOR IS 5. SINCE 5 WILL GO INTO 40 JUST 8 TIMES, THE QUOTIENT WILL BE 8.

The sign for division is (÷) and it is interpreted as "divided by". Thus 40÷5 means that 40 is to be divided by 5. The complete process can be written as 40÷5=8. Sometimes, you will find this expression written still another way, such as $\frac{40}{5} = 8$ and in this case, the 40 or dividend is placed above the 5 or the divisor, with a horizontal line separating them. The line in this case denotes the process of division.

Now let us work out a problem in division, as an example, dividing 193,648 by 52. We commence by laying out the work as at (A) in Fig. 10. That is, by writing the divisor slightly to the right of the dividend and placing a bracket around it as shown. The quotient or answer is to

```
             (A)                                  (B)
(Dividend)  193648 | 52   (Divisor)           193648 | 52
            156      3                        156      3724 (Quotient)
                                               376
                                               364
                                                124
                                                104
                                                 208
                                                 208
                                                   0
```

FIG. 10

be placed below the divisor as shown at (B) but first let us see the manner in which the quotient is obtained.

The first step in this division problem is to determine the least number of figures in the dividend, which will contain the divisor. That is, 52 in this example is not contained in 1, 9 or 19 but it will go into 193 a little over three times and so we place this 3 as the first digit in the quotient as at (A). Now we multiply the divisor or 52 by the 3 and this gives us a product of 156, which we place directly below the 1-9-3 or the first three digits of the dividend as shown at (A).

This done, we subtract 156 from 193, which leaves a remainder of 37 as shown at (B) and to this remainder of 37, we annex the next figure of the dividend or 6, thus giving us 376. Now we determine how many times that 52 will be contained in 376 and you will find this to be a little over 7 times, so place the 7 after the 3 in the quotient.

Multiply the divisor by this 7 and since 52 X 7=364, place this number under the 376 and subtract. The difference will be 12 to which the next number of the dividend or 4 is annexed, thus giving us 124.

The divisor 52 will go into 124 a little over 2 times, so place a 2 after the 7 in the quotient and multiply 52 by 2, placing this product of 104 under 124 as shown at (B). Subtract 104 from 124 and a difference of 20 will remain, to which the last figure 8 of the dividend is annexed, thus giving us 208. The divisor will go into this 208 exactly 4 times and therefore, a 4 is placed as the final number of this quotient. Multiplying the divisor by this 4 will give us a product of 208, which when subtracted from 208, leaves no remainder. Thus the quotient is 3724, meaning that 52 is contained in 193,648 just exactly 3724 times.

QUITE OFTEN, A PROBLEM IN DIVISION DOES NOT COME OUT EVEN, AS WHEN DIVIDING 2702839 BY 63. IF THIS IS THE CASE, THEN PLACE THE FINAL REMAINDER OVER THE DIVISOR AS A FRACTION TO BE ANNEXED TO THE QUOTIENT. THIS PROBLEM WOULD APPEAR AS SHOWN IN FIG. 11.

```
2702839 |63
252       42902  13/63 (QUOTIENT)
 182
 126
  568
  567
   139
   126
    13  REMAINDER
```

FIG. 11

THE TYPE OF DIVISION JUST DESCRIBED IS KNOWN AS "LONG DIVISION" BECAUSE ALL OF THE STEPS ARE INDICATED ON PAPER. ANOTHER TYPE OF DIVISION, WHERE SOME OF THE STEPS ARE MADE MENTALLY, WITHOUT SHOWING THEM ON PAPER, IS CALLED "SHORT DIVISION." LET US FOR EXAMPLE DIVIDE 2916 BY 3, USING SHORT DIVISION AND SEE HOW THIS WOULD LOOK. IT APPEARS IN FIG. 12.

THE DIVISOR 3 WILL GO INTO 29 A LITTLE OVER 9 TIMES, THUS 9 BECOMES THE FIRST DIGIT OF OUR QUOTIENT. THEN 3 X 9 = 27 AND SUBTRACTING 27 FROM 29 MENTALLY, WE HAVE A REMAINDER OF 2. WE PUT DOWN THIS 2 UNDER OUR DIVIDEND AS SHOWN AND ANNEX TO IT THE NEXT DIGIT OF THE DIVIDEND OR 1, THUS GIVING US 21.

```
(DIVIDEND)  2916 |3  (DIVISOR)
            21    972 (QUOTIENT)
             06
              0
```

FIG. 12

SINCE 3 WILL GO INTO 21 EXACTLY 7 TIMES, THE NUMBER 7 BECOMES THE SECOND DIGIT OF OUR QUOTIENT. UPON MULTIPLYING THE DIVISOR OF 3 BY 7 WE OBTAIN A PRODUCT OF 21 AND BY SUBTRACTING THIS 21 FROM THE PRESENT 21, WE HAVE A REMAINDER OF ZERO. TO THIS ZERO, WE ANNEX THE 6 OF OUR DIVIDEND AND BY DIVIDING THE 3 INTO THE 6 WE HAVE A RESULT OF 2. PUTTING THIS 2 AS THE FINAL DIGIT OF OUR QUOTIENT, WE OBTAIN AN ANSWER OF 972.

ONE OF THE METHODS BY WHICH A DIVISION PROBLEM CAN BE CHECKED IS TO MULTIPLY THE QUOTIENT BY THE DIVISOR AND ADD THE REMAINDER (IF THERE IS ANY) TO THE PRODUCT. THE FINAL RESULT WILL BE THE DIVIDEND. FOR EXAMPLE, TO PROVE OUR PREVIOUS DIVISION PROBLEM, WHERE WE DIVIDED 63 INTO 2702839 TO GET A QUOTIENT OF 42902 13/63, WE PROCEED AS SHOWN IN FIG. 13.

```
   42902  (QUOTIENT)
     X63  (DIVISOR)
  128706
 257412
 2702826
      13  (REMAINDER)
 2702839  (RESULT—DIVIDEND)
```

FIG. 13

A STILL QUICKER CHECK IS TO APPLY THE FOLLOWING RULES AS THEY ARE GIVEN.

(A) ADD THE DIGITS IN THE DIVIDEND AND IF THE SUM IS A NUMBER WITH MORE THAN 1 DIGIT, ADD THESE DIGITS UNTIL A SINGLE DIGIT IS OBTAINED.

(B) ADD THE DIGITS IN THE DIVISOR AND ADD THE DIGITS IN THIS SUM UNTIL A SINGLE DIGIT IS OBTAINED.

(C) ADD THE DIGITS IN THE QUOTIENT AND ADD THE DIGITS IN THIS SUM UNTIL A SINGLE DIGIT IS OBTAINED.

(D) ADD THE DIGITS IN THE REMAINDER AND ADD THE DIGITS IN THIS SUM UNTIL A SINGLE DIGIT IS OBTAINED.

(E) MULTIPLY THE RESULT OF NOTES (B) AND (C) AND ANNEX THE RESULTS IN (D) AND THEN ADD THE DIGITS IN THIS RESULT, WHICH SHOULD GIVE THE SAME AS THE RESULT OF NOTE (A) IF THE WORK IS CORRECT.

AS AN EXAMPLE FOR THE APPLICATION OF THIS CHECKING METHOD, LET US CHECK OUR PREVIOUS DIVISION PROBLEM WITH IT. HERE IT IS.

(A) THE SUM OF THE DIGITS IN THE DIVIDEND IS 2+7+0+2+8+3+9=31. THE DIGITS 3+1 GIVE US A SINGLE DIGIT OF 4.

(B) AS PER RULE (B), THE SUM OF THE DIGITS IN THE DIVISOR IS 6+3=9.

(C) AS PER RULE (C), THE SUM OF THE DIGITS IN THE QUOTIENT IS 4+2+9+0+2 =17 AND 7+1 GIVES US THE SINGLE DIGIT 8.

(D) THE DIGETS OF THE REMAINDER ARE 1 AND 3 WHOSE SUM EQUALS THE SINGLE DIGET 4.

(E) BY MULTIPLYING THE RESULTS OF NOTES (B) AND (C), WE HAVE 9 X 8 = 72 AND UPON ANNEXING TO THIS THE RESULT OF NOTE (D) OR 4, WE HAVE 724 THE SUM OF WHOSE DIGITS IS 7+2+4 =13. FINALLY BY ADDING THE DIGITS 1 AND 3 OF THIS SUM TOGETHER, WE HAVE A RESULT OF 4, THE VALUE OF WHICH CHECKS WITH THE RESULT OBTAINED IN NOTE (A). THE WORK THUS PROVES TO BE CORRECT.

FRACTIONS

THE NEXT SUBJECT FOR OUR CAREFUL CONSIDERATION IS THAT OF FRACTIONS. A FRACTION CONSISTS OF TWO NUMBERS, ONE ABOVE THE OTHER, WITH A LINE BETWEEN THEM, SUCH $\frac{3}{8}$, $\frac{5}{16}$, 1/2, 3/4 ETC. SOMETIMES THIS LINE IS TRULY HORIZONTAL WHILE IN OTHER CASES IT IS INCLINED BUT THIS IS SIMPLY A MATTER OF CHOICE. FROM OUR BRIEF DISCUSSION ON DIVISION, YOU WILL RECALL THAT THE FRACTION DENOTES THE PROCESS OF DIVISION AND WHEN CONSIDERED AS SUCH, THE NUMBER BELOW THE LINE TELLS US INTO HOW MANY EQUAL PARTS A WHOLE UNIT IS DIVIDED, WHILE THE NUMBER ABOVE THE LINE SPECIFIES HOW MANY OF THESE EQUAL PARTS ARE BEING USED. FOR EXAMPLE, IN THE CASE OF THE FRACTION 3/4, THE WHOLE UNIT OR 1 IS DIVIDED INTO 4 EQUAL PARTS BUT OF THESE ONLY 3 ARE BEING USED. IN THE CASE OF 5/16, THE WHOLE OR THE UNIT 1 IS DIVIDED INTO 16 EQUAL PARTS BUT OF THESE ONLY 5 OF THEM ARE BEING USED ETC. THE NUMBER ABOVE THE LINE IS CALLED THE NUMERATOR AND THE NUMBER BELOW THE LINE IS CALLED THE DENOMINATOR. VERY OFTEN, FRACTIONS ARE USED TOGETHER WITH A WHOLE NUMBER, SUCH AS 2 $^2/3$, WHICH BY THE WAY IS EQUIVALENT TO $2+\frac{2}{3}$. HERE 2 IS THE WHOLE NUMBER AND THE 2/3 IS THE FRACTION AND WE CALL SUCH A NUMBER, WHICH IS COMPOSED OF A WHOLE NUMBER AND A FRACTION, A MIXED NUMBER.

IF IN A CERTAIN FRACTION, THE NUMERATOR IS LESS THAN THE DENOMINATOR, THIS FRACTION IS CALLED A PROPER FRACTION. THUS 2/3, 1/2, 3/4, 5/16 ETC. ARE ALL PROPER FRACTIONS.

THEN ON THE OTHER HAND, WE ALSO HAVE IMPROPER FRACTIONS AND IN THIS CASE, THE NUMERATOR IS EQUAL TO OR GREATER THAN THE DENOMINATOR. THUS $\frac{13}{2}$

$\frac{5}{4}$; $\frac{6}{5}$; ETC. ARE ALL IMPROPER FRACTIONS.

REDUCING WHOLE OR MIXED NUMBERS TO IMPROPER FRACTIONS

A COMMON CALCULATION WITH FRACTIONS, WHICH YOU WILL FIND NEED FOR QUITE OFTEN, IS TO REDUCE A WHOLE OR MIXED NUMBER TO AN IMPROPER FRACTION. FOR EXAMPLE, THAT OF CHANGING 3 TO HALVES, 5 TO 6THS, $7\,{}^3/_5$ TO 5THS ETC.

TO BEGIN WITH, REMEMBER THAT WHENEVER THE NUMERATOR OF ANY FRACTION IS EQUAL TO ITS DENOMITOR, THEN THE VALUE OF THE FRACTION IS EQUAL TO UNITY OR 1. THAT IS, $\frac{5}{5}$, 3/3, 6/6, 8/8 ETC. ARE ALL EQUAL TO 1.

RULE: TO REDUCE A WHOLE NUMBER TO A FRACTION OF A GIVEN DENOMINATOR, FIRST CHANGE THE UNIT 1 TO A FRACTION OF THE GIVEN DENOMINATOR AND THEN MULTIPLY THE NUMERATOR BY THE GIVEN WHOLE NUMBER.

EXAMPLE 1: - REDUCE THE NUMBER 3 TO HALVES. HERE THE DENOMINATOR IS TO BE 2, SO OUR FIRST STEP ACCORDING TO THE RULE IS TO CHANGE 1 TO A FRACTION HAVING 2 AS A DENOMINATOR, WHICH WILL BE $\frac{2}{2}$. OUR SECOND STEP IS TO MULTIPLY THE NUMERATOR OF THIS FRACTION BY THE GIVEN WHOLE NUMBER OR 3 IN THIS CASE. THUS OUR FRACTION BECOMES $\frac{3 \times 2}{2}$ OR $\frac{6}{2}$, WHERE $\frac{6}{2}$ IS THE NUMBER 3 EXPRESSED IN HALVES.

EXAMPLE 2: - REDUCE THE NUMBER 5 TO 6THS.
SINCE $1 = \frac{6}{6}$; $5 = \frac{5 \times 6}{6} = \frac{30}{6}$

RULE: - TO REDUCE A MIXED NUMBER TO A FRACTION OF A GIVEN DENOMINATOR, FIRST REDUCE THE WHOLE NUMBER TO A FRACTION HAVING THE GIVEN DENOMINATOR AND THEN ADD TO THE NUMERATOR OF THIS FRACTION THE NUMERATOR OF THE FRACTIONAL PART OF THE MIXED NUMBER.

EXAMPLE: - REDUCE $7\,{}^3/5$ TO 5THS
SINCE $1 = 5/_5$ THEN $7 = \frac{7 \times 5}{5} = 35/5$. FINALLY $\frac{35+3}{5} = \frac{38}{5}$(ANS.)

REDUCING IMPROPER FRACTIONS TO WHOLE OR MIXED NUMBERS

ANOTHER COMMON CALCULATION, WHICH YOU WILL FIND USE FOR WHEN WORKING WITH FRACTIONS, IS TO REDUCE AN IMPROPER FRACTION TO A WHOLE OR MIXED NUMBER.

RULE: - TO REDUCE AN IMPROPER FRACTION TO A WHOLE OR MIXED NUMBER, PERFORM THE DIVISION INDICATED BY THE FRACTION. THE RESULTING QUOTIENT IS THE NUMBER OF UNITS. IF THERE IS NO REMAINDER FROM THIS DIVISION PROCESS, THE FRACTION REDUCES TO A WHOLE NUMBER. IF THERE IS A REMAINDER FROM THIS DIVISION PROCESS, THEN THE FRACTION REDUCES TO A MIXED NUMBER OF WHICH THE QUOTIENT IS THE WHOLE NUMBER PART AND THE REMAINDER BECOMES THE NUMERATOR OF THE FRACTIONAL PART.

EXAMPLE 1: - REDUCE $\frac{16}{4}$ TO A WHOLE NUMBER.

THE EXPRESSION $\frac{16}{4}$ IS EQUIVALENT TO $16 \div 4$, WHICH GIVES US A QUOTIENT

OF 4. HENCE 4 IS THE WHOLE NUMBER, WHICH IS EQUIVALENT TO $\frac{16}{4}$.

EXAMPLE 2: - REDUCE $\frac{46}{5}$ TO A MIXED NUMBER.

$$\frac{46}{5} = 46 \div 5 = 9\tfrac{1}{5} \text{ (ANSWER)}$$

THE NEXT POINT WHICH WE SHALL CONSIDER IS THAT OF REDUCING FRACTIONS TO THEIR LOWEST TERMS. A FRACTION IS IN ITS LOWEST TERMS WHEN THERE IS NO NUMBER THAT WILL DIVIDE BOTH OF THEM.

RULE:- TO REDUCE A FRACTION TO ITS LOWEST TERMS, DIVIDE BOTH TERMS SUCCESSIVELY BY THEIR COMMON FACTORS OR DIVIDE BY THE GREATEST COMMON DIVISOR OF THE TERMS.

EXAMPLE:- REDUCE $\frac{21}{42}$ TO ITS LOWEST TERMS. BY INSPECTION, IT IS SEEN THAT THE NUMERATOR AND THE DENOMINATOR OF THIS FRACTION ARE DIVISIBLE BY 7. FURTHERMORE, DIVIDING BOTH OF THESE TERMS BY THE SAME NUMBER DOES NOT CHANGE THE VALUE OF THE FRACTION. HENCE BY DIVIDING THE NUMERATOR AND DENOMINATOR OF 21/42 BY 7, WE HAVE $\frac{3}{6}$. AGAIN IT CAN BE SEEN BY INSPECTION THAT 3/6 CAN BE REDUCED TO STILL LOWER TERMS BECAUSE THE NUMBER 3 IS CONTAINED IN BOTH THE NUMERATOR AND DENOMINATOR OF THIS FRACTION. HENCE BY DIVIDING THESE TWO NUMBERS BY 3, WE HAVE $\frac{1}{2}$ AS THE FINAL RESULT. THE FRACTION $\frac{1}{2}$ THEN IS THE FRACTION $\frac{21}{42}$ REDUCED TO ITS LOWEST TERMS.

ALL OF THIS WORK OF COURSE COULD HAVE BEEN ACCOMPLISHED IN A SINGLE STEP DUE TO THE FACT THAT THE NUMERATOR AND DENOMINATOR OF THE FRACTION $\frac{21}{42}$ ARE DEVISIBLE BY 21, THUS REDUCING THE FRACTION TO ITS LOWEST TERMS IN THE FORM 1/2.

SUPPLYING THE SAME DENOMINATOR FOR A GROUP OF FRACTIONS

BEFORE SEVERAL FRACTIONS CAN BE ADDED TOGETHER OR BEFORE ONE FRACTION CAN BE SUBTRACTED FROM ANOTHER, IT IS NECESSARY THAT THEY HAVE THE SAME DENOMINATOR.

FOR EXAMPLE, IF WE ARE TO ADD THE FOLLOWING FRACTIONS OF $\frac{1}{4}$, $\frac{1}{6}$, $\frac{3}{8}$ TOGETHER, WE MUST FIRST DETERMINE A VALUE FOR THE DENOMINATOR WHICH WILL BE THE SAME FOR ALL THREE FRACTIONS. ONE WAY OF DETERMINING THIS COMMON DENOMINATOR IS TO MULTIPLY ALL OF THE DENOMINATORS OF THE GROUP TOGETHER, FOR EXAMPLE, IN THIS PARTICULAR CASE, WE MULTIPLY 4 X 6 X 8, WHICH GIVES US A PRODUCT OF 192. THIS VALUE IS SAID TO BE THE "MAXIMUM COMMON DENOMINATOR" AND EACH OF THE DENOMINATORS WILL BE CONTAINED IN THIS VALUE OF 192 AN EQUAL NUMBER OF TIMES.

TO CHANGE THE FRACTION OF 1/4, SO THAT IT WILL HAVE A DENOMINATOR OF 192, PROCEED BY DIVIDING 192 BY THE ORIGINAL DENOMINATOR 4 AND MULTIPLY THE RESULTING QUOTIENT BY THE ORIGINAL NUMERATOR 1. THE FRACTION OF 1/4 IS THUS TRANSFORMED TO A VALUE OF $\frac{48}{192}$.

APPLYING THIS METHOD, WE FIND THAT THE FRACTIONS OF $\frac{1}{4}$, 1/6 AND 3/8 CAN BE WRITTEN RESPECTIVELY IN THE FORM OF $\frac{48}{192}$, $\frac{32}{192}$ AND $\frac{72}{192}$ IN WHICH CASE THE NUMBER 192 IS SAID TO BE THE MAXIMUM COMMON DENOMINATOR OF THIS PARTICULAR GROUP OF FRACTIONS.

ALTHOUGH ANY GROUP OF FRACTIONS CAN BE ARRANGED TO HAVE THE SAME DENOMINATOR OF THE GROUP AS JUST SHOWN, YET IT IS STILL MORE PRACTICAL FOR LENGTHY CALCULATIONS TO DETERMINE THE LEAST OR LOWEST COMMON DENOMINATOR OF THE GROUP OF FRACTIONS SO THAT ALL OF THEM MAY HAVE THE SAME DENOMINATORS.

SO HERE IS WHERE ANOTHER FORM OF CALCULATION ENETERS, NAMELY THAT OF DETERMING THE LEAST COMMON DENOMINATOR FOR A GROUP OF FRACTIONS.

REDUCING FRACTIONS TO THE LEAST COMMON DENOMINATOR

EXAMPLE: - REDUCE 3/20, 1/4, $\frac{11}{32}$ AND 5/8 TO FRACTIONS WITH A LOWEST COMMON DENOMINATOR. THE LEAST COMMON DENOMINATOR FOR THIS GROUP OF FRACTION IS 160. THAT IS, 160 IS THE SMALLEST NUMBER WHICH WILL CONTAIN ALL OF THE DENOMINATORS OF THE FRACTIONS OF THE ABOVE GROUP AN EQUAL NUMBER OF TIMES. THIS IS DETERMINED BY INSPECTION.

TO CHANGE 3/20 TO A FRACTION HAVING 160 AS ITS DENOMINATOR, DIVIDE 160 BY THE DENOMINATOR OF THE GIVEN FRACTION OR 20 IN THIS CASE. THE QUOTIENT FROM THIS DIVISIONAL PROCESS WILL BE 8. MULTIPLY THIS RESULT BY THE NUMERATOR OF THE GIVEN FRACTION, WHICH IS 3 IN THIS CASE, THUS GIVING A PRODUCT OF 24. THE 24 WILL THEREFORE BE THE NUMERATOR OF THE NEW FRACTION HAVING 160 FOR ITS DENOMINATOR. THAT IS, 3/20 IS EQUIVALENT TO $\frac{24}{160}$. THE FRACTION 1/4 EXPRESSED IN TERMS OF A FRACTION HAVING THE LOWEST COMMON DENOMINATOR OF 160 WILL BE $\frac{40}{160}$. IN LIKE MANNER, $\frac{11}{32}$ BECOMES $\frac{55}{160}$ AND 5/8 BECOMES $\frac{100}{160}$.

GENERALLY, THE FRACTIONS BEING HANDLED HAVE SUCH DENOMINATORS THAT THEIR LEAST COMMON DENOMINATOR CAN BE DETERMINED BY INSPECTION. HOWEVER, IF THIS CANNOT BE DONE READILY, THEN A SIMPLE METHOD OF DETERMINING THE LEAST COMMON DENOMINATOR IS BY MEANS OF THE FOLLOWING RULE: DIVIDE THE GIVEN DENOMINATORS BY A PRIME NUMBER THAT WILL DIVIDE TWO OR MORE OF THEM (A PRIME NUMBER IS ANY NUMBER WHICH IS ONLY DIVISABLE EITHER BY 1 OR ITSELF, SUCH AS 1,2,5,7 ETC.). THEN DIVIDE THE REMAINING NUMBER AND THE QUOTIENT BY A PRIME NUMBER THAT WILL DIVIDE TWO OR MORE OF THEM. CONTINUE THIS AS LONG AS POSSIBLE. THE LEAST COMMON DENOMINATOR IS THEN EQUAL TO THE PRODUCT OF ALL THE DIVISORS AND THE QUOTIENTS OR NUMBERS WHICH ARE LEFT. FOR EXAMPLE, TO FIND THE LEAST COMMON DENOMINATOR OF $\frac{11}{30}$, 7/45, $\frac{14}{135}$ AND $\frac{13}{25}$ PROCEED AS SHOWN IN FIG. 14. THE LEAST COMMON MULTIPLE AS PER FIG. 14 IS 5 X 3 X 3 X 2 X 1 X 3 X 5 = 1350.

DIVISOR	5	30	45	135	25	GIVEN DENOMINATORS
"	3	6	9	27	5	QUOTIENTS
"	3	2	3	9	5	"
		2	1	3	5	"

FIG. 14

ADDITION OF FRACTIONS

NOW WE COME TO THE ADDITION OF FRACTIONS. THE FIRST RULE FOR THE ADDITION OF FRACTIONS IS AS FOLLOWS: TO ADD FRACTIONS, WHICH ALREADY HAVE A LEAST COMMON DENOMINATOR, SIMPLY ADD THE NUMERATOR OF THE FRACTIONS AND PLACE THEIR SUM OVER THE THE LEAST COMMON DENOMINATOR. IF THIS GIVES AN AN IMPROPER FRACTION, THEN IT SHOULD BE REDUCED TO A WHOLE OR MIXED NUMBER.

EXAMPLE: - ADD $\frac{3}{16}$; $\frac{9}{16}$; $\frac{11}{16}$ AND $\frac{13}{16}$. SINCE ALL OF THESE FRACTIONS HAVE THE SAME DENOMINATOR OR AS WE MIGHT SAY, THE LEAST COMMON DENOMINATOR, WE CAN WRITE THE PROBLEM IN THE FOLLOWING FORM:

$$\frac{3}{16}+\frac{9}{16}+\frac{11}{16}+\frac{13}{16}=\frac{36}{16}=2\frac{4}{16}=2\frac{1}{4}$$

THE SECOND RULE FOR THE ADDITION OF FRACTION IS AS FOLLOWS: IF THE GIVEN FRACTIONS DO NOT HAVE A LEAST COMMON DENOMINATOR, THEN FIRST REDUCE THEM TO FRACTIONS HAVING A LEAST COMMON DENOMINATOR AND ADD.

EXAMPLE: - FIND THE SUM OF $\frac{3}{10}$, $\frac{2}{11}$, $\frac{3}{5}$, AND 3/4. THE LOWEST COMMON DENOMINATOR FOR 10, 11, 5 AND 4 IS 220. HENCE BY CHANGING OUR GIVEN FRACTIONS TO VALUES HAVING THIS LEAST COMMON DENOMINATOR, WE HAVE:

$$\frac{66}{220}+\frac{40}{220}+\frac{135}{220}+\frac{165}{220}=\frac{403}{220}=1\ \frac{183}{220}$$

THE THIRD RULE FOR THE ADDITION OF FRACTIONS IS AS FOLLOWS: TO ADD MIXED NUMBERS, ADD THE WHOLE NUMBERS AND FRACTIONS SEPARATELY AND THEN UNITE THE SUMS.

EXAMPLE:- FIND THE SUM OF $41\frac{1}{2}$, $40\frac{1}{4}$ AND $3\ \frac{2}{3}$ IT IS MOST CONVENIENT TO ARRANGE THESE NUMBERS IN A VERTICAL COLUME AS AT THE LEFT OF 15. THE NEXT STEP IS TO CONVERT THE GIVEN FRACTIONS INTO EQUIVALENT FRACTIONS HAVING THE LEAST COMMON DENOMINATOR, WHICH IS THIS CASE IS 12. THE NUMBERS ARE THEN REWRITTEN AS AT THE RIGHT OF FIG. 15 SO THAT ALL OF THE FRACTIONS HAVE THE SAME DENOMINATER.

$$\begin{array}{ll}
41\ \ 1/2 = 41\ \frac{6}{12} & \\
40\ \ 1/4 = 40\ \frac{3}{12} & \\
3\ \ 2/3 = 3\ \frac{8}{12} & \\
\hline
84\ \ 17/12 = 85 & 5/12
\end{array}$$

FIG. 15

BY ADDING THE NUMERATORS OF THESE FRACTIONS, WE OBTAIN A TOTAL OF $\frac{17}{12}$ AND UPON ADDING THE WHOLE NUMBERS, 84. THE DENOMINATOR 12 WILL GO INTO 17 JUST 1 5/12 TIMES SO THAT THE ANSWER TO THIS PROBLEM BECOMES 85 5/12 (NOTE THAT THE 1 OBTAINED UPON DIVIDING THE FRACTION IS ADDED TO THE SUM OF THE WHOLE NUMBERS.)

SUBTRACTION OF FRACTIONS

NEXT LET US CONSIDER THE SUBTRACTION OF FRACTIONS. THE FIRST RULE FOR SUBTRACTION IS AS FOLLOWS: TO FIND THE DIFFERENCE BETWEEN TWO GIVEN FRACTIONS, WHICH ALREADY HAVE A COMMON DENOMINATOR, SIMPLY SUBTRACT THE LARGER NUMERATOR FROM THE SMALLER ONE AND WRITE THE RESULTING DIFFERENCE OVER THE COMMON DENOMINATOR. REDUCE TO LOWEST TERMS.

EXAMPLE: SUBTRACT $\frac{5}{12}$ FROM $\frac{11}{12}$

THUS $\frac{11}{12} - \frac{5}{12} = \frac{6}{12} = 1/2$ (ANSWER)

THE SECOND RULE FOR THE SUBTRACTION OF FRACTIONS IS AS FOLLOWS: TO FIND THE DIFFERENCE BETWEEN TWO FRACTIONS, WHEN THEY DO NOT HAVE A LEAST COMMON DENOMINATOR, FIRST REDUCE THEM TO SUCH BEFORE SUBTRACTING.

EXAMPLE: - SUBTRACT $\frac{3}{34}$ FROM $\frac{8}{17}$ (NOTE THAT THE LEAST COMMON DENOMINATOR FOR 17 AND 34 IS 34.)

THUS $\frac{8}{17} - \frac{3}{34} = \frac{16}{34} - \frac{3}{34} = \frac{13}{34}$ (ANSWER).

THE THIRD RULE FOR THE SUBTRACTION OF FRACTIONS IS AS FOLLOWS: IF THE NUMBERS ARE MIXED NUMBERS, SUBTRACT THE FRACTIONAL PARTS AND THEN THE WHOLE NUMBERS, REDUCING THE FRACTIONAL PARTS TO THE LEAST COMMON DENOMINATOR, IF SUCH IS NOT ALREADY THE CASE.

EXAMPLE: - SUBTRACT 2 3/5 FROM 8 3/4. IT IS MOST CONVENIENT TO PLACE THIS MINUEND AND SUBTRAHEND IN A VERTICAL FORMATION AS IN THE LEFT HAND COLUMN OF FIG. 16. TO THE RIGHT OF THE EQUAL MARKS IN FIG. 16, WE HAVE THE FRACTIONS REDUCED TO THE LEAST COMMON DENOMINATOR. THE NUMERATORS ARE THEN SUBTRACTED, GIVING 3/20, AFTER WHICH THE WHOLE NUMBERS ARE SUBTRACTED, GIVING 6. THUS THE FINAL ANSWER IS 6 3/20.

$$\begin{array}{rl} 8\ 3/4 = 8 & \frac{15}{20} \\ -2\ 3/5 = 2 & \frac{12}{20} \\ \hline 6 & \frac{3}{20} \text{ (ANSWER)} \end{array}$$

FIG. 16

IN CASE THAT THE FRACTION OF THE SUBTRAHEND IS GREATER THAN THAT IN THE MINUEND, AS WHEN SUBTRACTING 3 2/3 FROM 7 1/2, THEN PROCEED AS IN FIG. 17. THAT IS, FIRST REDUCE THE FRACTIONS TO THE LEAST COMMON DENOMINATOR AND AS CAN BE SEEN BY INSPECTION, 4/6 CANNOT BE SUBTRACTED FROM 3/6. THEREFORE, 1 IS TAKEN AWAY FROM THE 7 OF THE MINUEND AND IS ADDED TO ITS FRACTION, THEREBY CHANGING ITS VALUE. THAT IS, $1 = \frac{6}{6}$ AND $\frac{3}{6} + \frac{6}{6} = \frac{9}{6}$.

CONSEQUENTLY, 4/6 CAN NOW BE SUBTRACTED FROM 9/6 GIVING US A FRACTIONAL DIFFERENCE OF 5/6 AND UPON SUBTRACTING 3 FROM 6 IN OUR WHOLE NUMBER COLUMN, WE OBTAIN OUR FINAL ANSWER OF $3\frac{5}{6}$.

$$\begin{array}{rl} 7\ 1/2 = 7\ \frac{3}{6} = & 6\ 9/6 \\ -3\ 2/3 = 3\ \frac{4}{6} = & 3\ 4/6 \\ \hline & 3\ 5/6 \text{ (ANSWER)} \end{array}$$

FIG. 17

MULTIPLYING WITH FRACTIONS

WE ARE NOW PREPARED TO SEE HOW FRACTIONS CAN BE MULTIPLIED. FIRST LET US CONSIDER THE MATTER OF MULTIPLYING A FRACTION BY A WHOLE NUMBER.

THE RULE FOR THIS PROCESS IS AS FOLLOWS:

RULE:- TO MULTIPLY A FRACTION BY A WHOLE NUMBER, FIRST MULTIPLY THE WHOLE NUMBER BY THE NUMERATOR OF THE FRACTION AND THEN DIVIDE THIS PRODUCT BY THE DENOMINATOR OF THE FRACTION.

EXAMPLE:- MULTIPLY 8 BY 4/5. $8 \times \frac{4}{5} = \frac{8 \times 4}{5} = \frac{32}{5} = 6\ ^{2}/5$ (ANSWER)

TO MULTIPLY A FRACTION BY A FRACTION, APPLY THE FOLLOWING RULE:

RULE:- MULTIPLY THE NUMERATORS TOGETHER AND THEN MULTIPLY THE DENOMINATOR TOGETHER. PLACE THE PRODUCT OF THE NUMERATORS OVER THE PRODUCT OF THE DENOMINATORS AND REDUCE TO LOWEST TERMS WHEN POSSIBLE.

EXAMPLE:- $\frac{2}{3} \times \frac{5}{7} = \frac{2 \times 5}{3 \times 7} = \frac{10}{21}$ (ANSWER)

TO MULTIPLY TWO NUMBERS, ONE OR BOTH OF WHICH ARE MIXED NUMBERS, REDUCE THE MIXED NUMBERS TO IMPROPER FRACTIONS AND THEN MULTIPLY AS WITH FRACTIONS.

EXAMPLE 1:- $6\ ^{1}/4 \times 8 = \frac{25}{4} \times 8 = \frac{25 \times 8}{4} = \frac{200}{4} = 50$ (ANSWER)

EXAMPLE 2:- $3\ ^{2}/3 \times 4\ ^{3}/4 = \frac{11}{3} \times \frac{19}{4} = \frac{11 \times 19}{3 \times 4} = \frac{209}{12} = 17\ ^{5}/12$ (ANSWER)

DIVIDING WITH FRACTIONS

NOW LET US SEE HOW FRACTIONS CAN BE HANDLED IN DIVISION PROBLEMS. TO DIVIDE A FRACTION BY A WHOLE NUMBER, MULTIPLY THE DENOMINATOR OF THE FRACTION BY THE WHOLE NUMBER.

EXAMPLE:- $2/3 \div 3 = \frac{2}{3 \times 3} = \frac{2}{9}$ (ANSWER)

TO DIVIDE A WHOLE NUMBER BY A FRACTION, INVERT THE DIVISOR AND MULTIPLY IT BY THE DIVIDEND.

EXAMPLE:- $7 \div \frac{3}{4} = 7 \times \frac{4}{3} = \frac{7 \times 4}{3} = \frac{28}{3} = 9\ ^{1}/3$ (ANSWER)

TO DIVIDE A FRACTION BY A FRACTION, INVERT THE DIVISOR AND MULTIPLY IT BY THE DIVIDEND.

EXAMPLE:- $3/4 \div 1/3 = 3/4 \times 3/1 = \frac{3 \times 3}{4 \times 1} = \frac{9}{4} = 2\ ^{1}/4$ (ANSWER)

TO DIVIDE A MIXED NUMBER BY A MIXED NUMBER, FIRST CHANGE THEM TO IMPROPER FRACTIONS AND THEN DIVIDE.

EXAMPLE:- $3\ ^{2}/3 \div 1\ ^{3}/5 = \frac{11}{3} \div \frac{8}{5} = \frac{11}{3} \times 5/8 = \frac{11 \times 5}{3 \times 8} = \frac{55}{24} = 2\ ^{7}/24$ (ANS.)

DECIMAL FRACTIONS

NOW WE COME TO A DIFFERENT TYPE OF FRACTIONS, NAMELY DECIMAL FRACTIONS. FRACTIONS, WHICH COME UNDER THIS CLASSIFICATION, HAVE 10; 100; 1000;

ETC. FOR DENOMINATORS. FOR EXAMPLE $\frac{2}{10}$, $\frac{3}{100}$, $\frac{22}{1000}$ ETC. ARE ALL DECIMAL FRACTIONS, HOWEVER, INSTEAD OF WRITING DECIMAL FRACTIONS IN THIS FORM, IT IS MORE CONVIENT TO WRITE THEM WITH A DECIMAL POINT, SO THAT THE POSITION OF THE DECIMAL POINT INDICATES THE DENOMINATOR. THAT IS, AS A DECIMAL FRACTION, WE WOULD EXPRESS 2/10 IN THE FORM .2; $\frac{3}{100}$ WOULD BE EXPRESSED AS .03, AND $\frac{22}{1000}$ AS .022 ETC. THE PERIOD, WHICH IS USED, IS CALLED THE "DECIMAL POINT" AND IT IS VERY IMPORTANT WHERE THIS PERIOD IS PLACED. THAT IS, AS THE DECIMAL POINT IS GRADUALLY MOVED TO THE RIGHT ONE PLACE AT A TIME, THE VALUE OF THE NUMBER WILL BE MULTIPLIED BY 10. FOR EXAMPLE, 37.236; 372.36 AND 3723.6 ETC. IN THIS CASE 372.36 IS 10 TIMES GREATER THAN 37.236 AND 3723.6 IS 100 TIMES GREATER THAN 37.236 SIMPLY ON ACCOUNT OF THE POSITION OF THE DECIMAL POINT.

MOVING THE DECIMAL POINT TO THE LEFT GRADUALLY OR ONE PLACE AT A TIME WILL DECREASE A NUMBER BY 1/10 ITS VALUE, WHICH IS THE SAME AS DIVIDING IT BY 10. THAT IS, CONSIDERING THE NUMBER 423.74, 42.374 AND 4.2374, IT IS APPARANT THAT BY FIRST MOVING THE DECIMAL POINT ONE PLACE TOWARD THE LEFT, THE VALUE OF THE NUMBER IS REDUCED TO 1/10 ITS VALUE, BY MOVING IT TWO PLACES TOWARD THE LEFT, THE NUMBER IS REDUCED TO $\frac{1}{100}$ OF ITS VALUE, WHICH IS THE SAME AS DIVIDING IT BY 100 ETC.

ONE OF THE IMPORTANT THINGS TO REMEMBER IN THIS RESPECT IS THAT THE FIRST PLACE TO THE RIGHT OF THE DECIMAL POINT INDICATES A DENOMINATOR OF TEN; THE SECOND PLACE, A DENOMINATOR OF 100; THE THIRD PLACE 1000 ETC. THE FIRST PLACE TOWARDS THE LEFT OF THE DECIMAL POINT INDICATES UNITS; THE SECOND PLACE TENS; THE THIRD PLACE HUNDREDS ETC. THIS CAN BE ILLUSTRATED AS IN FIG. 18 FOR YOUR CONVENIENCE.

THOUSANDS	HUNDREDS	TENS	UNITS	DECIMAL POINT	TENTHS	HUNDREDTHS	THOUSANDTHS	TEN-THOUSANDTHS	HUNDRED-THOUSANDTHS	MILLIONTHS	TEN MILLIONTHS	HUNDRED MILLIONTHS
0	0	0	0	.	0	0	0	0	0	0	0	0

FIG. 18

THE NUMBER 256.3734, FOR EXAMPLE, WOULD BE READ AS TWO HUNDRED FIFTY-SIX AND THREE THOUSAND, SEVEN-HUNDRED THIRTY-FOUR TEN-THOUSANDTHS. FOR CONVENIENCE, A NUMBER AS THIS IS SOMETIMES READ AS TWO HUNDRED FIFTY-SIX, POINT, THREE, SEVEN, THREE, FOUR.

CHANGING COMMON FRACTIONS TO DECIMAL FRACTIONS

SO MUCH FOR THE PRELIMINARY EXPLANATION, NOW LET US PROCEED AND SEE HOW WE WORK WITH DECIMAL FRACTIONS. THE FIRST STEP WILL BE TO SEE HOW TO CHANGE COMMON FRACTIONS TO DECIMAL FRACTIONS. THE RULE FOR CHANGING COMMON FRACTIONS TO DECIMAL FRACTIONS IS AS FOLLOWS: ANNEX ZEROS TO THE NUMERATOR AND DIVIDE BY THE DENOMINATOR. PLACE THE DECIMAL POINT SO AS TO MAKE AS MANY DECIMAL PLACES IN THE RESULT AS THERE WERE ZEROS ANNEXED.

EXAMPLE I:— CHANGE $\frac{2}{5}$ TO A DECIMAL FRACTION.

```
2.0000 |5
20      0.40 000 (ANSWER)
 000
```

THAT IS. $2/5 = 0.4$

EXAMPLE 2:- CHANGE 7/8 TO A DECIMAL FRACTION.

```
7.0000 |8
64      0.875  (ANSWER)
 60
 56
  40
```

ADDING NUMBERS WITH DECIMAL FRACTIONS

TO ADD NUMBERS CONTAINING DECIMAL FRACTIONS, WRITE THE NUMBERS, SO THAT THE DECIMAL POINTS ARE ALL UNDER EACHOTHER. THEN ADD THE VERTICAL ROW OF FIGURES IN THE CUSTOMARY MANNER AND PLACE THE DECIMAL POINT IN THE SUM DIRECTLY UNDER THE OTHER DECIMAL POINTS.

EXAMPLE;- ADD 372.431; 27.24; 8374.364; AND 1.002. THIS PROCESS WOULD APPEAR AS ILLUSTRATED IN FIG. 19.

```
 372.431
  27.24
8374.364
   1.002
8775.037 (ANSWER)
```

FIG. 19

SUBTRACTING NUMBERS WITH DECIMAL FRACTIONS

TO SUBTRACT NUMBERS CONTAINING DECIMAL FRACTIONS, WRITE THE NUMBERS, SO THAT THE DECIMAL POINTS ARE UNDER EACHOTHER. THEN SUBTRACT IN THE CUSTOMARY MANNER AND PLACE THE DECIMAL POINT OF THE REMAINDER UNDER THE OTHER DECIMAL POINTS.

EXAMPLE:- SUBTRACT 86.014 FROM 374.325. THE SOLUTION APPEARS IN FIG. 20.

```
374.325
-86.014
288.311 (ANSWER)
```

FIG. 20

MULTIPLYING NUMBERS WITH DECIMAL FRACTIONS

TO MULTIPLY NUMBERS CONTAINING DECIMAL FRACTIONS, MULTIPLY IN THE USUAL WAY AND THEN POINT OFF AS MANY DECIMAL PLACES IN THE PRODUCT AS THE SUM OF THE NUMBERS OF DECIMAL PLACES IN THE MULTIPLICAND AND MULTIPLIER.

EXAMPLE:- MULTIPLY 436.256 BY 4.271 (SEE FIG. 21 FOR SOLUTION).

```
   436.256
     4.271
    436256
  3053792
   872512
 1745024
1863.249376 (ANSWER)
```

FIG. 21

NOTE THAT IN THIS EXAMPLE, THERE ARE THREE NUMBERS TO THE RIGHT OF THE DECIMAL POINT IN THE MULTIPLICAND AND THREE NUMBERS TO THE RIGHT OF THE DECIMAL POINT IN THE MULTIPLIER. THEREFORE, THERE MUST BE 3+3 OR 6 NUMBERS TO THE RIGHT OF THE DECIMAL POINT IN THE ANSWER OR PRODUCT. THIS DETERMINES WHERE TO PLACE THE DECIMAL POINT IN THE ANSWER.

DIVIDING NUMBERS WITH DECIMAL FRACTIONS

TO DIVIDE WITH NUMBERS CONTAINING DECIMAL FRACTIONS, PROCEED AS FOLLOWS: IF THE NUMBER OF PLACES TO THE RIGHT OF THE DECIMAL POINT IN THE dividend is less than the number of places to the right of the decimal point in the divisor, then annex zeros to the dividend until there are as many or more places to the right of the decimal point as in the divisor. Divide as in whole numbers and point off as many decimal places in the quotient as there are more decimal places in the dividend than in the divisor.

EXAMPLE 1:- Divide 8.7234 by .325 (Solution appears in Fig. 22.)

```
8.723400 |.325
650        26.841 (ANSWER)
2223
1950
 2734
 2600
  1340
  1300
   400
   325
    75
```

FIG. 22

Note that in this example, two zeros were annexed to the dividend so that the problem could be worked out to a greater number of decimal places. Without annexing these two zeros, the answer would be 26.8. Also observe that after annexing the two zeros to the dividend, we have in this number 6 places to the right of the decimal point. In the divisor there are three places to the right of the decimal point. Therefore, in the quotient, there must be 6 minus 3 or three decimal places to the right of the point.

EXAMPLE 2:- Divide 4726 by .034

Since the divisor has three more decimal places then the dividend, we must annex 3 zeros to the dividend. There are no decimal places in the answer because there are no decimal places in the dividend. (See Fig. 23 for solution).

```
4726000 |.034
34        139,000   (ANSWER)
132
102
 306
 306
  000
```

FIG. 23

SQUARING NUMBERS

The next form of computation, which we shall consider, is that of SQUARING NUMBERS. By squaring a number, we mean to MULTIPLY IT BY ITSELF. For example, to square 6, we mean to multiply 6 by 6, the result of which is 36. The square of 8 is 64 because 8 X 8 = 64 etc.

A convenient method of indicating that a number is to be squared is to place a small 2 to the upper right of the number. For example, to indicate that 3 is to be squared, we would write this as 3^2. Thus 3^2 is equal to 3 X 3 or 9.

Should you be solving a problem, in which you find the expression 732^2, then it means that you must multiply 732 by 732 as in Fig. 24.

```
    732
    732
   1464
  2196
 5124
535,824   (ANSWER)
```

FIG. 24

Consequently, when we have an expression such as $10^2 + 4^2$, it means that we must square 10 and 4 and then add the two products together. That is, $10^2 + 4^2 = (10 \times 10) + (4 \times 4) = 100 + 16 = 116$ (Answer)

Thus you see, that the problem of squaring numbers is quite simple after all.

SQUARE ROOT

WITH THIS POINT SETTLED, LET US NEXT TURN OUR ATTENTION TO ANOTHER SUBJECT, WHICH IS CLOSELY RELATED TO THE SQUARING OF NUMBERS, NAMELY THAT OF EXTRACTING THE SQUARE ROOT OF NUMBERS. THE SQUARE ROOT OF A NUMBER IS A NUMBER WHICH WHEN SQUARED, WILL GIVE THE FIRST NUMBER. FOR EXAMPLE, 12 IS THE SQUARE ROOT OF 144 BECAUSE 12 X 12 = 144. IN LIKE MANNER, 6 IS THE SQUARE ROOT OF 36 BECAUSE 6 X 6 = 36 AND 7 IS THE SQUARE ROOT OF 49 BECAUSE 7 X 7 = 49 ETC. TO INDICATE THAT THE SQUARE ROOT OF A NUMBER IS TO BE FOUND WE DRAW A BRACKET ($\sqrt{}$) AROUND THE NUMBER. THAT IS, TO SHOW THAT WE ARE TO FIND THE SQUARE ROOT OF 81, WE WRITE THIS EXPRESSION AS $\sqrt{81}$. SO WHENEVER, YOU SEE A NUMBER ENCLOSED IN THIS BRACKET, IT INDICATES THAT YOU ARE TO FIND THE SQUARE ROOT OF THIS NUMBER.

CALCULATING THE SQUARE ROOT

FOR THE SMALLER NUMBERS, WE CAN GENERALLY DETERMINE THE SQUARE ROOT BY INSPECTION BUT FOR THE LARGER ONES, WE RESORT TO COMPUTATION. FOR EXAMPLE, TO FIND THE SQUARE ROOT OF 104,976 OR $\sqrt{104976}$ PROCEED AS FOLLOWS:

FIRST WRITE DOWN THE NUMBER OF WHICH THE SQUARE ROOT IS TO BE FOUND AS AT (A) IN FIG. 25 AND DRAW A BRACKET TO THE RIGHT OF IT AS SHOWN. THE NEXT STEP IS TO START AT THE RIGHT OF THIS NUMBER AND DIVIDE UP THIS NUMBER INTO GROUPS OF TWO NUMBERS EACH. THESE GROUPS ARE POINTED OUT TO YOU IN (A) BY THE COMMAS. NOW THEN, THE NUMBER 10 APPEARS IN THE LEFT HAND

	(A)		(B)		(C)
	10'49'76 ⌊3		10'49'76 ⌊32		10'49'76 ⌊324 (ANSWER)
	9		9		9
6	1 49	62	1 49	62	1 49
			1 24		1 24
		64	25 76	644	25 76
					25 76

FIG. 25

GROUP; SO THE THING TO DO NOW IS TO DETERMINE THE LARGEST PERFECT SQUARE WHICH IS EITHER EQUAL TO OR LESS THAN 10. THIS OF COURSE IS 9 OF WHICH THE SQUARE ROOT IS 3, SO WE PLACE THE 3 IN THE BRACKET AS SHOWN AT (A) AND THE 9 UNDER THE 10. WE NOW SUBTRACT THE 9 FROM 10, WHICH LEAVES A REMAINDER OF 1 AND TO THIS WE ANNEX THE NEXT GROUP OF TWO FIGURES OR 49, THUS GIVING US THE NUMBER 149.

THIS DONE, THE NEXT STEP IS TO MULTIPLY THE 3 IN THE BRACKET BY 2 (THIS IS SIMPLY A RULE). SINCE 3 X 2 = 6, WE PLACE THIS 6 TO THE LEFT OF THE 149 AS SHOWN IN (A), SEPARATING THESE TWO NUMBERS BY THE VERTICAL LINE. NOW DETERMINE HOW MANY TIMES THAT 6 IS CONTAINED IN 14. YOU WILL FIND THIS TO BE 2, SO ANNEX THE 2 TO THE 6 AS SHOWN AT (B) AND ALSO ANNEX THE 2 TO THE 3 IN THE BRACKET AS ALSO SHOWN AT (B).

NOW MULTIPLY THIS 62 BY THE 2 AND PLACE THIS PRODUCT OF 124 UNDER THE 149 AS SHOWN AT (B). UPON SUBTRACTING 124 FROM 149, WE HAVE A REMAINDER OF 25 AND TO THIS, WE ANNEX THE NEXT GROUP OF TWO FIGURES OF THE NUMBER WHOSE SQUARE WE ARE CALCULATING. THAT IS, IN OUR PRESENT PROBLEM, WE ANNEX THE 7 AND THE 6 TO THE REMAINDER OF 25, THEREBY GIVING US THE NUMBER 2576.

in (b). Multiply the 32 in the bracket by 2 and place this result of 64 to the left of the number 2576 as shown at (b).

Now determine how many times that 64 is contained in 257 . You will find this to be 4, so annex this 4 to the 32 in the bracket as shown at (c) and also to the 64. Proceed by multiplying the 644 by 4 and place this product of 2576 under the other 2576 as at (c). Since there is no remainder upon subtracting 2576 from 2576, we have that the square root of 104,976 is exactly 324.

Sometimes, you will work with a number having an odd number of figures or digits, such as when extracting the square root from 7,360,369 in which there are seven digits. In this case, divide this number into groups of two digits each as at (a) in Fig. 26. This will leave only the single digit 7 at the extreme left, so determine the greatest possible square which is equal to or less than 7. This, of course is 4, of which the square root is 2 and therefore, we place this 2 as the first figure in the

```
         (A)                        (B)                           (C)
   7'36'03'69 |27           7'36'03'69 |271             7'36'03'69 |2713  (ANSWER
   4                        4                           4
47 | 3 36              47 | 3 36                 47   | 3 36
   | 3 29                 | 3 29                      | 3 29
   |    7 03          541 |    7 03              541  |    7 03
   |                      |    5 41                   |    5 41
                          |    1 62 69           5423 |    1 62 69
                                                           1 62 69
```

FIG. 26

bracket at (a), place the 4 under the 7, subtract the 4 from 7 so as to obtain the remainder of 3 to which we annex the next two figures or 3 and 6 in order to obtain the number 336 in (a). Twice 2 is 4, so the 4 is placed to the left of 336. Since this 4 is contained in 33 seven times, we place the 7 in our answer space and annex the 7 to the 4 at the left. It then follows that 7 X 47 = 329, so the 329 is placed below 336 and subtracted from it, thus leaving the remainder of 7 at (a) to which the digits 0 and 3 are annexed.

Twice 27 is 54 and so the number 54 is placed to the left of 703. Since 54 is contained in 70 once, we annex the 1 to the 27 in our answer space and to the 54. Hence 1 times 541 is 541 and so the 541 is placed below the 703 and subtracted from it, thus leaving a remainder of 162. To this, the 6 and 9 are annexed, giving us the number 16269 at (b).

Twice 271 is 542 and so the 542 is placed to the left of 16269 as at (c). Then it is seen that 542 will go into 1626 three times, so the 3 is annexed to the 271 in our answer space and to the 542. Then 3 X 5423 = 16269. Since no remainder is left, we find th that the square root of 7,360,369 is just exactly 2,713.

SQUARE ROOT CALCULATION WITH NUMBERS HAVING DECIMAL FRACTIONS

Now let us find the square root of a number, which contains a decimal fraction, such as 327.465. We first divide this number into groups as shown at (a) in Fig. 27. In doing this, note that we start at the dec

```
           (A)                              (B)
    3'27.46'50 |18.              3'27.46'50 |18.09599   (ANSWER)
        |                            |
   28 |2 27                     28 |2 27
      |2 24                        |2 24
   36 |   3 46                 3609 |  3 46 50
                                    |  3 24 81
                                         |21  6900
                                         |18  0925
                               361909    |  3 597500
                                         |  3 257181
                               3619189   |   34031900
                                         |   32572701
                                              1459199
```

FIG. 27

imal point, marking off groups of two towards the left. We then mark off groups of two towards the right but whenever there are an odd number of places to the RIGHT of the decimal point, we annex an extra zero so that there will be an even number of groups to the right of the decimal point. This does not in any way change the VALUE of the number.

We then follow the general routine of extracting the square root of the number as already explained and as shown in details in steps (A) and (B) of Fig. 27. Notice, however that when we come to the final step in (A), that 36 will not go into 34, therefore we must put a zero after the 8 in our answer and also after the 36 at the left of (A) as shown at (B), at the same time annexing the 5 and 0 to the 346, thus obtaining the number 34650 in (B). The number 360 will go into 3465 nine times, so the 9 is placed after the 0 in the answer and we proceed with the calculations in the usual way.

As you will note, we continually have a remainder, no matter how far we go. The reason for this is that the number 327.465 is not a perfect square, so all that we can do is to calculate its square root as close as possible, which in this case works out to be 18.09599. For convenience, we could say that the square root of 327.465 is approximately 18.096.

We have covered considerable mathematical territory in this one lesson. This is an important lesson and you should find it very handy when confronted with problems involving general mathematics. Study it carefully, make-up practice problems of your own and you will be surprised how quickly that you will be able to master all of the calculations described herein. This is PRACTICAL MATHEMATICS for the PRACTICAL MAN and you should always keep it within easy reach so that you can refer to it whenever necessary. In other words, use this lesson as a HANDBOOK.

• METRIC EQUIVALENTS •

LENGTH

1 CENTIMETER = .3937 INCH	INCH = 2.54 CENTIMETER
1 METER = 3.28 FEET	FOOT = .305 METER
1 METER = 1.094 YARDS	YARD = .914 METER
1 KILOMETER = .621 MILE	MILE = 1.61 KILOMETER

AREA

SQUARE CENTIMETER = 0.1550 SQ. INCH	SQUARE INCH = 6.452 SQ. CENTIMETERS
SQUARE METER = 10.764 SQ. FEET	SQUARE FOOT = .0929 SQUARE METER
SQUARE METER = 1.196 SQ. YARDS	SQUARE YARD = .836 SQUARE METER
HECTARE = 2.47 ACRES	ACRE = 0.405 HECTARE
SQUARE KILOMETER = .386 SQUARE MI.	SQUARE MILES = 2.59 SQUARE KILOM.

VOLUME

CUBIC CENTIMETER = .061 CUBIC INCH	CUBIC INCH = 16.4 CU. CENTIMETER
CUBIC METER = 35.31 CUBIC FEET	CUBIC FOOT = .028 CUBIC METER
CUBIC METER = 1.308 CUBIC YARDS	CUBIC YARD = .765 CUBIC METER

CAPACITY

LITRE = .0353 CUBIC FOOT	CUBIC FOOT = 28.32 LITRES
LITRE = .2642 GAL. (U.S.)	GALLON = 3.785 LITRES
LITRE = 61.023 CUBIC INCHES	CUBIC INCH = .0164 LITRE

LITRE = 2.202 LB. OF FRESH WATER AT 62° F.

WEIGHT

GRAM = 15.423 GRAINS	OUNCE = 28.35 GRAM
GRAM = .0353 OUNCE	LB. = .454 KILOG'M
KILOG'M = 2.205 LB.	TON (SHORT) = 907.03 KILOG'M
KILOG'M = .0011 TON (SHORT)	TON (SHORT) = .907 MET. TON
MET. TON = 1.1025 TON (SHORT)	TON (SHORT) = 2,000 LB.
GRAIN = .0684 GRAM	

PRESSURE

KILOGRAMS PER SQUARE CENTIMETER = 14.225 POUNDS PER SQUARE INCH.
POUNDS PER SQUARE INCH = .0703 KILOGRAMS PER SQUARE CENTIMETER.
KILOGRAMS PER SQUARE METER = .205 POUNDS PER SQUARE FOOT.
POUNDS PER SQUARE FOOT = 4.88 KILOGRAMS PER SQUARE METER.
KILOGRAMS PER SQUARE CENTIMETER = .968 ATMOSPHERE.
ATMOSPHERE = 1.033 KILOGRAMS PER SQUARE CENTIMETER.

MISCELLANEOUS

KILOGRAMMETER = 7.233 FOOT POUNDS.	LITRE PER SECOND = 2.12 CUBIC FEET PER MINUTE.
FOOT POUND = .1383 KILOGRAMMETER.	
METRIC HORSE POWER = .986 HORSE POWER.	LITRE PER SECOND = 15.85 U.S. GALLONS PER MINUTE.
HORSE POWER = 1.014 METRIC HORSE POWER.	

METRIC AND DECIMAL EQUIVALENTS OF COMMON FRACTIONS

FRACTIONS OF AN INCH	DECIMALS OF AN INCH	MILLIMETERS	FRACTIONS OF AN INCH	DECIMALS OF AN INCH	MILLIMETERS
1/64	.0156	0.397	33/64	.5156	13.097
1/32	.0313	0.794	17/32	.5313	13.494
3/64	.0469	1.191	35/64	.5469	13.891
1/16	.0625	1.588	9/16	.5625	14.287
5/64	.0781	1.985	37/64	.5781	14.684
3/32	.0938	2.381	19/32	.5938	15.081
7/64	.1094	2.778	39/64	.6094	15.478
1/8	.1250	3.175	5/8	.6250	15.875
9/64	.1406	3.572	41/64	.6406	16.272
5/32	.1563	3.969	21/32	.6563	16.688
11/64	.1719	4.366	43/64	.6719	17.085
3/16	.1875	4.762	11/16	.6875	17.462
13/64	.2031	5.159	45/64	.7031	17.859
7/32	.2188	5.556	23/32	.7188	18.256
15/64	.2344	5.953	47/64	.7344	18.653
1/4	.2500	6.350	3/4	.7500	19.050
17/64	.2656	6.747	49/64	.7656	19.447
9/32	.2813	7.144	25/32	.7813	19.843
19/64	.2969	7.541	51/64	.7969	20.240
5/16	.3135	7.937	13/16	.8125	20.637
21/64	.3281	8.334	53/64	.8281	21.034
11/32	.3438	8.731	27/32	.8438	21.430
23/64	.3594	9.128	55/64	.8594	21.827
3/8	.3750	9.525	7/8	.8750	22.224
25/64	.3906	9.922	57/64	.8906	22.621
13/32	.4063	10.319	29/32	.9063	23.018
27/64	.4219	10.716	59/64	.9219	23.415
7/16	.4375	11.12	15/16	.9375	23.812
29/64	.4531	11.509	61/64	.9531	24.209
15/32	.4688	11.906	31/32	.9688	24.606
31/64	.4844	12.303	63/64	.9844	25.003
1/2	.5000	12.700	1	1.0000	25.400

EQUIVALENTS OF ELECTRICAL UNITS

1 KILOWATT = 1000 WATTS.
1 KILOWATT = 1.34 HORSE POWER.
1 KILOWATT = 44,257 FOOT-POUNDS PER MINUTE.
1 KILOWATT = 56.87 (BRITISH THERMAL UNITS) B.T.U. PER MINUTE.
1 HORSE POWER = 746 WATTS.
1 HORSE POWER = 33,000 FOOT POUNDS PER MINUTE.
1 HORSE POWER = 42.41 BRITISH THERMAL UNITS (B.T.U.) PER MINUTE.
1 B.T.U. (BRITISH THERMAL UNIT) = 778 FOOT-POUNDS.
1 B.T.U (BRITISH THERMAL UNIT) = 0.2930 WATT-HOUR.
1 JOULE = 1 WATT-SECOND.

EXAMINATION QUESTIONS

LESSON NO. 37

1. - What is the sum of 432.17; 36.875; 0.062; 3.496 and 20754.182?

2. - What is the difference between 8736.294 and 629.01?

3. - What is the product of 762.34 and 2.04?

4. - How many times is 34.02 contained in 7643.096?

5. - How much is 437^2 equal to?

6. - What is the square root of 54,756?

7. - What is the product of $\frac{3}{4}$ and $\frac{4}{7}$ reduced to lowest terms?

8. - What is the quotient obtained when dividing 2/3 by 1/4?

9. - What is the sum of $\frac{1}{2}$; $\frac{7}{8}$; and 3/4?

10. - Subtract $\frac{3}{24}$ from 3/4 and reduce your answer to low est terms.

DEAR STUDENT —

The right thing for us to do each day is to do our best -- unmindful of mistakes. But after our work is done and we realize our blunders, let us not shirk. Let's be honest with ourselves, and admit them.

By so doing we can avoid their re-occurrence in the future and thereby profit from them.

JaR

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Los Angeles, California

LESSON NO. 38

VOLTAGE DISTRIBUTION IN MODERN RECEIVERS

IN A-C RECEIVERS WE OBTAIN THE VARIOUS D-C VOLTAGES, SUCH AS THE PLATE VOLTAGE, GRID BIAS VOLTAGE, AND SCREEN GRID VOLTAGE, FROM A COMMON SOURCE, THE A-C LIGHTING LINE. AS YOU HAVE ALREADY LEARNED, THIS A-C LINE VOLTAGE IS "STEPPED UP" BY A POWER TRANSFORMER, CONVERTED TO A D-C SUPPLY BY MEANS OF A RECTIFIER, AND THE REMAINING PULSATIONS THEN SMOOTHED OUT BY THE FILTER SYSTEM. FINALLY THE D-C, NOW FREE FROM RIPPLE, IS PASSED THRU A RESISTANCE NETWORK FROM WHICH IT IS DISTRIBUTED AT THE PROPER VOLTAGE TO THE VARIOUS CIRCUITS OF THE RECEIVER.

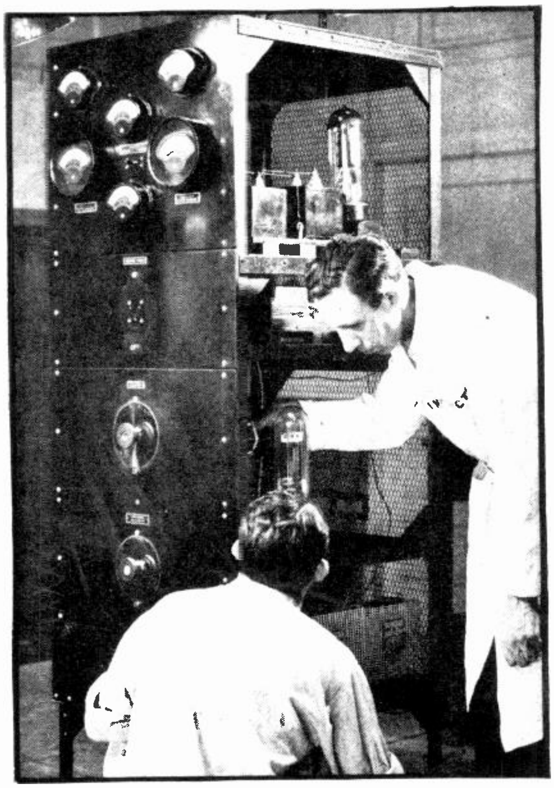

FIG. 1
A SECTION OF NATIONAL'S BROADCAST TRANSMITTER.

YOU ARE ALREADY FAMILIAR WITH THIS SYSTEM AND WITH THE PARTS WHICH WE WILL AGAIN DISCUSS IN THIS LESSON. AT THIS TIME, HOWEVER, WE WILL TREAT THE SUBJECT OF D-C VOLTAGE DISTRIBUTION FROM A DIFFERENT ANGLE, AND IN THE FIRST SECTION OF THIS LESSON, YOU WILL BE SHOWN HOW TO DESIGN VOLTAGE DISTRIBUTION SYSTEMS. WITH THIS KNOWLEDGE, YOU WILL BE ABLE TO DETERMINE THE VARIOUS SIZES OF RESISTORS USED FOR THIS PURPOSE, THEIR WATT RATING, ETC.

LET US ASSUME THAT A RADIO RECEIVER HAS JUST BEEN BUILT IN ACCORDANCE WITH THE CIRCUITS SHOWN IN FIG. 2, AND IT IS NECESSARY TO PROVIDE A RESISTANCE SYSTEM THAT WILL SATISFACTORILY SUPPLY THIS RECEIVER

WITH THE PROPER "B", "C" AND SCREEN-GRID VOLTAGES. FOR THE PRESENT, WE ARE NOT CONCERNED WITH THE FILAMENT CIRCUIT.

DETERMINING THE TUBE LOAD

OUR FIRST STEP IS TO DETERMINE THE VOLTAGES AND CURRENTS REQUIRED BY THE DIFFERENT TUBES, AND BY REFERRING TO FIG. 2 AND THE OPERATING CHARACTERISTICS OF THE TUBES USED, WE HAVE THE FOLLOWING DATA AT HAND.

EACH OF THE TYPE 6D6 R.F. TUBES REQUIRES A PLATE VOLTAGE OF 250, A SCREEN VOLTAGE OF 100 VOLTS AND A MINIMUM BIAS VOLTAGE OF -3. UNDER THESE CONDITIONS, THE PLATE CURRENT DRAWN BY EACH OF THESE TUBES WILL BE 8.2 MA., AND THE SCREEN CURRENT APPROXIMATELY 2 MA. FOR EACH TUBE.

THE TYPE 42 POWER AMPLIFIER TUBE REQUIRES A PLATE VOLTAGE OF 250, A SCREEN GRID VOLTAGE OF 250, AND A GRID BIAS OF -16.5 VOLTS. THIS TUBE WILL THEN DRAW A PLATE CURRENT OF 34 MA., AND A SCREEN CURRENT OF 6.5 MA.

WE WILL ASSUME THAT THE 6C6 DETECTOR TUBE IN THIS CASE REQUIRES A PLATE SUPPLY VOLTAGE OF 250 VOLTS, A GRID BIAS OF -4.3 VOLTS, AND A SCREEN GRID VOLTAGE OF 75. WHEN SO OPERATED, ABOUT 0.33 MA. OF PLATE CURRENT WILL FLOW, AND APPROXIMATELY 0.1 MA. OF SCREEN GRID CURRENT.

IT IS TO BE NOTED THAT WHEN SPECIFYING VALUES FOR TUBES OPERATED AS RESISTANCE-COUPLED POWER DETECTORS, SUCH AS EMPLOYED IN THE CIRCUIT OF FIG. 2, THE TUBE MANUFACTURERS MAKE IT A GENERAL PRACTICE TO SPECIFY

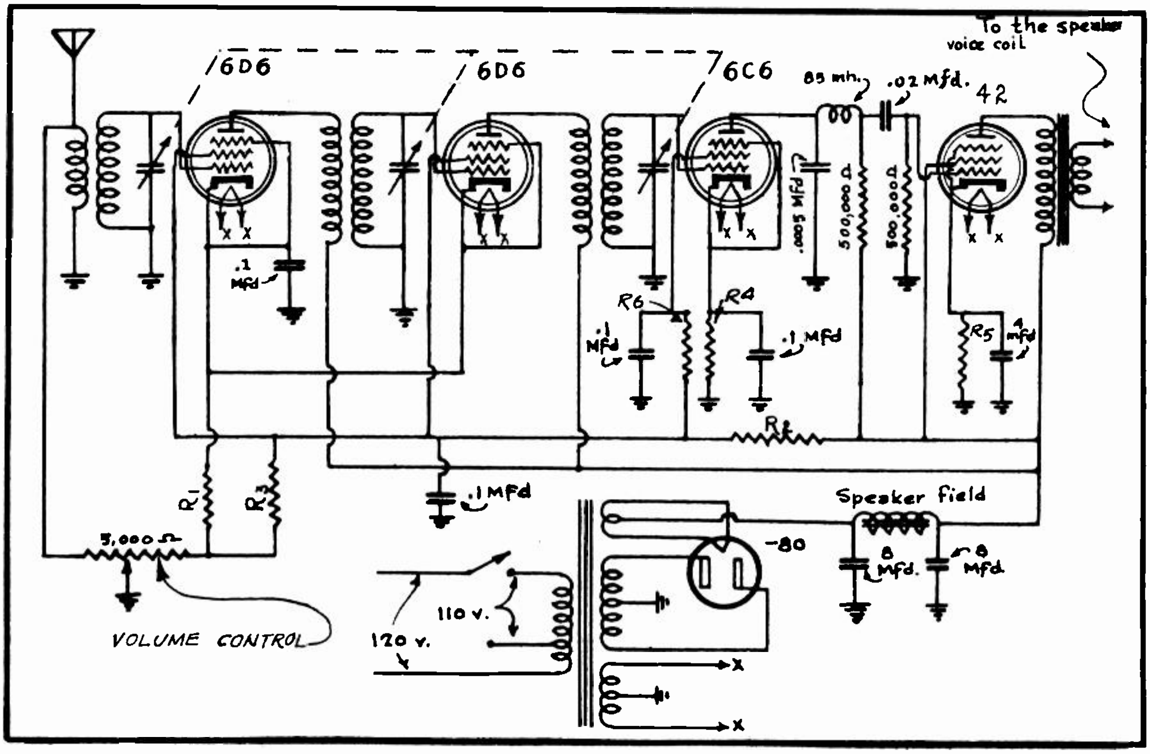

FIG. 2
FIVE-TUBE RADIO RECEIVER CIRCUITS.

THE B VOLTAGE SOURCE NECESSARY FOR THE DETECTOR'S PLATE SUPPLY, TOGETHER WITH THE REQUIRED PLATE CIRCUIT RESISTOR VALUE FOR BEST OPERATION, RATHER THAN SPECIFYING THE ACTUAL PLATE VOLTAGE AS MEASURED AT THE TUBE SOCKET. FOR THE 6C6 A PLATE CIRCUIT RESISTOR OF 0.5 MEGOHM IS SPECIFIED.

ALSO, BEAR IT IN MIND THAT SOMETIMES THE OPERATING VALUES FOR THE SAME TYPE OF TUBE VARY SOMEWHAT IN THE DIFFERENT MAKES, BUT IN ANY EVENT, THE DESIGN PROCEDURE SUGGESTED IN THIS LESSON SHOULD BE CARRIED OUT.

THE R.F. LOAD

THE NEXT STEP IS TO DETERMINE THE COMBINED CURRENT THAT THE TWO R.F. STAGES WILL REQUIRE FROM THE B SUPPLY. TO SIMPLIFY THIS ANALYSIS, THE BASIC DIAGRAM OF FIG. 3 IS PRESENTED. THE RESISTORS HERE SHOWN ARE INDEXED AS R_1 AND R_2, TO CORRESPOND WITH THE SAME RESISTORS SHOWN IN FIG. 2.

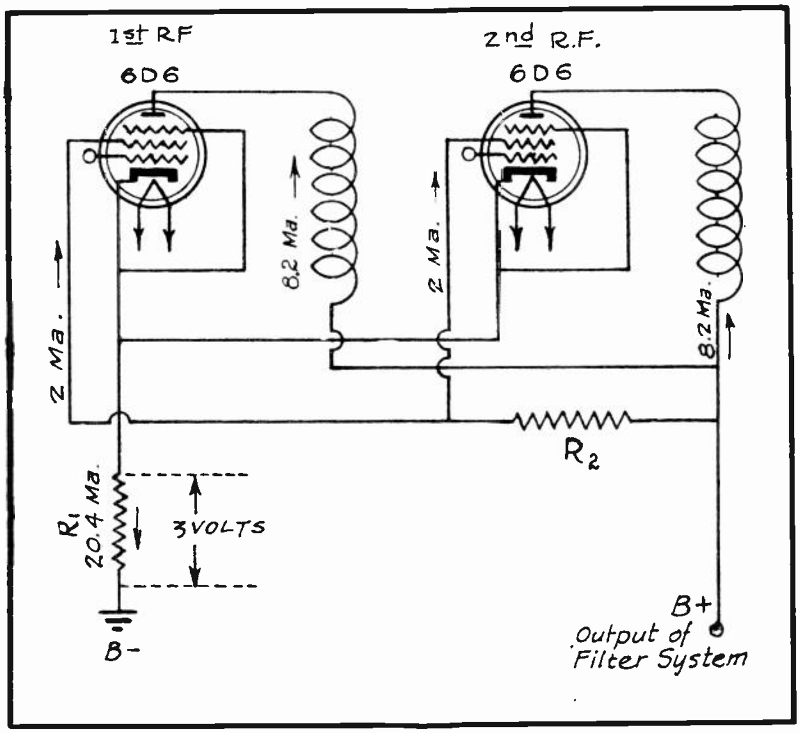

FIG. 3
SIMPLIFIED R.F. LOAD CIRCUIT.

UPON STUDYING FIG. 3 CLOSELY YOU WILL SEE THAT THIS CIRCUIT IS SUCH THAT THE COMBINED PLATE AND SCREEN CURRENTS OF BOTH THE R.F. TUBES WILL FLOW THRU R_1. SINCE THE PLATE CURRENT THRU EACH TUBE IS 8.2 MA., AND THE SCREEN CURRENT 2 MA., THE TOTAL CURRENT FLOWING THRU EACH OF THESE TUBES WILL BE $8.2 + 2 = 10.2$ MA. THIS TOTAL B CURRENT PER TUBE IS SOMETIMES CALLED THE "CATHODE CURRENT", BECAUSE ALL OF IT MUST FLOW THROUGH THE CATHODE IN ORDER TO COMPLETE THE CIRCUIT.

THE CIRCUIT CONNECTION OF RESISTOR R_1 IS SUCH THAT THE CATHODE CURRENT OF BOTH OF THE R.F. TUBES MUST FLOW THRU IT, AND THEREFORE IT WILL CARRY A CURRENT OF $2 \times 10.2 = 20.4$ MA.

CALCULATING THE R.F. BIAS RESISTOR

BY AGAIN REFERRING TO FIG. 2, YOU WILL OBSERVE THAT IN THE ACTUAL CIRCUIT, THE GROUND OR B- CONNECTION FOR R_1 IS COMPLETED THRU THE ARM TERMINAL OF THE 5000 OHM POTENTIOMETER THAT IS USED AS THE VOLUME CON-

TROL. WHEN THE ARM OF THE POTENTIOMETER SHOWN IN FIG. 2 IS MOVED TO THE EXTREME RIGHT IT WILL GROUND THE LOWER END OF R_1. WHEN SUCH IS THE CASE, THE MINIMUM PERMISSIBLE RESISTANCE IS INCLUDED IN THE CATHODE CIRCUIT OF THE R.F. AMPLIFIER, RESULTING IN MINIMUM BIAS VOLTAGE AND MAXIMUM VOLUME. (THE 6D6 TUBES HAVE A VARIABLE-MU CHARACTERISTIC THAT IS HERE USED TO ASSIST THE CONTROL OF VOLUME).

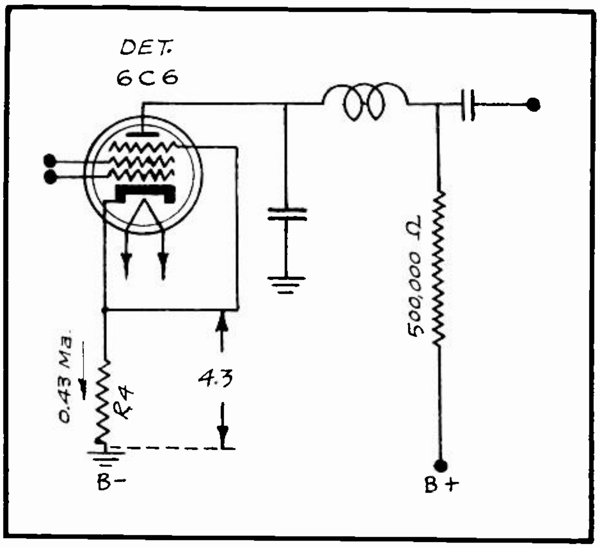

FIG. 4
CALCULATING DETECTOR BIAS RESISTOR.

WITH THE VOLUME CONTROL IN THIS POSITION, THE CATHODE CIRCUIT BECOMES EQUIVALENT TO THAT ILLUSTRATED IN FIG. 3, WHERE FOR THE SAKE OF SIMPLICITY THE VOLUME CONTROL HAS BEEN OMITTED. AT THIS TIME IT IS THE DUTY OF R_1 TO FURNISH THE MINIMUM BIAS OF -3 VOLTS AS PREVIOUSLY SPECIFIED IN THIS LESSON.

THE REQUIRED RESISTANCE RATING FOR R_1 IS DETERMINED BY APPLICATION OF OHM'S LAW IN THE FOLLOWING MANNER: $R = \frac{E}{I} = \frac{3}{.0204} =$ 147 OHMS (APPROXIMATELY). NOTICE THAT WHEN APPLYING OHM'S LAW, THE CURRENT VALUE 20.4 MA. MUST FIRST BE CONVERTED TO ITS EQUIVALENT 0.0204 AMP.

RESISTORS OF SUCH ODD RATINGS AS 147 OHMS ARE NOT COMMERCIALLY AVAILABLE UNLESS THEY ARE SPECIALLY CONSTRUCTED. THEREFORE, IF A STANDARD RESISTOR IS TO BE USED FOR THIS PURPOSE, WE MUST SELECT THE NEAREST STANDARD COMMERCIAL VALUE, WHICH IS 150 OHMS. FROM A PRACTICAL STANDPOINT, THIS SLIGHT DIFFERENCE FROM THE CALCULATED VALUE CAN BE NEGLECTED, AS IT WILL NOT RESULT IN ANY NOTICEABLE EFFECT UPON THE PERFORMANCE OF THE SET. IN FACT, EVEN A VALUE AS HIGH AS 200 OHMS WOULD NOT BE ENTIRELY IMPRACTICAL, IF NECESSARY TO USE IT.

THRU THE USE OF THE VOLUME CONTROL, THE EFFECTIVE BIAS RESISTANCE AND BIAS VOLTAGE CAN BE INCREASED, AND THE VOLUME CORRESPONDINGLY REDUCED.

THE DETECTOR BIAS RESISTOR

THE ESSENTIAL PARTS OF THE CIRCUIT CONCERNED IN THE CALCULATION OF THE VALUE OF THE DETECTOR'S BIAS RESISTOR ARE SHOWN IN FIG. 4. THE BIAS RESISTOR R_4 WILL PASS A CURRENT OF 0.33+ 0.1 = 0.43 MA. THEREFORE, SINCE

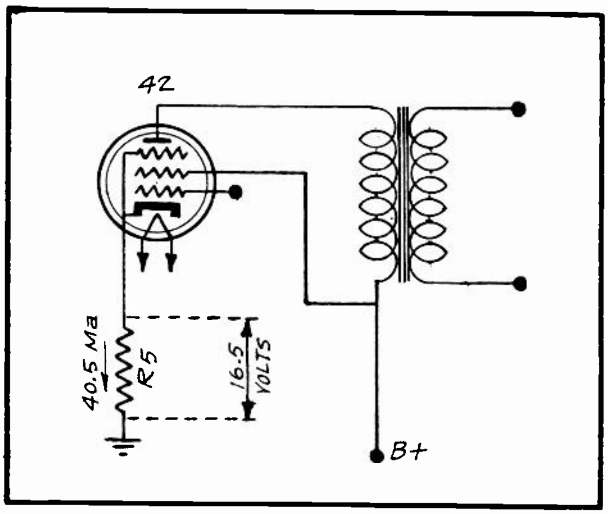

FIG. 5
CALCULATING POWER STAGE BIAS RESISTOR.

A BIAS VOLTAGE OF -4.3 VOLTS IS REQUIRED, THE NECESSARY VALUE FOR R_4 IS $R = \frac{E}{I} = \frac{4.3}{.00043}$ = 10,000 OHMS. THIS RATING IS COMMERCIALLY AVAILABLE.

POWER STAGE BIAS RESISTOR

FIG. 5 ILLUSTRATES THE BASIC PARTS AND VALUES CONCERNED IN CALCULATING THE RATING OF THE BIAS RESISTOR OF THE TYPE 42 POWER TUBE. SINCE THE PLATE CURRENT DRAWN BY THIS TUBE IS 34 MA., AND THE SCREEN CURRENT 6.5 MA., THE TOTAL CURRENT FLOWING THRU THE BIAS RESISTOR R_5, IS 34 + 6.5 = 40.5 MA. THEREFORE, TO PRODUCE THE NECESSARY BIAS VOLTAGE OF -16.5, THIS RESISTOR MUST HAVE A VALUE OF $R = \frac{E}{I} = \frac{16.5}{0.0405}$ = 407 OHMS, AND A STANDARD RESISTOR OF 400 OHMS WILL PROVE SATISFACTORY.

EFFECTIVE PLATE VOLTAGE

AN IMPORTANT POINT TO REMEMBER IS THAT THE B VOLTAGE SUPPLIED TO THE PLATE CIRCUIT OF ANY TUBE IS NOT NECESSARILY OF THE SAME VALUE AS THE PLATE VOLTAGE EFFECTIVE AT THE TUBE. FOR EXAMPLE, FIG. 6 SHOWS AN AUDIO AMPLIFIER STAGE WHEREIN THE TUBE IS OPERATING WITH A BIAS OF -10 VOLTS.

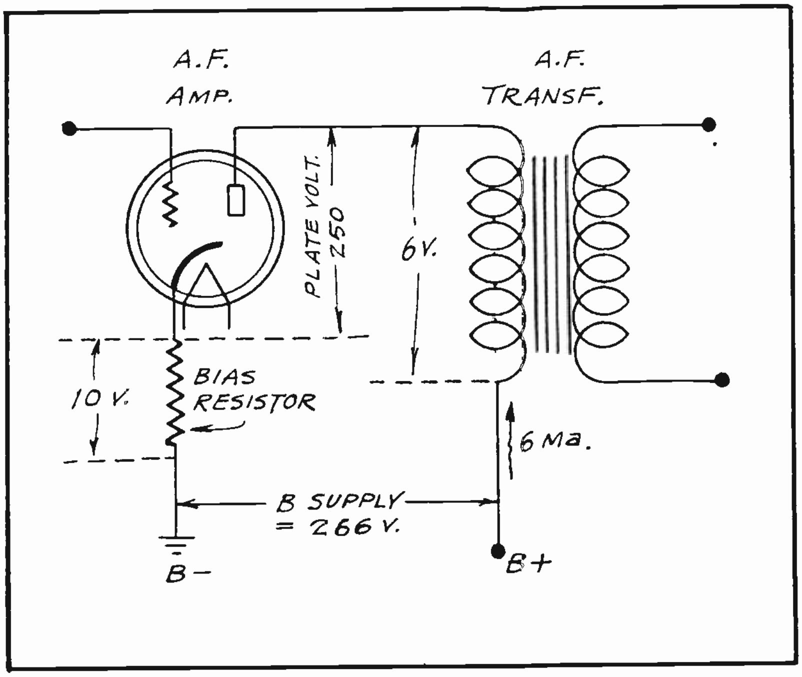

FIG. 6
VOLTAGE DROPS IN THE CIRCUIT.

ALSO NOTE THAT IN THIS SAME TUBE'S PLATE CIRCUIT IS INCLUDED THE PRIMARY WINDING OF AN AUDIO TRANSFORMER, THE RESISTANCE OF WHICH IS 1000 OHMS. THE B SUPPLY VOLTAGE ACROSS THE B+ AND B- TERMINALS IS 266 VOLTS, AND A PLATE CURRENT OF 6 MA. FLOWS THRU THE CIRCUIT.

THE FLOW OF 6 MA. OF PLATE CURRENT THRU THE 1000 OHMS OF RESISTANCE OFFERED BY THE A.F. TRANSFORMER'S PRIMARY ACCOUNTS FOR A VOLTAGE DROP OF 6 VOLTS ACROSS THE EXTREMITIES OF THIS WINDING. ($E = I \times R$ = 0.006 x 1000 = 6 VOLTS).

THE SUM OF THE VOLTAGE DROPS ACROSS THIS TRANSFORMER WINDING AND THE BIAS RESISTOR IS 6 + 10 = 16 VOLTS. THEREFORE, THE ACTUAL OR EFFECTIVE PLATE VOLTAGE, MEASURED BETWEEN THE TUBE'S PLATE AND CATHODE, IS 266—16, OR 250 VOLTS.

THIS EXAMPLE THUS SHOWS WHY, IN PRACTICE, THE PLATE VOLTAGE IS AL-

WAYS LESS THAN THE B SUPPLY VOLTAGE.

CALCULATING THE SCREEN GRID CIRCUIT RESISTORS

FIG. 7 ILLUSTRATES THE BASIC CIRCUIT FOR WORKING OUT THE VALUES FOR THE VARIOUS RESISTANCE THAT ARE INCLUDED IN THE SCREEN GRID CIRCUITS OF THIS RECEIVER.

THE HIGHEST B VOLTAGE REQUIRED BY ANY OF THE TUBES WILL BE DEMANDED BY THE 42, WHICH REQUIRES A PLATE VOLTAGE OF 250 AND A BIAS OOF -16.5 VOLTS.

IN ADDITION, THE PRIMARY WINDING OF THE OUTPUT TRANSFORMER, HAVING A RESISTANCE OF 500 OHMS, IS CONNECTED IN THIS TUBE'S PLATE CIRCUIT. WITH A PLATE CURRENT OF 34 MA. FLOWING THROUGH THIS WINDING, THE VOLTAGE DROP ACROSS IT WILL BE 17 VOLTS ($E = I \times R = 0.034 \times 500 = 17$). THE TOTAL B SUPPLY VOLTAGE REQUIRED BY THIS TUBE, AND MEASURED ACROSS THE OUTPUT TERMINALS OF THE POWER SUPPLY FILTER SYSTEM, THUS BECOMES $250 + 16.5 + 17 = 283.5$ VOLTS.

TO PROTECT THE FILTER CONDENSERS AGAINST BREAK-DOWN DURING THE RECEIVER TUBES' WARMING-UP PERIOD, MEANS MUST BE PROVIDED FOR CIRCULATION OF A BLEEDER CURRENT. IN THE CIRCUITS OF FIG. 2 AND 7, THIS IS ACCOMPLISHED BY R_2 AND R_3 IN COMBINATION, PROVIDING A PERMANENTLY CLOSED CIRCUIT ACROSS THE FILTER OUTPUT.

THE AMOUNT OF BLEEDER CURRENT IS LEFT TO THE DESIGNER'S JUDGEMENT,

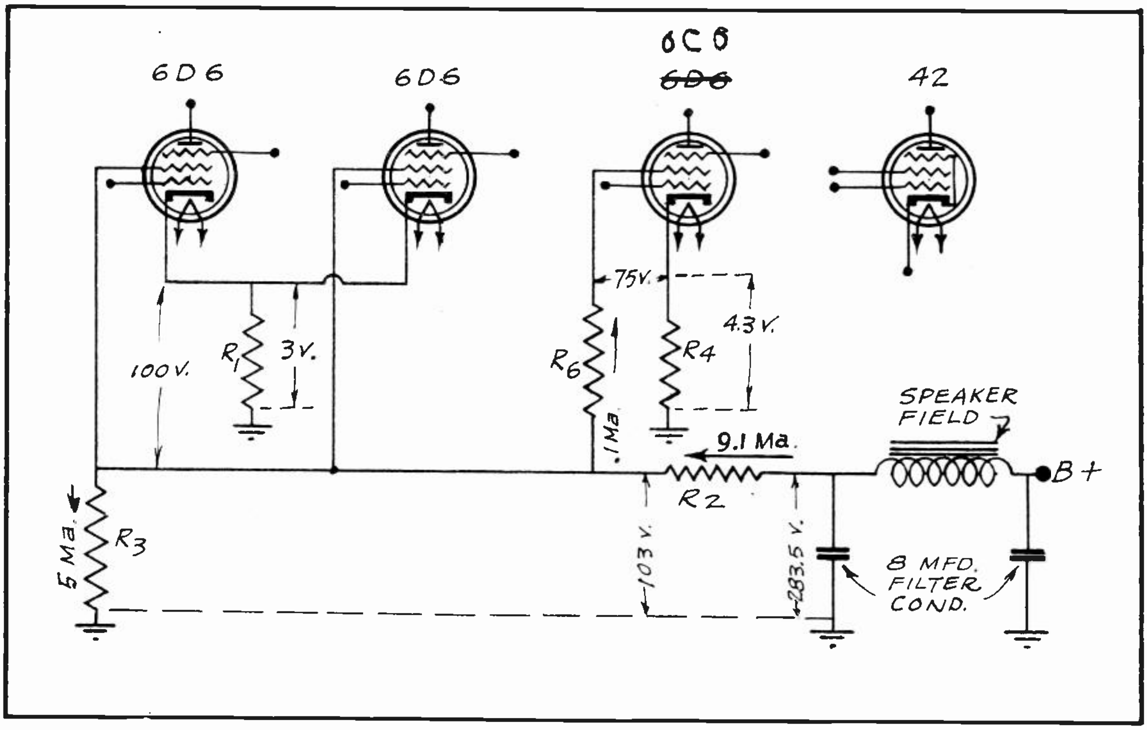

FIG. 7
CALCULATING SCREEN RESISTOR VALUES.

BUT TOO MUCH BLEEDER CURRENT INCREASES THE TOTAL LOAD UPON THE RECTIFIER, AND THE VOLTAGE DROP ACROSS THE FILTER SYSTEM IS ALSO INCREASED. ON THE OTHER HAND, TOO LITTLE BLEEDER CURRENT WILL MAKE THE SYSTEM LESS STABLE IN OPERATION, SO WE TRY TO ARRIVE AT A HAPPY MEDIUM BY ALLOWING FROM 3 TO 10 MA. FOR OUR PARTICULAR EXAMPLE WE SHALL SELECT A BLEEDER CURRENT OF 5 MA.

THE TOTAL CURRENT FLOW THROUGH R_2 WILL BE EQUAL TO THE SUM OF THE BLEEDER CURRENT AND THE SCREEN CURRENT DRAWN BY THE R.F. AND DETECTOR TUBES. FROM THE DATA ALREADY FURNISHED IN THIS LESSON, THE TOTAL CURRENT FLOW THROUGH R_2 IS THEREFORE $5 + 2 + 2 + 0.1 = 9.1$ MA.

A VOLTAGE OF 100 IS REQUIRED BY THE SCREEN GRIDS OF THE 6D6 TUBES, AND SINCE THIS SCREEN VOLTAGE MUST EXIST ACROSS THE SCREEN GRID AND CATHODE TERMINALS OF THESE TUBES (WHICH OPERATE WITH A BIAS VOLTAGE OF -3 VOLTS) THE SCREEN GRID SUPPLY VOLTAGE AT THE SCREEN GRID END OF THE CIRCUIT (OUTPUT) OF R_2) MUST BE 100 + 3 OR 103 VOLTS. THIS MEANS THAT A VOLTAGE DROP OF 283.5 - 103, OR ABOUT 180, MUST BE FURNISHED BY R_2. THE VALUE OF R_2 MUST THEREFORE BE APPROXIMATELY 20,000 OHMS ($R = \frac{E}{I} = \frac{180}{0.0091} = 19{,}780$).

SINCE THIS SAME 103 VOLTS IS APPLIED ACROSS THE EXTREMITIES OF R_3, AND THE CURRENT CARRIED BY THIS RESISTOR IS 5 MA., THE VALUE OF R_3 MUST ALSO BE 20,000 OHMS ($R = \frac{E}{I} = \frac{103}{0.005} = 20{,}600$).

THE VOLTAGE REQUIRED AT THE SCREEN GRID END OF R_6 IS $75 + 4.3 = 79.3$ VOLTS. THEREFORE, THE VOLTAGE DROP ACROSS R_6 MUST BE $103 - 79.3 =$

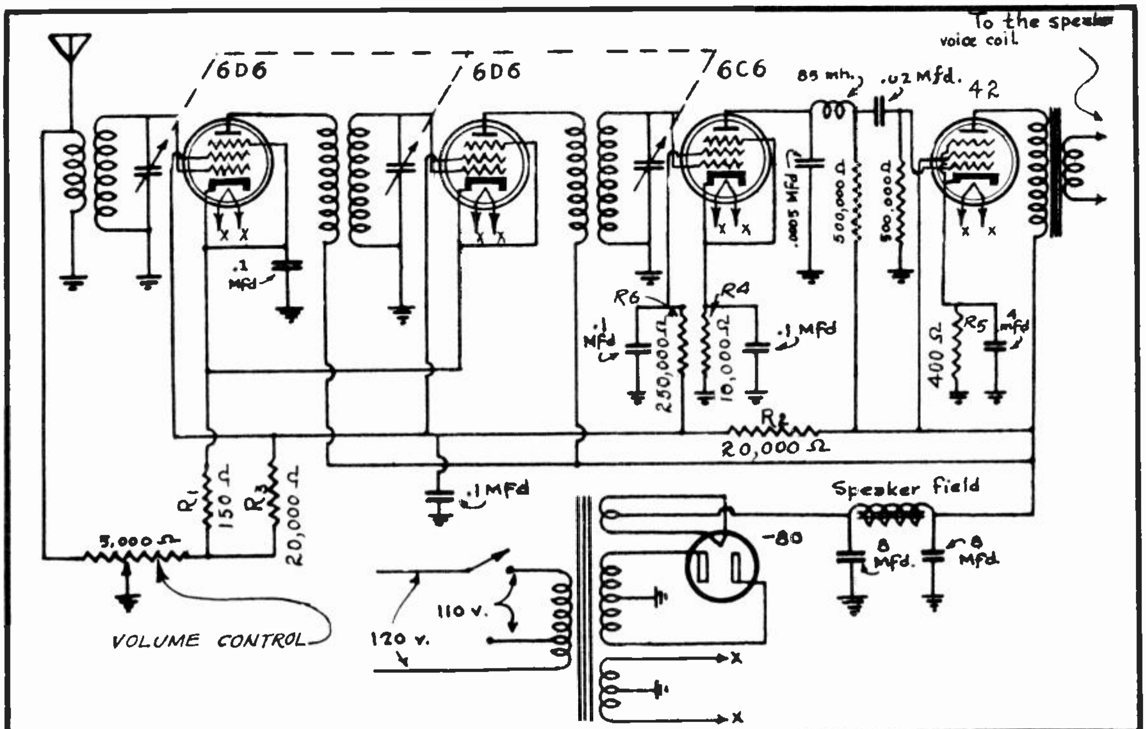

FIG. 8
COMPLETE CIRCUITS WITH RESISTOR VALUES DESIGNATED.

23.7 volts, and since this resistance passes 0.1 ma., the resistance value required for R_6 is 237,000 ohms ($R = \frac{E}{I} = \frac{23.7}{0.0001} = 237,000$. We would employ the nearest standard rating available, or 250,000 ohms.

VARIATIONS IN PLATE VOLTAGE

Another important point to notice in the circuit of Fig. 2 is that the plate circuits of the R.F. and detector tubes are connected to the 283.5 volt point of the system. In reality, and according to our calculations, the plate circuits of the R.F. tubes should be connected to a point of 250 + 3 or 253 volts, and the detector plate circuit to a point of 250 volts. To make this possible, additional resistance would have to be included in these plate circuits, together with an additional by-pass condenser, but this would necessitate an additional expense to make a correction of only about 30 volts, in a circuit operating at between 250 and 300 volts.

Fig. 9
Reminder Formula.

The tube operating characteristics, as furnished by the tube manufacturers, are sufficiently flexible so that this variation of about 12% from the calculated value will have no noticeable effect upon the sensitivity and fidelity performance of the receiver, as far as the human ear is concerned. Therefore, it is practical to connect all of the plate circuits of this receiver to the same 283.5 volt point.

The circuit is again shown in its complete form in Fig. 8, with the values of all resistors indicated. The 500,000 ohm detector plate circuit resistor and the 500,000 ohm grid leak for the type 42 tube do not enter into our calculations at this time, because they are not regarded as a part of the voltage distribution system.

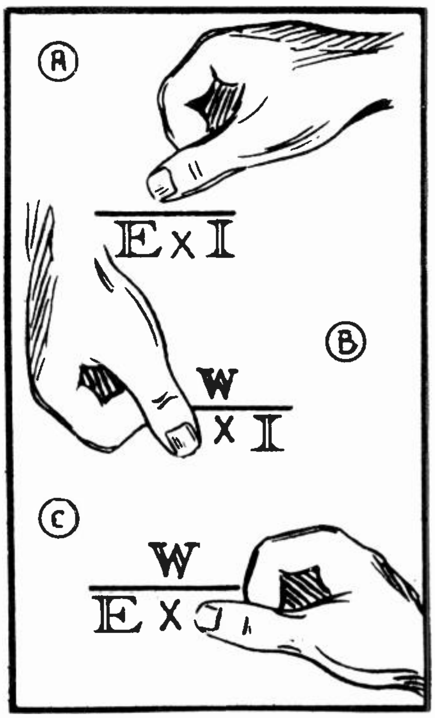

Fig. 10
Three Forms Of
Watt's Law.

ELECTRIC POWER

We still are not through with figuring on this voltage-divider for the receiver, because even though its resistance values are correct, this does not mean that the resistor will "stand-up" under the strain of service. Whenever a current flows through a resistance the result is not only a voltage drop, but also a certain amount of POWER will be dissipated in the form of heat. We measure this power in WATTS.

The watt is the unit of electric power, and represents the work done by a current flow of one ampere which is being forced to flow by an electric pressure of one volt. To find the number of watts in a circuit it is only necessary to multiply the number of amperes flowing in that circuit by the number of volts impressed across the circuit. This relation between watts, amperes, and volts is known as "Watt's Law" and the expression shown in Fig. 9 offers an easy method for remembering this important relation. In this case, W stands for watts, E for volts, and I for amperes.

In using Ohm's Law you are already familiar with the fact that if we know any two values of the formula, the third can be determined very readily. The same is true in respect to Watt's Law. For example, by using the expression as given in Fig. 9, you can simply cover up the value you wish to determine, and the remaining portion of the formula will tell you how to find it.

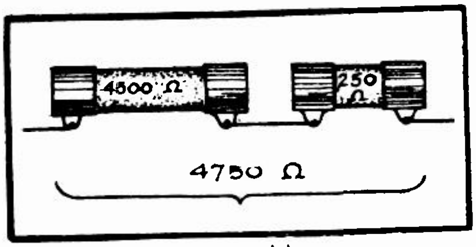

Fig. 11
"Building Up" a Resistor To Proper Value.

To illustrate this more clearly, we call your attention to Fig. 10. To find the watts in a circuit, simply cover the W as shown at (a), and the remaining portion tells us to multiply the volts by the amperes. To find the volts, cover the E as shown at (b), and the balance of the expression tells us to divide the watts by the amperes. Finally, at (c) covering up the I, we can find the amperes by dividing the watts by the volts.

Remember then, that watts equal volts multiplied by amps ($W = E \times I$). Volts equals watts divided by amperes ($E = \frac{W}{I}$), and amperes equals watts divided by volts ($I = \frac{W}{E}$).

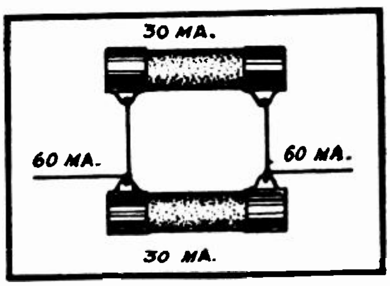

Fig. 12
Parallelled Resistors.

You may encounter a problem in which the current or voltage in the circuit is unknown, and some value in Watt's Law is to be found. In such case, two other handy relations are at your disposal: $W = I^2 \times R$, and (2) $W = \frac{E^2}{R}$.

In the first example, (1) the watts may be found by multiplying the current by itself (squaring it) and then multiplying by the resistance. This formula is useful when voltage and watts are both unknown. In the second example (2), the watts or power can be found by multiplying the voltage by itself (squaring it) and then dividing this value by the resistance. This relation is very valuable when watts and current are both unknown.

In radio work we frequently handle such small amounts of electric power that the watt is too large a unit, and for such purposes the milliwatt is generally used. One milliwatt is equivalent to $\frac{1}{1000}$ of

ONE WATT, BUT SOMETIMES EVEN THIS UNIT IS RATHER LARGE, SO A STILL SMALLER UNIT OF POWER IS NEEDED. THIS VERY SMALL UNIT IS THE MICROWATT, AND IS EQUIVALENT TO $\frac{1}{1,000,000}$ WATT (THE ONE-MILLIONTH PART OF 1 WATT).

ON THE OTHER HAND, IN TRANSMISSION WORK, WHERE LARGE AMOUNTS OF POWER ARE HANDLED, IT IS CONVENIENT TO USE A LARGE UNIT, LARGER THAN THE WATT, AND FOR SUCH PURPOSES WE USE THE KILOWATT. ONE KILOWATT (KW) IS EQUAL TO 1000 WATTS.

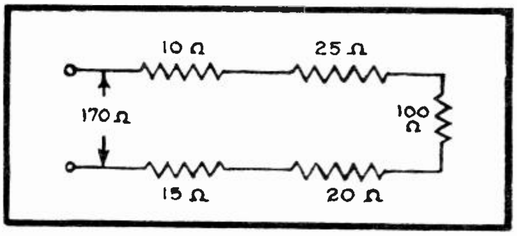

FIG. 13
SERIES-CONNECTED RESISTORS.

WATT RATING OF RESISTORS

ALL RESISTORS ARE RATED ACCORDING TO THE WATTS THAT THEY WILL DISSIPATE, OR EVEN ACCORDING TO BOTH WATTS AND CURRENT. IN OTHER WORDS, IF YOU NEED A 1000-OHM RESISTOR, YOU CAN GET ONE WITH A RATING OF 1/2 WATT, 1 WATT, 10 WATTS, AND MANY OTHER RATINGS, YET ALL OF THEM HAVING THE SAME RESISTANCE VALUE.

SHOULD YOU, BY CHANCE, PUT A RESISTOR RATED 5000 OHMS AND 1 WATT IN A CIRCUIT WHERE THE CURRENT THRU THIS RESISTOR AND THE VOLTAGE ACROSS IT WILL REQUIRE IT TO DISSIPATE 20 WATTS, THE RESISTOR WILL BURN OUT, AND WILL HAVE TO BE REPLACED WITH ANOTHER OF A HIGHER WATT RATING. CHOOSING THE PROPER RESISTORS IS AN IMPORTANT PART OF THE RADIO TECHNICIAN'S WORK, AND CAN BY NO MEANS BE SLIGHTED IF HE PLANS ON HAVING SATISFIED CUSTOMERS.

NOW THAT YOU ARE FAMILIAR WITH THE ELECTRICAL UNIT OF POWER (THE WATT) AND ITS RELATION TO RESISTOR RATINGS, LET US CONTINUE BY DETERMINING THE NECESSARY WATT RATINGS FOR THE VARIOUS RESISTANCE RATINGS CONSIDERED IN THE CIRCUIT OF FIG. 8. IN EACH CASE THE WATT RATING IS EQUAL TO THE CURRENT FLOWING THRU THE RESISTOR, MULTIPLIED BY THE VOLTAGE DROP ACROSS IT, AND THESE WATT RATINGS WORK OUT TO THE VALUES SHOWN IN TABLE I.

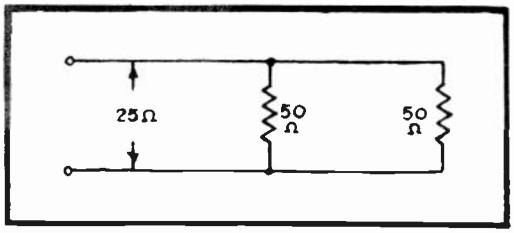

FIG. 14
TWO RESISTORS IN PARALLEL.

HIGHER WATT RATING REQUIRED THAN THOSE CALCULATED

THE WATT VALUES AS THUS FAR CALCULATED ARE NOT SUITABLE FOR USE, BECAUSE THE COMMERCIAL RATINGS GIVEN RESISTORS ARE THOSE UNDER WHICH THE RESISTOR REACHES A TEMPERATURE OF NEARLY 500° F., IN AN AIR SPACE OF ONE CUBIC FOOT SURROUNDING THE RESISTOR, AND WITH AN AIR TEMPERATURE OF 68° F. A RESISTOR AT 500° F WOULD BE UNSAFE IN A RECEIVER, SO WE MUST USE A RESISTOR WITH A WATT RATING OF FROM TWO TO FOUR TIMES THAT DETERMINED BY THE FOREGOING CALCULATIONS. FURTHERMORE, WE MUST ALLOW A SUFFICIENT MARGIN OF SAFETY, SO THAT THE RESISTORS WILL HOLD UP UNDER THE MOST ABNORMAL CONDITIONS THAT MAY OCCUR IN SERVICE.

IT SHOULD ALSO BE NOTED THAT THE RESISTANCE OF A RESISTOR VARIES

TABLE I							
WATT-RATING CALCULATIONS							
WATT RATING OF	R_1	=	E x I	=	3 x 0.0204	=	0.0612 WATT
" " "	R_2	=	E x I	=	180 x 0.0091	=	1.638 "
" " "	R_3	=	E x I	=	103 x 0.005	=	0.515 "
" " "	R_4	=	E x I	=	4.3 x 0.00043	=	0.0018 "
" " "	R_5	=	E x I	=	16.5 x 0.0405	=	0.668 "
" " "	R_6	=	E x I	=	23.7 x 0.0001	=	0.0024 "

WITH A CHANGE IN ITS TEMPERATURE; THIS MEANS THAT A HOT RESISTOR WILL PRODUCE A DIFFERENT VOLTAGE DROP THAN WHEN IT IS COLD OR JUST WARM.

TO GIVE THE RESISTORS A "FIGHTING CHANCE" AGAINST HIGH TEMPERATURES AND THE CONDITION JUST MENTIONED, WE MUST CHOOSE THEM WITH A WATT RATING SUFFICIENTLY HIGH. TO ALLOW THE RESISTORS IN THE VOLTAGE DISTRIBUTION SYSTEM UNDER DISCUSSION TO OPERATE AT ONE-QUARTER THEIR WATT RATING, LET US LOOK BACK AT OUR FIGURES, AND DETERMINE THE WATT RATINGS REQUIRED FOR THE VARIOUS SECTIONS OF THE SYSTEM, SO THAT WE WILL INSURE THEM AGAINST "BURN OUTS". THESE VALUES, CORRECTED TO TWO TIMES THE CALCULATED VALUES, APPEAR IN TABLE II, TOGETHER WITH NEAREST STANDARD WATT RATING AVAILABLE.

SERIES AND PARALLEL RESISTOR COMBINATIONS

AT THIS POINT IT IS WELL TO MENTION THAT IN CASE THAT A RESISTOR OF A CERTAIN RESISTANCE AND WATT RATING IS NOT AVAILABLE, TWO OR MORE RESISTORS OF VARIOUS RESISTANCE VALUES MAY BE CONNECTED IN A SERIES COMBINATION, THUS PROVIDING THE REQUIRED RESISTANCE VALUE. THE WATT RATING OF EACH OF THESE, HOWEVER, MUST COME UP TO THE REQUIREMENTS.

TO ILLUSTRATE THIS POINT, LET US SUPPOSE THAT YOU NEED A 4750-OHM RESISTOR WITH A 20 WATT RATING. IF THIS SIZE IS NOT AVAILABLE, THEN A 4500-OHM, 20-WATT RESISTOR AND A 250-OHM, 20-WATT RESISTOR MAY BE CONNECTED IN SERIES AS SHOWN IN FIG. 11.

ON THE OTHER HAND, IF YOU HAVE TROUBLE IN GETTING THE PROPER WATT RATING, BUT HAVE QUITE AN ASSORTMENT OF RESISTANCE VALUES TO CHOOSE

TABLE II		
CORRECTED WATT RATINGS		
CORRECTED RATING		STANDARD RATING
R_1 = 0.0612 x 2 = 0.12	WATT (APPROX.)--------	1/4 WATT
R_2 = 1.638 x 2 = 3.25	" " --------	3 "
R_3 = 0.515 x 2 = 1.03	" " --------	1 "
R_4 = 0.0018 x 2 = 0.0036	" " --------	1/4 "
R_5 = 0.668 x 2 = 1.336	" " --------	2 "
R_6 = 0.0024 x 2 = 0.0048	" " --------	1/4 "

FROM, YOU CAN WORK OUT A SOLUTION AS PICTURED IN FIG. 12. HERE THE RESISTOR IS EXPECTED TO CARRY 60 MA., BUT IT IS ASSUMED THAT THE RESISTORS AVAILABLE HAVE A SAFE CARRYING CAPACITY OF ONLY 30 MA.

TWO OF THESE RESISTORS CAN BE CONNECTED IN PARALLEL, TO PERMIT THE 60 MA. TO BE PASSED SAFELY, EACH CARRYING HALF OF THE CURRENT OR 30 MA. WHEN CONNECTING TWO SUCH RESISTORS IN PARALLEL, EACH MUST HAVE DOUBLE THE RESISTANCE REQUIRED. THAT IS, IF A TOTAL RESISTANCE OF 1000 OHMS IS NEEDED, THEN EACH OF THESE PARALLELED RESISTORS MUST HAVE A RESISTANCE VALUE OF 2000 OHMS.

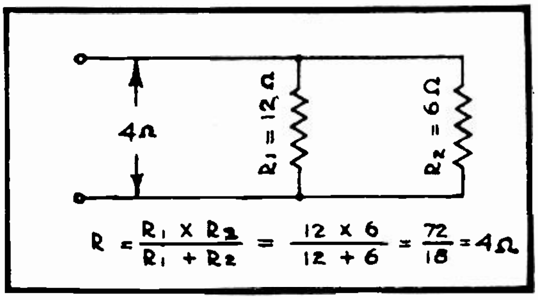

FIG. 15
TWO UNEQUAL PARALLEL-CONNECTED RESISTORS.

SERIES RESISTOR COMBINATIONS

YOU HAVE ALREADY LEARNED THAT THE TOTAL RESISTANCE OF A SERIES-CONNECTED RESISTOR GROUP IS EQUAL TO THE SUM OF THE INDIVIDUAL RESISTANCES CONNECTED IN THE GROUP. FOR INSTANCE, IN FIG. 13 FIVE RESISTORS, HAVING VALUES OF 10 OHMS, 25 OHMS, 100 OHMS, 20 OHMS AND 15 OHMS, RESPECTIVELY, ARE ALL CONNECTED IN SERIES. THE TOTAL RESISTANCE OF THIS CIRCUIT THEN BECOMES EQUAL TO 10 + 25 + 100 + 20 + 15, OR A TOTAL OF 170 OHMS.

PARALLEL RESISTOR COMBINATIONS

WHEN RESISTORS ARE CONNECTED IN PARALLEL THE RESULT IS ENTIRELY DIFFERENT. WE SHALL START THIS INSPECTION OF PARALLEL RESISTOR COMBINATIONS WITH THE MOST SIMPLE FORM, NAMELY TWO RESISTORS OF THE SAME RESISTANCE VALUE CONNECTED IN PARALLEL, AS PICTURED IN FIG. 14.

WHENEVER TWO RESISTORS OF THE SAME VALUE ARE CONNECTED IN PARALLEL, THE TOTAL RESISTANCE OF THE COMBINATION IS JUST ONE-HALF THAT OF EACH OF THE TWO RESISTORS. FOR EXAMPLE, WITH THE RESISTORS INDICATED IN FIG. 14, WHERE EACH HAS A VALUE OF 50 OHMS, THE COMBINED RESISTANCE OF THE TWO WILL BE ONE-HALF OF 50 OHMS, OR 25 OHMS.

IN CASE THAT TWO RESISTORS OF DIFFERENT VALUES ARE CONNECTED IN PARALLEL, AS IN FIG. 15, THE TOTAL RESISTANCE OF THE COMBINATION IS CALCULATED BY DIVIDING THE PRODUCT OF THE TWO RESISTOR VALUES BY THE SUM OF THE SAME VALUES. THIS CAN BE EXPRESSED AS A FORMULA IN THE FOLLOWING MANNER: $R = \frac{R_1 \times R_2}{R_1 + R_2}$ WHEREIN R = THE TOTAL OR COMBINED RESISTANCE, AND R_1 AND R_2 ARE THE INDIVIDUAL RESISTOR VALUES.

IN THE CIRCUIT OF FIG. 15, WHERE R_1 = 12 OHMS, AND R_2 = 6 OHMS, WE CAN SUBSTITUTE THESE VALUES IN THE FORM-

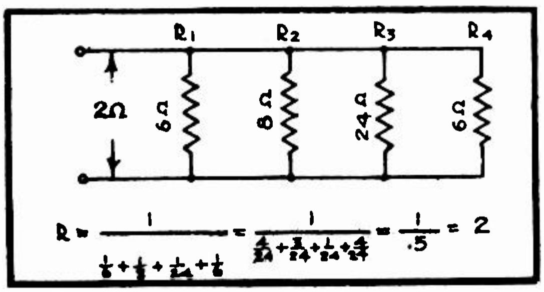

FIG. 16
A PARALLEL RESISTOR COMBINATION.

ULA: $R = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{12 \times 6}{12 + 6} = \frac{72}{18} = 4$ OHMS, WHICH IS THE TOTAL OR COMBINED RESISTANCE OF THIS CIRCUIT.

WHENEVER MORE THAN TWO RESISTORS ARE CONNECTED IN PARALLEL, SUCH AS THE RESISTOR COMBINATION INDICATED IN FIG. 16, THE TOTAL RESISTANCE OF THE COMBINATION IS CALCULATED IN TERMS OF CONDUCTANCE. THE CONDUCTANCE OF ANY RESISTANCE IS EQUAL TO THE RECIPROCAL OF THE RESISTANCE VALUE. FOR INSTANCE, THE CONDUCTANCE OF 25 OHMS IS $\frac{1}{25}$; THE CONDUCTANCE OF 30 OHMS IS $\frac{1}{30}$, ETC.

THE UNIT OF CONDUCTANCE IS MHO, OR THE WORD "OHM" SPELLED BACKWARD.

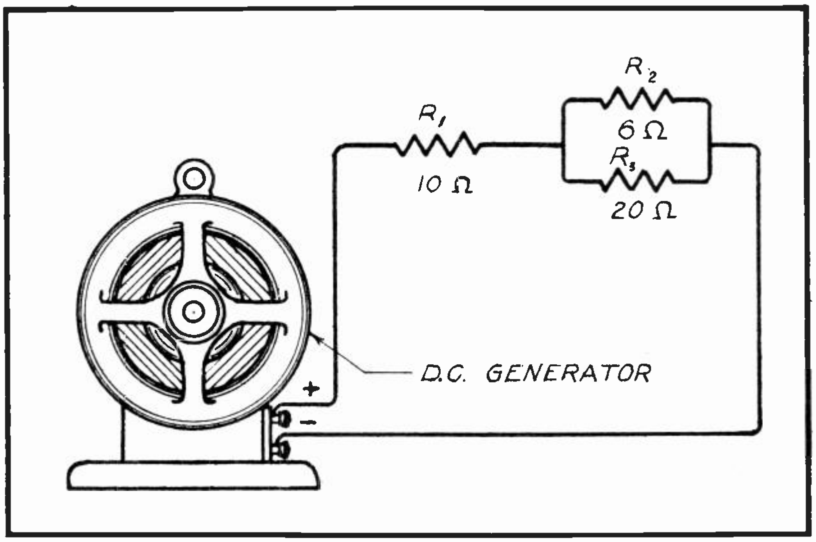

FIG. 17
THE COMBINATION CIRCUIT.

THE RULE FOR CALCULATING THE TOTAL OR COMBINED RESISTANCE OF A COMBINATION OF ANY NUMBER OF PARALLEL RESISTORS IS AS FOLLOWS: "THE CONDUCTANCE OF THE ENTIRE PARALLEL CIRCUIT IS EQUAL TO THE SUM OF THE CONDUCTANCES OF THE INDIVIDUAL BRANCHES". EXPRESSED AS A FORMULA THIS WOULD BE $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$ ETC.

APPLYING THIS FORMULA TO THE CIRCUIT INDICATED IN FIG. 16, WE HAVE: $\frac{1}{R} = \frac{1}{6} + \frac{1}{8} + \frac{1}{24} + \frac{1}{6} = \frac{4}{24} + \frac{3}{24} + \frac{1}{24} + \frac{4}{24} = \frac{12}{24} = \frac{1}{2}$. THEN, IF $\frac{1}{R} = \frac{1}{2}$, OR THE CONDUCTANCE OF THE TOTAL RESISTANCE IS EQUAL TO $\frac{1}{2}$, WE CAN CHANGE THIS CONDUCTANCE VALUE TO OHMS OR RESISTANCE BY INVERTING IT, SO THAT IT BECOMES 2 OHMS. IN OTHER WORDS, THE TOTAL OR COMBINED RESISTANCE OF THE CIRCUIT IN FIG. 16 IS 2 OHMS.

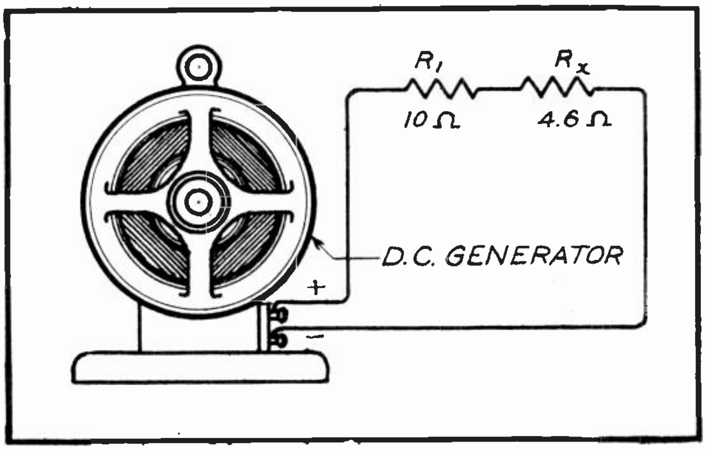

FIG. 18
THE EQUIVALENT CIRCUIT.

SERIES-PARALLEL CIRCUITS

IN FIG. 17 YOU ARE SHOWN A TYPICAL SERIES-PARALLEL COMBINATION OF RESISTAN-

CES. HERE THE RESISTANCES R_2 AND R_3 ARE CONNECTED IN PARALLEL, WHILE RESISTANCE R_1 IS CONNECTED IN SERIES WITH THE GENERATOR AND THE TWO PARALLELED RESISTORS.

THE MOST SIMPLE PROCEDURE FOR SOLVING A PROBLEM OF THIS TYPE IS FIRST TO REDUCE THE TWO PARALLEL RESISTANCES TO A SINGLE EQUIVALENT RESISTANCE. THAT IS TO SAY, IN THE CIRCUIT OF FIG. 18 THE COMBINED RESISTANCE OF R_2 AND R_3 IS FOUND AS FOLLOWS:

$$R = \frac{R_2 \times R_3}{R_2 + R_3} = \frac{6 \times 20}{6 + 20} = \frac{120}{26} = 4.6 \text{ OHMS.}$$

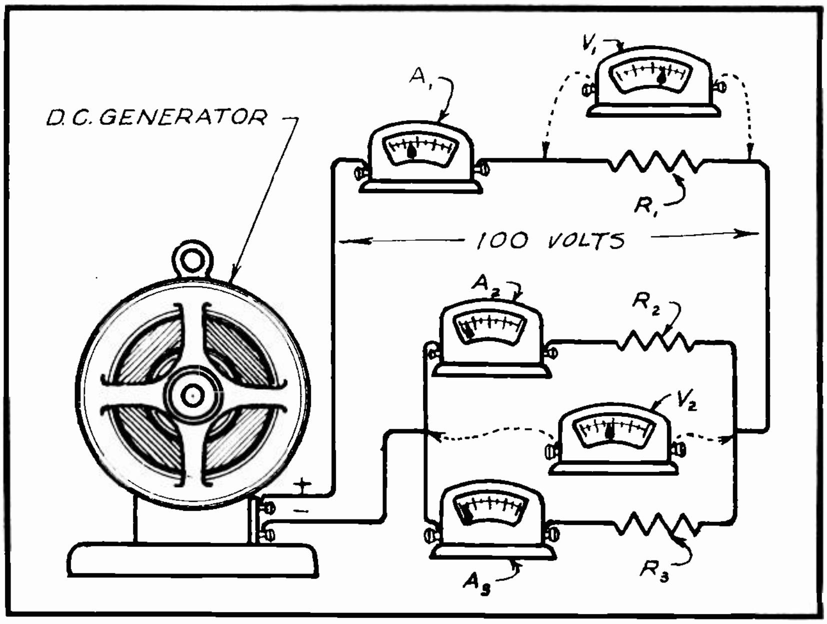

FIG. 19
CURRENT AND VOLTAGE DISTRIBUTION.

BY GIVING THIS COMBINED RESISTANCE OF R_2 AND R_3 THE IDENTIFYING SYMBOL Rx, WE CAN SUBSTITUTE IT FOR R_2 AND R_3, AND CONNECT IT IN SERIES WITH R_1 AS DONE IN THE EQUIVALENT CIRCUIT SHOWN IN FIG. 18. THE TOTAL RESISTANCE OF THE CIRCUIT IN FIG. 18 IS EQUAL TO 10 OHMS PLUS 4.6 OHMS, OR 14.6 OHMS, WHICH IS ALSO EQUAL TO THE COMBINED RESISTANCE OF THE CIRCUIT ILLUSTRATED IN FIG. 17.

THE CIRCUIT OF FIG. 17 CAN BE STILL FURTHER ANALYZED IN THE FOLLOWING MANNER: KNOWING THE TOTAL RESISTANCE OF THE CIRCUIT TO BE 14.6 OHMS, AND ASSUMING THE GENERATOR TO PRODUCE AN E.M.F. OF 100 VOLTS, WE CAN DETERMINE THE TOTAL CURRENT FLOW THROUGH THE CIRCUIT BY APPLYING OHM'S LAW IN THE FORM $I = E/R = \frac{100}{14.6} =$ 6.85 AMPS. THIS CURRENT FLOW WILL BE INDICATED BY AMMETER A_1 IN FIG. 19, WHERE WE HAVE THE SAME CIRCUIT AS IN FIG. 17 BUT WITH AMMETERS AND VOLTMETERS INSTALLED AT SUITABLE POINTS.

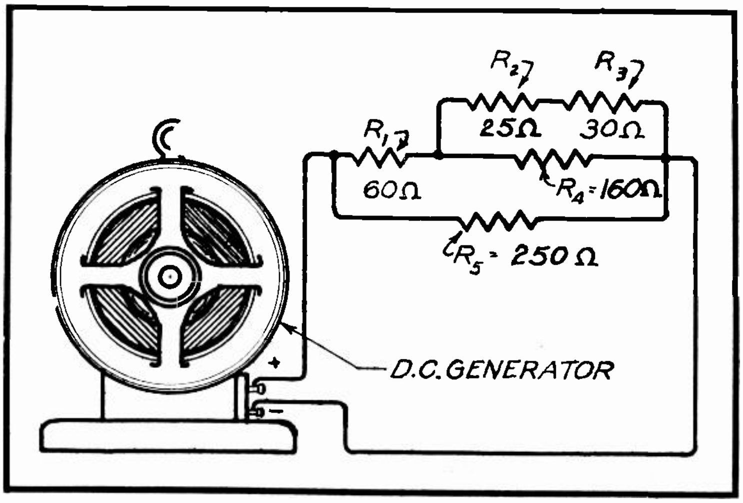

FIG. 20
THE COMPLEX CIRCUIT.

IT IS OBVIOUS THAT THIS CURRENT OF 6.85 AMPS MUST FLOW THRU R_1,

AND THEREFORE THE VOLTAGE DROP ACROSS R_1, AS INDICATED BY VOLTMETER V_1, WILL BE $E = I \times R_1 = 6.85 \times 10 = 68.5$ VOLTS.

ASSUMING THAT THE GENERATOR VOLTAGE IS 100 VOLTS, THE VOLTAGE-DROP ACROSS THE EXTREMITIES OF R_2 AND R_3, AS INDICATED BY VOLTMETER V_2, WILL BE EQUAL TO 100 MINUS 68.5, OR 31.5 VOLTS. THE CURRENT FLOW THRU R_2, AS SHOWN BY AMMETER A_2, WILL THEN BE $I = E/R_2 = \frac{31.5}{6} = 5.25$ AMPS.

SIMILARLY, THE CURRENT FLOW THROUGH R_3, AS INDICATED BY AMMETER A_3, WILL BE $I = \frac{E}{R_3} = \frac{31.5}{20} = 1.575$ AMPS.

ANALYSIS OF COMPLEX NETWORKS

IN FIG. 20 IS INDICATED A RESISTANCE NETWORK OF A RATHER COMPLEX TYPE. TO DETERMINE THE COMBINED RESISTANCE OF SUCH AN ARRANGEMENT, EACH SECTION OF THE CIRCUIT IS REDUCED TO ITS EQUIVALENT IN A MORE SIMPLE FORM.

THE SUCCESSIVE STEPS IN THE ANALYSIS OF THIS CIRCUIT ARE SHOWN IN FIG. 21. NOTICE AT A THAT SERIES RESISTANCES R_2 AND R_3 HAVE BEEN REDUCED TO AN EQUIVALENT RESISTANCE R_a OF $(25 + 30) = 55$ OHMS. AT B THE PARALLELED RESISTANCES R_a AND R_4 HAVE BEEN REDUCED TO AN EQUIVALENT RESISTANCE R_6, HAVING A VALUE OF 40.9 OHMS, AS DETERMINED BY THE

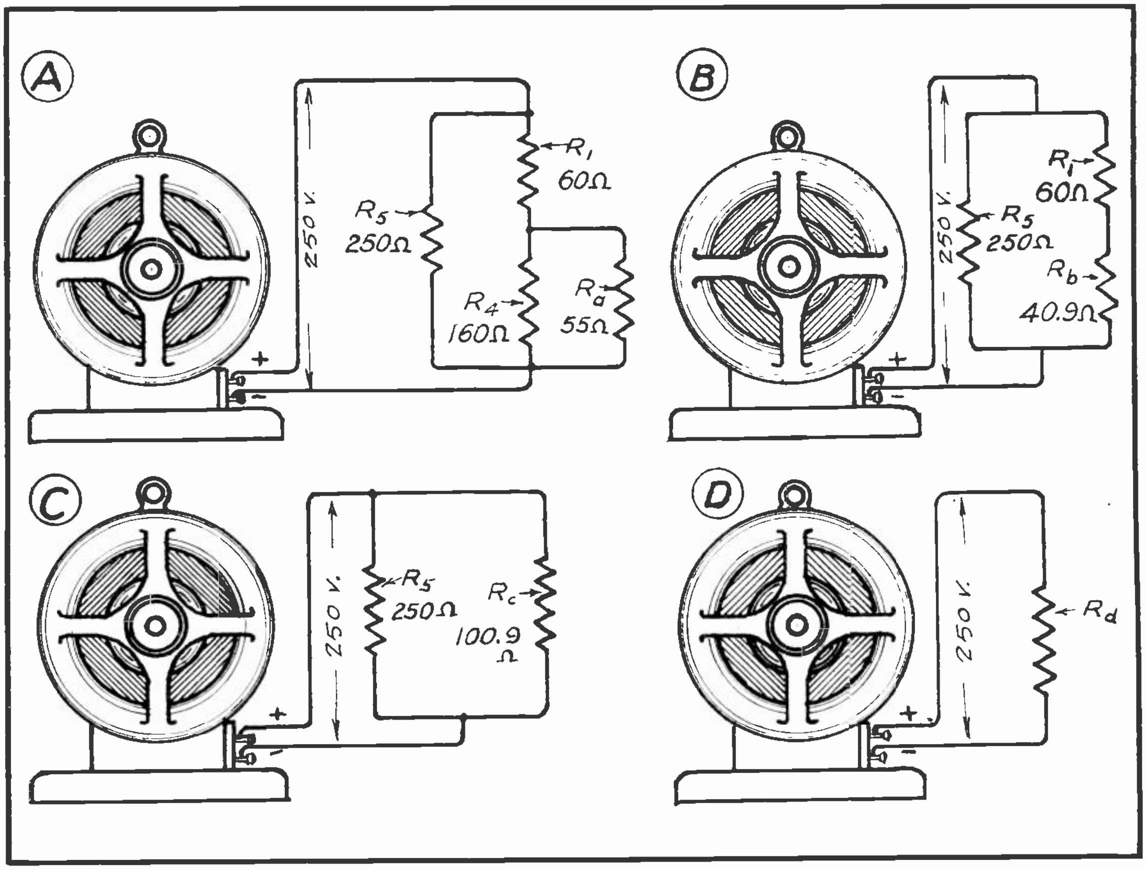

FIG. 21
THE CIRCUIT ANALYSIS.

CALCULATION $R_b = \frac{R_a \times R_4}{R_a + R_4} = \frac{55 \times 160}{55 + 160} = \frac{8800}{215} = 40.9$ OHMS. AT C THE SERIES RESISTANCES R_1 AND R_b HAVE BEEN REDUCED TO AN EQUIVALENT RESISTANCE R_c, AS FOLLOWS: $R_1 + R_6 = 60 + 40.9 = 100.9$ OHMS. FINALLY, AT D THE TWO PARALLELED RESISTANCES R_c AND R_5 HAVE BEEN REDUCED TO A SINGLE EQUIVALENT RESISTANCE R_d, WHOSE VALUE IS 7.88 OHMS, ACCORDING TO THE FOLLOWING CALCULATION: $R_d = \frac{R_c \times R_5}{R_c + R_5} = \frac{100.9 \times 250}{100.9 + 250} = \frac{25,225}{350.9} = 71.88$ OHMS. THUS, THE COMBINED RESISTANCE OF THE CIRCUIT ILLUSTRATED IN FIG. 20 AMOUNTS TO 71.88 OHMS.

TO CALCULATE THE CURRENT FLOWING THRU THE VARIOUS SECTIONS OF THIS CIRCUIT, AS WELL AS THE VOLTAGE-DROP ACROSS THE VARIOUS SECTIONS, START WITH D OF FIG. 21 AND WORK BACK TOWARD A OF THE SAME ILLUSTRATION. THAT IS TO SAY, IF THE GENERATOR E.M.F. IS 250 VOLTS, THE TOTAL CURRENT FLOW THRU THE CIRCUIT WOULD BE $I = \frac{E}{R_d} = \frac{250}{71.88} = 3.48$ AMPS. (APPROXIMATELY).

THE VOLTAGE-DROP ACROSS BOTH R_5 AND R_c, ACCORDING TO C OF FIG. 21, IS 250 VOLTS, AND THE CURRENT FLOW THRU R_5 IS $I = \frac{E}{R_5} = \frac{250}{250} = 1$ AMPERE. THE CURRENT FLOW THRU R_c IS $I = \frac{E}{R_c} = \frac{250}{100.9} = 2.47$ AMP.

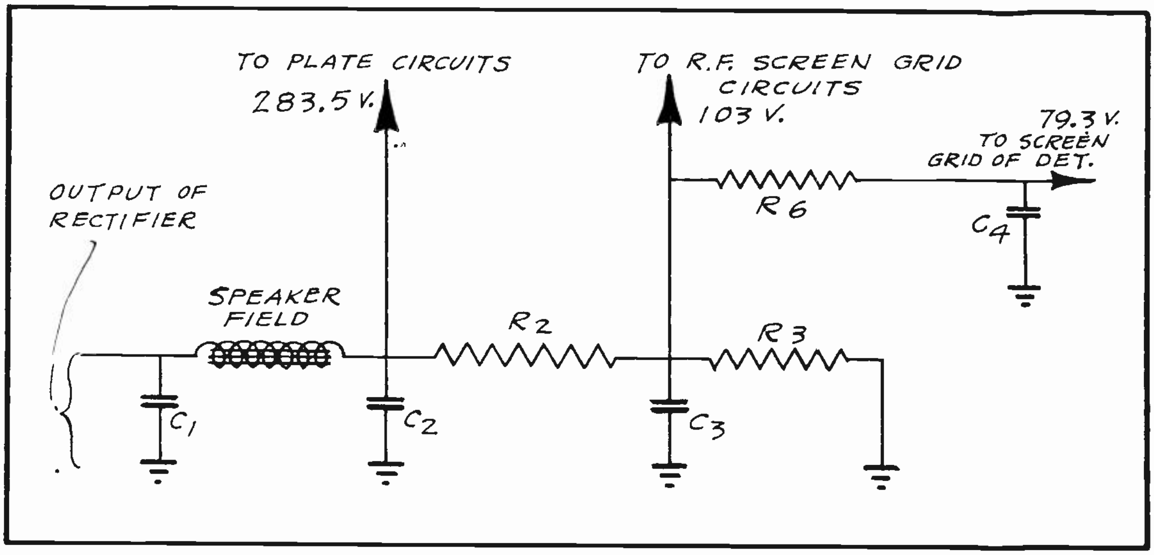

FIG. 22
THE RESISTANCE NETWORK.

ACCORDING TO B AND C OF FIG. 21, THE CURRENT FLOW THRU BOTH R_1 AND R_b OF CIRCUIT B AMOUNTS TO 2.47 AMPS, SINCE THE VALUE OF $R_c = R_1 + R_b$. THIS BEING TRUE, THE VOLTAGE-DROP DEVELOPED ACROSS R IS EQUAL TO $E = I \times R = 2.47 \times 60 = 148.20$ VOLTS. THE VOLTAGE-DROP ACROSS R_1 IS EQUAL TO 250-148.2 = 101.8 VOLTS. THIS SAME VOLTAGE IS ALSO APPLIED ACROSS THE EXTREMITIES OF THE PARALLEL RESISTANCES R_a AND R_4. THE CURRENT FLOW THROUGH R_a WILL THEN BE $I = \frac{E}{R_a} = \frac{101.8}{55} = 1.85$ AMPS, AND THE CURRENT FLOW

THROUGH R_4 WILL BE $I = \frac{E}{R_4} = \frac{101.8}{160} = .636$ AMP.

The analysis as given for Figs. 17 to 21 inclusive can be applied in the same manner, whether the voltage supply be furnished by a D.C. generator as shown, by a battery, or by the output of a B supply's filter circuit.

SELECTION OF BY-PASS CONDENSERS

Another important point to be considered is the selection of the by-pass condensers for the voltage distribution system which we have just designed. To assist you in this matter, the major part of the voltage distribution system is indicated in detail in Fig. 22, including its condensers.

For the present, we are not particularly interested in the capacity values of these condensers, as this problem is treated in detail in a later lesson.

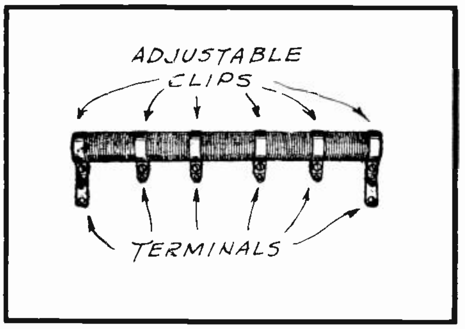

Fig. 23
Typical Voltage Divider.

Our chief concern at this time is to select these condensers from the standpoint of their rating in D.C. working voltage, to prevent their breaking down from excess voltage.

Condensers C_1 and C_2 are, of course, a part of the B power filter system, and have an E.M.F. of approximately 300 volts applied across them during normal operation of the receiver. However, when the power switch is operated to switch the receiver on or off, momentary surge voltages result, and such surges may reach values as high as 400 volts. It is therefore customary to use condensers rated at a "peak D.C. working voltage" of approximately 500 for this purpose.

Under normal conditions condenser C_3 has 103 volts applied across its extremities, and therefore a standard D.C. working voltage rating of 200 volts will give an ample margin of safety for this unit.

Condenser C_4 is subjected to 79.3 volts, and although a rating of about 150 volts would be sufficient, it is practical to use the nearest common standard rating of 200 volts.

Condensers C_5, C_6, and C_7 are used to by-pass the bias resistors R_1, R_4, and R_5, respectively, and the voltage applied across them is therefore of relatively low value. In other words, C_5 is subjected to 3 volts, C_6 to 4.3 volts, and C_7 to 16.5 volts. It can readily be seen that for these condensers, any D.C. working voltage exceeding approximately 25 volts would be sufficient.

In commercial receivers you will usually find these cathode re-

SISTOR BY-PASS CONDENSERS RATED CONSIDERABLY HIGHER(AS TO THE D.C. WORKING VOLTAGE) THAN IS TECHNICALLY NECESSARY, FOR THE REASON THAT CONDENSERS WITH RATINGS OF 200 AND 400 VOLTS ARE MANUFACTURED IN THE GREATEST NUMBER FOR GENERAL "ALL-AROUND" PURPOSE, AND THEREFORE ARE JUST AS LOW IN COST AS NON-STANDARD CONDENSERS OF LOWER VOLTAGE RATINGS.

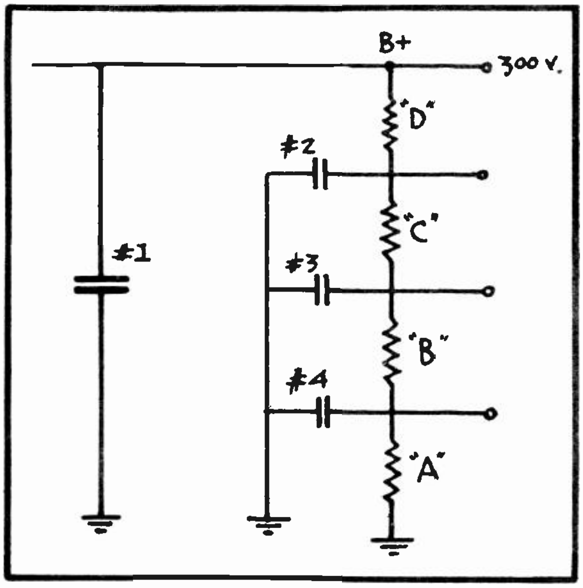

FIG. 24
VOLTAGE DIVIDER SYSTEM.

VOLTAGE DIVIDERS

VOLTAGE-DIVIDER SYSTEMS OF THE TYPE ILLUSTRATED IN FIGS.23 AND 24 CAN BE CALCULATED IN THE SAME MANNER AS ALREADY EXPLAINED FOR A COMBINATION OF INDIVIDUAL RESISTORS. FOR INSTANCE, IN THE SYSTEM SHOWN IN FIG. 24, SIMPLY STUDY THE RECEIVER CIRCUIT'S CURRENT REQUIREMENTS AND THEN DETERMINE THE CURRENT FLOW THROUGH THE VARIOUS RESISTANCE SECTIONS A,B,C, AND D. THIS DONE, DETERMINE THE REQUIRED VOLTAGE-DROP ACROSS EACH RESISTOR SECTION, AND WITH THIS DATA DETERMINED, CALCULATE THE RESISTANCE VALUE OF EACH SECTION.

IT IS THE MORE COMMON PRACTICE TO USE INDIVIDUAL RESISTORS RATHER THAN VOLTAGE DIVIDERS IN THE LATE MODEL RECEIVERS, AS BY SO DOING REPLACEMENTS CAN BE MADE AT A LATER TIME WITH GREATER EASE -- ALSO, LESS CHASSIS SPACE IS REQUIRED FOR THEIR MOUNTING. FURTHERMORE, THIS ARRANGEMENT PERMITS THE USE OF RESISTORS OF COMPARATIVELY LOW WATT RATING, BECAUSE ANY SINGLE RESISTOR DOES NOT NECESSARILY CARRY CURRENT FOR SO MANY DIFFERENT CIRCUITS. THIS FEATURE MATERIALLY REDUCES THE RESISTOR COST.

WITH THE NEXT LESSON, YOU ARE GOING TO COMMENCE YOUR ADVANCED STUDIES OF ALTERNATING CURRENT CIRCUITS. SO FAR, ALL OF THE LESSONS TREATING WITH A.C. HAVE BEEN OF A RATHER SIMPLE NATURE BUT FROM NOW ON, YOU ARE GOING TO LEARN MANY OF THE MORE IMPORTANT TECHNICAL LAWS GOVERNING SUCH CIRCUITS, AS WELL AS THE FORMULAS AND CALCULATIONS RELATED THERETO. YOU ARE GOING TO FIND THESE COMING STUDIES ESPECIALLY INTERESTING AND INSTRUCTIVE.

Answered 9/10/60

LESSON NO. 38

1. - IF FOR A CERTAIN TUBE A GRID BIAS OF 10 VOLTS IS REQUIRED, AND 5 MA. OF PLATE CURRENT FLOWS THRU THE TUBE, WHAT WILL BE THE PROPER VALUE FOR THE BIAS RESISTOR?

2. - IF THREE SCREEN GRID TUBES EACH PASS 8 MA., INCLUDING BOTH THE PLATE CURRENT AND SCREEN CURRENT, AND ALL THREE TUBES USE A COMMON BIAS RESISTOR ACROSS WHICH 3 VOLTS MUST BE DEVELOPED, WHAT WILL BE THE CORRECT VALUE OF BIAS RESISTOR TO USE?

3. - IF THROUGH A CERTAIN SECTION OF A VOLTAGE DIVIDER SYSTEM, A BLEEDER CURRENT OF 10 MA. IS FLOWING, IN ADDITION TO 5 MA. OF PLATE CURRENT FOR A TUBE, AND A VOLTAGE DROP OF 75 VOLTS IS TO BE DEVELOPED ACROSS THIS RESISTOR SECTION, WHAT WILL BE THE REQUIRED RESISTANCE VALUE OF THIS SECTION?

4. - A CERTAIN 2000 OHM RESISTOR CARRIES A CURRENT OF 65 MA. HOW MUCH WATTAGE WILL BE PRODUCED?

5. - WHY IS IT ADVISABLE TO SELECT RESISTORS OF GREATER WATT RATING THAN ACTUALLY REQUIRED ACCORDING TO WATT'S LAW?

6. - A 200 OHM AND A 400 OHM RESISTOR ARE CONNECTED IN PARALLEL. WHAT IS THE TOTAL RESISTANCE OF THIS COMBINATION?

7. - FOUR RESISTORS HAVING VALUES OF 10; 30; 15 AND 60 OHMS ARE ALL CONNECTED IN PARALLEL. WHAT IS THE TOTAL RESISTANCE OF THIS COMBINATION?

8. - WHY IS IT SO IMPORTANT TO CONSIDER THE D.C. WORKING VOLTAGE OF BYPASS CONDENSERS?

9. - A CERTAIN TUBE DRAWS A PLATE CURRENT OF 5 MA. WITH AN APPLIED PLATE VOLTAGE OF 150 VOLTS AND A GRID BIAS OF 9 VOLTS. AN A.F. CHOKE HAVING A D.C. RESISTANCE OF 1000 OHMS IS CONNECTED IN ITS PLATE CIRCUIT. WHAT "B" VOLTAGE MUST BE FURNISHED THIS CIRCUIT SO THAT THE EFFECTIVE PLATE VOLTAGE MAY BE 150 VOLTS?

10. - EXPLAIN THE GENERAL PROCEDURE WHICH YOU WOULD FOLLOW TO DESIGN A RESISTANCE NETWORK FOR VOLTAGE DISTRIBUTION IN A CONVENTIONAL RECEIVER.

DEAR STUDENT—

Practical Training means the acquisition of Technical information and facts, and the learning how to apply them in a useful manner.

In order to acquire knowledge we must use our brain. Our brain, like our body, only grows and develops when properly used.

When we stop using any part of our body it starves and dies. When we fail to use our brain cells they decay and die of starvation.

Let's learn how to use intelligently our natural abilities, talents, and gifts, and apply them efficiently to our task at hand.

JAR

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LESSON NO. 39

• THE ESSENTIALS OF A.C. CIRCUITS •

YOU HAVE BEEN MAKING SPLENDID PROGRESS IN YOUR RADIO STUDIES AND ARE TO BE CONGRATULATED UPON THE CONSCIENTIOUS EFFORT WHICH YOU ARE SHOWING IN ORDER TO PREPARE YOURSELF TO BECOME A THOROUGHLY TRAINED RADIO EXPERT. IT TAKES COMPLETE TRAINING NOWADAYS FOR A MAN TO BE A SUCCESS IN THIS LINE OF WORK AND THIS IS THE ONE BIG REASON WHY RADIO WAGES ARE HIGHER AND WHY YOU WILL HAVE LESS COMPETITION TO MEET THAN IN THOSE FIELDS WHERE TRAINING IS NOT SO ESSENTIAL.

IT IS OUR EARNEST DESIRE TO MAKE YOU CAPABLE OF HOLDING DOWN HIGH CLASS RADIO JOBS, WHERE YOUR EARNING POWER WILL BE STILL GREATER AND FOR THIS REASON WE ARE SEEING TO IT THAT YOU RECEIVE COMPLETE INSTRUCTIONS ABOUT THE TECHNICAL MATTERS CONCERNING THIS WORK IN ADDITION TO THE PRACTICAL CONSTRUCTION SIDE OF THE SUBJECT. REMEMBER, THAT ALL OF THIS TRAINING, WHEN TAKEN TOGETHER, IS THE TYPE OF TRAINING THAT WILL LIFT YOU ABOVE THE AVERAGE, WHERE YOU WILL BE IN A POSITION TO DIRECT THE WORK OF OTHERS RATHER THAN BEING THE MAN WHO MUST BE CONTENT TO PUT SOMEONE ELSE'S IDEAS INTO ACTION.

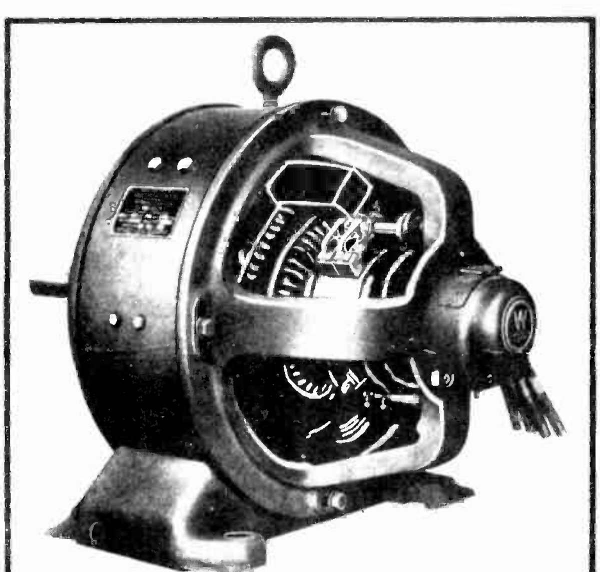

FIG. 1
An A.C. Generator.

AS YOU WERE TOLD BEFORE, YOU ARE AT THIS TIME ENTERING A VERY IMPORTANT PART OF YOUR TRAINING, FOR YOU ARE NOW LEARNING THE FUNDAMENTAL PRINCIPLES UPON WHICH THE DESIGNING OF RADIO EQUIPMENT IS BASED. IN THIS WORK YOU WILL LEARN HOW TO DETERMINE THE NUMBER OF TURNS TO WIND ON AN R.F. TRANSFORMER SO THAT IT WILL TUNE WITH A CERTAIN CONDENSER OVER ANY DESIRED WAVE BAND; YOU WILL LEARN HOW TO DESIGN AND CONSTRUCT AMPLIFIERS, POWER TRANSFORMERS; FIL-

TER SYSTEMS ETC. AND THIS KIND OF KNOWLEDGE IS GOING TO MAKE YOU A VALUABLE MAN -- THE TYPE OF MAN WHO IS IN DEMAND.

THERE ARE A FEW IMPORTANT BASIC FACTS WITH WHICH YOU MUST FIRST BECOME FAMILIAR BEFORE CONTINUING WITH THIS ADVANCED WORK AND WE SHALL COMMENCE IMMEDIATELY IN GETTING THESE FACTS FIRMLY IMBEDDED IN YOUR MIND. FOR THE PRESENT, WE ARE GOING TO DEAL WITH A.C. CIRCUITS ENTIRELY AND WITH MANY OF THE POINTS TO BE CONSIDERED, YOU ARE TO A CERTAIN EXTENT ALREADY FAMILIAR BUT YOU ARE GOING TO LEARN MANY NEW AND INTERESTING ELECTRICAL TERMS WHICH AS YET ARE PROBABLY UNKNOWN TO YOU.

IN ORDER FOR YOU TO BE ABLE TO GRASP EACH IMPORTANT POINT AS WE CONTINUE WITH THIS DISCUSSION, IT IS NECESSARY THAT YOU BE THOROUGHLY FAMILIAR WITH THE TERM "DEGREE". THEREFORE, WE SHALL CLEAR YOU UP ON THIS MATTER IMMEDIATELY.

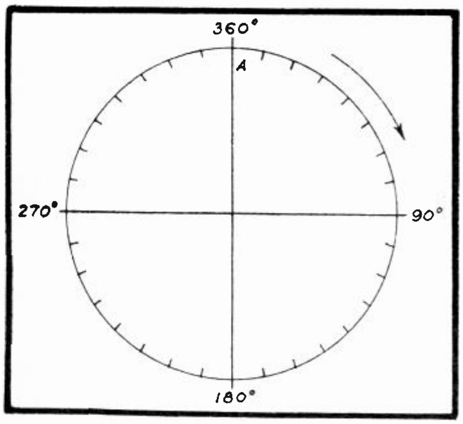

FIG. 2
The Circle.

THE DEGREE

NOW IN FIG. 2, YOU WILL FIND A CIRCLE, WHICH HAS BEEN DIVIDED INTO MANY EQUAL PARTS. THE DISTANCE AROUND THIS CIRCLE OR THE CIRCLE'S BORDER LINE, IF YOU WANT TO CONSIDER IT AS SUCH, IS CALLED THE CIRCUMFERENCE OF THE CIRCLE. SHOULD YOU DIVIDE THE CIRCUMFERENCE OF THIS CIRCLE, OR THE CIRCUMFERENCE OF ANY SIZE CIRCLE FOR THAT MATTER, INTO 360 EQUAL PARTS, THEN EACH OF THESE 360 EQUAL PARTS WOULD BE CALLED A "DEGREE".

BY PLACING THE POINT OF YOUR PENCIL ON THE CIRCUMFERENCE OF THIS CIRCLE AT "A" IN FIG. 2 AND TRACING THE CIRCUMFERENCE WITH IT IN THE DIRECTION INDICATED BY THE ARROW, THEN BY THE TIME YOUR PENCIL POINT TRAVELLED ONE QUARTER OF THE DISTANCE AROUND THE CIRCLE'S CIRCUMFERENCE, IT WOULD HAVE TRAVELLED A DISTANCE OF 90°. THE DISTANCE FROM POINT "A" TO ANOTHER POINT HALF-WAY AROUND THE CIRCUMFERENCE WOULD COMPLETE A DISTANCE OF 180°. TRAVELING FROM POINT "A" TO ANOTHER POINT 3/4 OF THE WAY AROUND THE CIRCUMFERENCE WOULD CALL FOR A TRAVERSED DISTANCE OF 270° AND TO MAKE A ROUND TRIP FROM POINT "A" AND BACK TO POINT "A" WOULD REQUIRE YOUR PENCIL TO TRAVEL A DISTANCE OF 360° ETC.

REMEMBER NOW. - IN ANY CIRCLE, IRRESPECTIVE OF ITS SIZE, THERE ARE 360° AND 1/4 OF THE DISTANCE AROUND ITS CIRCUMFERENCE IS EQUAL TO 90°; 1/2 THE DISTANCE AROUND THE CIRCUMFERENCE IS EQUAL TO 180°; 3/4 THE DISTANCE AROUND IS EQUAL TO 270°; ALL OF THE WAY AROUND IS EQUAL TO 360°: 1/8 OF THE WAY AROUND IS EQUAL TO 45° ETC. THE SMALL "ZERO" TO THE UPPER RIGHT OF THE NUMBER DENOTES DEGREES.

REPRESENTING DEGREES ALONG A STRAIGHT LINE

NOW SUPPOSE THAT WE SHOULD TAKE OUR CIRCLE OF FIG. 2 AND LAY OFF THE CIRCUMFERENCIAL DISTANCE AS A STRAIGHT LINE. THE VARIOUS DEGREES COULD THEN BE ILLUSTRATED ALONG THIS STRAIGHT LINE AS SHOWN YOU IN FIG. 3. IN OTHER WORDS, THE LENGTH OF THIS STRAIGHT LINE IS EQUAL TO THE CIRCUMFERENCE OR DISTANCE AROUND THE CIRCLE. THE VARIOUS DEGREE MARKS CAN THEN BE REPRESENTED ALONG THIS LINE AS SHOWN AND HAVE EXACTLY THE SAME MEANING

AS THOUGH PICTURED ON THE CIRCLE. YOU WILL FIND THIS PRACTICE CARRIED OUT A GREAT DEAL IN TECHNICAL ARTICLES ETC. AND IT IS ADVISABLE THAT YOU BECOME THOROUGHLY FAMILIAR WITH THIS SYSTEM OF REPRESENTING DEGREES. IN FACT, WE ARE ALREADY GOING TO PUT IT TO PRACTICAL USE IN THIS LESSON.

GENERATING AN A.C. VOLTAGE

SINCE WE ARE GOING TO DEAL WITH ALTERNATING CURRENT CIRCUITS IN THIS LESSON, IT IS ADVISABLE THAT BEFORE GOING ANY FARTHER, YOU FIRST BECOME FAMILIAR WITH THE METHOD WHEREBY A.C. VOLTAGES ARE PRODUCED BY MEANS OF A GENERATOR.

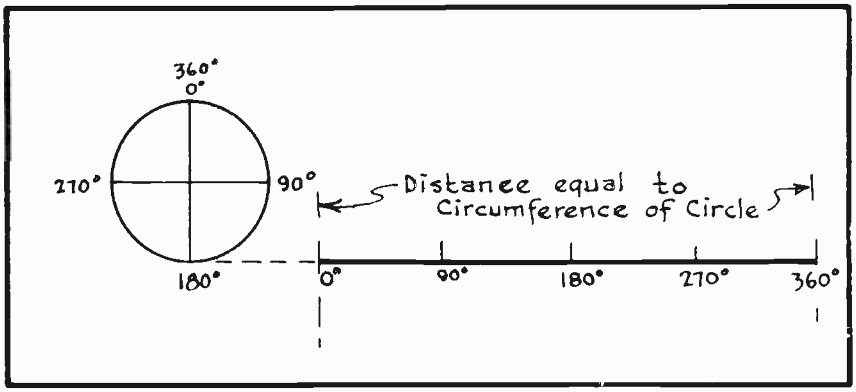

FIG. 3

Representing Degrees Along A Straight Line.

THE FIRST IMPORTANT POINT FOR YOU TO REMEMBER REGARDING THIS MATTER IS THAT ALL GENERATORS DEVELOPE A VOLTAGE OR E.M.F. (ELECTROMOTIVE FORCE), THROUGH THE ACT OF A CONDUCTOR, CUTTING MAGNETIC LINES OF FORCE. THIS IMPORTANT PRINCIPLE IS ILLUSTRATED IN FIG. 4 AND THE FOLLOWING EXPLANATION WILL AID YOU IN SEEING JUST HOW THIS IS ACCOMPLISHED.

UPON CAREFUL INSPECTION OF FIG. 4, YOU WILL OBSERVE THAT HERE WE HAVE A COPPER WIRE LOCATED BETWEEN A NORTH AND SOUTH POLE OF TWO MAGNETS, SO THAT IT IS COMPLETELY SURROUNDED BY THE MAGNETIC FIELD OR LINES OF FORCE, WHICH ARE PRODUCED BY THE MAGNETS. NOW THEN, IF WE SHOULD BY SOME MECHANICAL MEANS FORCE THIS WIRE TO MOVE THROUGH THIS MAGNETIC FIELD IN AN UPWARD DIRECTION, AS INDICATED BY THE ARROW, IT IS OBVIOUS THAT THE WIRE WILL AT THIS TIME BE CUTTING LINES OF FORCE.

THIS ACTION CAUSES A VOLTAGE TO BE DEVELOPED OR GENERATED ACROSS THE ENDS OF THE COPPER WIRE AND IF THE CIRCUIT OF THIS WIRE IS COMPLETED BY CONNECTING ITS ENDS TOGETHER, THIS GENERATED VOLTAGE WILL BE CAPABLE OF FORCING AN ELECTRIC CURRENT TO FLOW THROUGH THE COPPER WIRE. IN OTHER WORDS, THIS VOLTAGE IS GENERATED IN THE COPPER WIRE THROUGH THE ACT OF INDUCTION AND BECAUSE OF THIS FACT, WE REFER TO THE WIRE CUTTING THE LINES OF FORCE AS BEING THE INDUCTOR.

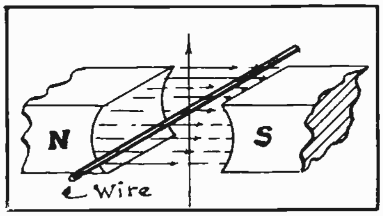

FIG. 4

Cutting Lines of Force.

SHOULD THE INDUCTOR IN FIG. 4 AGAIN BE MOVED THROUGH THIS SAME MAGNETIC FIELD BUT IN A DOWNWARD DIRECTION, YOU WOULD FIND THAT A VOLTAGE WOULD ONCE MORE BE GENERATED, ONLY THAT AT THIS TIME, THE POLARITY OF THE INDUCED VOLTAGE WOULD BE REVERSED. THE RESULT WOULD BE THAT IF THE CIRCUIT SHOULD BE COMPLETED BY CONNECTING THE ENDS OF THE WIRE TOGETHER, THIS PRESENT INDUCED VOLTAGE WOULD CAUSE A CURRENT TO FLOW THROUGH IT IN A DIRECTION OPPOSITE TO THAT AS

YOU FOUND IT WHEN MOVING THE INDUCTOR UPWARDS.

IN OTHER WORDS, IT IS APPARENT THAT BY MOVING A CONDUCTOR, WHICH HAS A COMPLETE CIRCUIT, RAPIDLY UP AND DOWN WITHIN A MAGNETIC FIELD, AN ALTERNATING CURRENT WILL BE GENERATED. THIS IS YOUR FUNDAMENTAL OR BASIC GENERATOR PRINCIPLE AND IT IS APPLIED IN PRACTICE AS ILLUSTRATED IN FIG. 5.

THE A.C. GENERATOR

IN FIG. 5, YOU WILL NOTE THAT OUR INDUCTOR TAKES THE SHAPE OF A LOOP, INSTEAD OF A STRAIGHT WIRE AND A BRASS OR COPPER RING IS FASTENED TO EACH END OF THE LOOP AT "A" AND "B" AND WE CALL THESE RINGS COLLECTOR RINGS OR SLIP RINGS. A STATIONARY CARBON BRUSH MAKES A WIPING CONTACT WITH EACH OF THE COLLECTOR RINGS, SO THAT EVEN THOUGH THE COLLECTOR RINGS SHOULD REVOLVE, THE BRUSHES WILL EACH MAINTAIN A SLIDING CONTACT WITH ITS INDIVIDUAL COLLECTOR RING. THESE TWO BRUSHES ARE THEN CONNECTED ACROSS AN EXTERNAL CIRCUIT OR LOAD, WHICH IN THE CASE OF FIG.5 HAPPENS TO BE A LAMP.

NOW THEN, WITH THE WIRE LOOP IN THE POSITION SHOWN AT THE LEFT OF FIG.5, YOU WILL OBSERVE THAT THE SIDE OF THE LOOP MARKED 1 AND 2 IS NEXT TO THE NORTH POLE PIECE (N) AND SIDE 3 AND 4 OF THE LOOP IS UNDER THE INFLUENCE OF THE SOUTH POLE PIECE (S). WITH THIS CONDITION FIRMLY FIXED IN YOUR MIND, LET US NEXT SEE WHAT HAPPENS AS THE LOOP IS ROTATED IN A CLOCKWISE DIRECTION OR AS INDICATED BY THE ARROW OF ROTATION.

DURING THIS MOVEMENT OF THE LOOP, IT IS CLEAR THAT SIDE 1 AND 2 OF THE LOOP WILL BE CUTTING THE FIELD'S LINES OF FORCE IN AN UPWARD DIRECTION, WHILE SIDE 3 AND 4 IS AT THIS SAME TIME CUTTING THE LINES OF FORCE IN A DOWNWARD DIRECTION. THE RESULT IS THAT THE VOLTAGE INDUCED BY THIS CUTTING OF THE LINES OF FORCE WILL CAUSE A CURRENT TO FLOW THROUGH THE LOOP AND OUTER CIRCUIT IN THE DIRECTION AS INDICATED. NOTICE ESPECIALLY THAT THE GENERATED CURRENT IS AT THIS TIME FLOWING OVER THE EXTERNAL CIRCUIT FROM BRUSH "A" TOWARDS BRUSH "B".

AFTER THE WIRE LOOP HAS BEEN ROTATED ONE-HALF REVOLUTION OR 180°, IT WILL COME TO THE POSITION AS PICTURED AT THE RIGHT OF FIG. 5. AT THIS TIME, YOU WILL NOTE THAT SIDE 1 AND 2 IS NOW CUTTING LINES OF FORCE IN A DOWNWARD DIRECTION, WHILE SIDE 3 AND 4 IS CUTTING THEM IN AN UPWARD DIR-

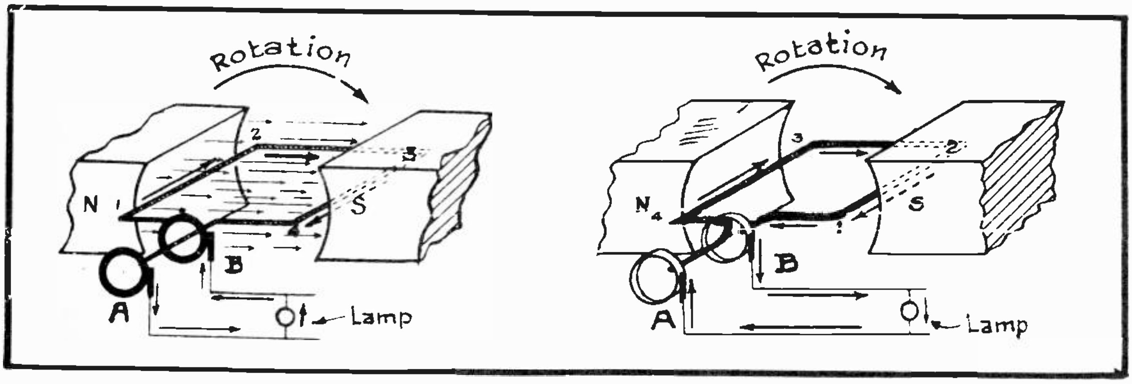

FIG. 5
Generating Alternating Current.

ECTION. IN OTHER WORDS, THE TWO SIDES OF THE LOOP ARE NOW EACH CUTTING LINES OF FORCE IN A DIRECTION OPPOSITE TO WHAT THEY DID WHILE IN THE POSITION PREVIOUSLY DESCRIBED AND THIS MEANS THAT NOW THE INDUCED VOLTAGE CAUSES CURRENT TO FLOW THROUGH THE LOOP IN AN OPPOSITE DIRECTION.

BY CAREFULLY COMPARING THE RIGHT AND LEFT ILLUSTRATIONS OF FIG. 5, YOU WILL NOTICE THAT AT THE RIGHT, THE GENERATED CURRENT IS FLOWING OVER THE EXTERNAL CIRCUIT FROM "B" TOWARDS "A" -- EXACTLY OPPOSITE TO ITS DIRECTION OF FLOW AS FOUND IN THE UNIT AT THE LEFT OF FIG. 5. IN OTHERWORDS, ALTERNATING CURRENT IS BEING GENERATED BY THIS SIMPLE DEVICE AND THE FLOW OF CURRENT WILL REVERSE ITSELF AS EACH HALF-REVOLUTION OR 180° OF THE LOOP'S TRAVEL IS COMPLETED.

IN ACTUAL PRACTICE, INSTEAD OF ONLY A SINGLE WIRE LOOP BEING REVOLVED IN THE MAGNETIC FIELD, MANY LOOPS, EACH CONSISTING OF A GREAT MANY TURNS, ARE ALL PLACED ON AN IRON CORE OR ROTOR WHICH IS PROVIDED WITH A SHAFT THROUGH ITS CENTER. THIS ENTIRE UNIT IS CALLED AN ARMATURE AND IT REVOLVES AS A BODY, SUPPORTED IN BEARINGS.

THE MECHANICAL FORCE WITH WHICH TO ROTATE THE GENERATOR ARMATURE MAY BE SUPPLIED BY AN ELECTRIC MOTOR, A GASOLINE, DIESEL OR STEAM ENGINE, BY A WATER TURBINE ETC.

NOW LET US CONTINUE AND INVESTIGATE SOME MORE IMPORTANT AND INTERESTING FACTS CONCERNING ALTERNATING CURRENTS.

THE REVOLVING ARMATURE

AT THE LEFT OF FIG. 6, WE HAVE A SIMPLE TWO-POLE A.C. GENERATOR, SHOWING ONLY A SINGLE ROTATING CONDUCTOR OR ARMATURE WIRE FOR THE SAKE OF SIMPLICITY. THIS CONDUCTOR IS GOING TO BE ROTATED THROUGH THE MAGNETIC FIELD OF THE GENERATOR IN A CLOCKWISE DIRECTION AS INDICATED BY THE SMALL ARROW HEADS.

AT THE RIGHT OF FIG. 6, WE HAVE LAID OUT AS A STRAIGHT LINE, THE

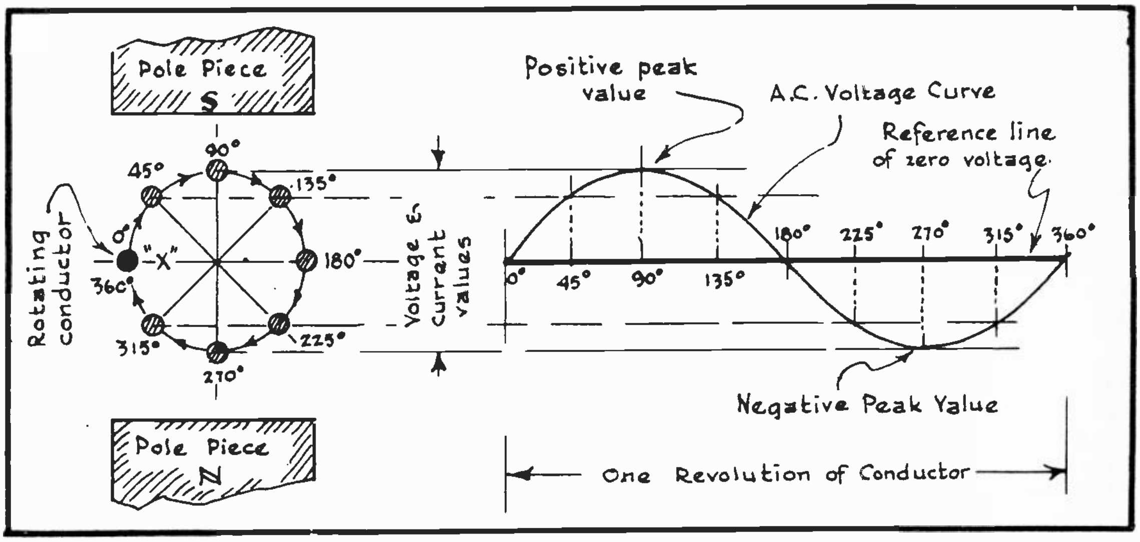

FIG. 6
Producing the "Sine Curve".

CIRCUMFERENCIAL DISTANCE TO BE TRAVELLED BY THIS CONDUCTOR, MARKING EACH 45° FROM 0° TO 360°. THE COMPLETE LENGTH OF THIS HORIZONTAL LINE WILL REPRESENT 1 REVOLUTION OF THE CONDUCTOR AS STATED ON THE DRAWING AND THIS LINE IS GOING TO REPRESENT THE REFERENCE LINE OF ZERO VOLTAGE ON THIS GRAPH.

THE SINE CURVE

NOW THEN, YOU ALREADY KNOW THAT THE LINES OF FORCE, WHICH ARE PRODUCED BY THE POLE PIECES OF THE GENERATOR, FLOW STRAIGHT ACROSS THE ARMATURE FROM THE NORTH POLE TO THE SOUTH POLE. THEREFORE, WHEN OUR ROTATING CONDUCTOR IS AT POINT "X", WHICH IS OUR STARTING OR 0° POINT, IT WILL BE MOVING PARALLEL TO THE LINES OF FORCE. CONSEQUENTLY, IT WILL NOT BE CUTTING ANY LINES OF FORCE AT THIS TIME AND FOR THIS REASON, THE GENERATED VOLTAGE AND CURRENT WILL BE ZERO. THAT IS TO SAY, NO GENERATION IS OCCURRING AT THIS INSTANT.

HOWEVER, AS THE ROTATING CONDUCTOR MOVES FROM POINT "X" TO THE 45° POINT OF ITS TRAVEL, IT WILL COMMENCE CUTTING LINES OF FORCE AND THEREFORE A VOLTAGE IS BEING GENERATED AND IT INCREASES IN VALUE RAPIDLY AS THE ROTATING CONDUCTOR COMMENCES TO CUT MORE LINES OF FORCE AT NEARLY RIGHT ANGLES. WE CAN SHOW THIS VOLTAGE INCREASE GRAPHICALLY BY MEANS OF THE CURVE AT THE RIGHT OF FIG. 6.

THE SHAPE OF THIS CURVE IS OBTAINED BY MEANS OF PROJECTION. THAT IS WE DRAW A HORIZONTAL DOTTED LINE FROM THE 45° POSITION OF THE ROTATING CONDUCTOR SO AS TO INTERSECT THE VERTICAL LINE WHICH IS DRAWN THROUGH THE 45° MARK ON THE REFERENCE LINE AT THE RIGHT. THE SLOPE OF THE FIRST PORTION OF THE CURVE MUST THEN BE SUCH AS TO EXTEND FROM THE 0° POINT OF THE REFERENCE LINE THROUGH THE POINT WHERE THE TWO LINES CROSS AT THE 45° POSITION OF THE REFERENCE LINE.

AS THE CONDUCTOR IS ROTATED FARTHER, OR FROM THE 45° MARK TO THE 90° POSITION, IT WILL CUT STILL MORE LINES OF FORCE AND STILL MORE NEARLY AT RIGHT ANGLES SO THAT THE GENERATED VOLTAGE CONTINUES TO INCREASE. FINALLY, AT THE 90° POSITION, THE MAXIMUM NUMBER OF LINES OF FORCE ARE BEING CUT AT RIGHT ANGLES AND THEREFORE, THE GENERATED VOLTAGE IS AT THIS TIME AT ITS PEAK OR MAXIMUM VALUE. THEN BY PROJECTING THE 90° POSITION OF THE CONDUCTOR OVER TO THE VERTICAL LINE, WHICH IS DRAWN THROUGH THE 90° POINT OF OUR GRAPH, WE DETERMINE THE HIGHEST OR PEAK POSITION FOR THE VOLTAGE CURVE.

DURING THE TIME THAT THE CONDUCTOR TRAVELS FROM ITS 90° POINT TO THE 180° POSITION, IT WILL BEGIN CUTTING LESS LINES OF FORCE AT A MORE NEARLY PARALLEL PLANE UNTIL THE 180° POSITION IS FINALLY REACHED. THIS MEANS THAT THE GENERATED VOLTAGE WILL BE DECREASING AT THIS TIME, SO THAT THE VOLTAGE CURVE GRADUALLY APPROACHES THE REFERENCE LINE OF ZERO VOLTAGE. THEN AS THE CONDUCTOR PASSES THROUGH ITS 180° POSITION, NO VOLTAGE AT ALL IS BEING GENERATED DUE TO THE FACT THAT THE CONDUCTOR IS MOVING PARALLEL TO LINES OF FORCE. CONSEQUENTLY, OUR VOLTAGE CURVE DROPS TO A ZERO VALUE AT THE 180° MARK.

FROM THE 180° TO THE 270° POSITION, THE REVOLVING CONDUCTOR WILL AGAIN COMMENCE CUTTING MORE AND MORE LINES OF FORCE AT AN INCREASING ANGLE BUT AT THIS TIME, THE LINES OF FORCE ARE BEING CUT IN AN OPPOSITE DIRECTION THAN BEFORE. FOR THIS REASON, THE POLARITY OF THE VOLTAGE IS NOW REVERSED

AND THE VOLTAGE INCREASE IS THEREFORE AT THIS TIME REPRESENTED BY THAT PORTION OF THE CURVE WHICH IS DRAWN BELOW THE REFERENCE LINE OF ZERO VOLTAGE. AT THE 270° POINT, OF COURSE, THE CONDUCTOR IS CUTTING A MAXIMUM NUMBER OF LINES OF FORCE AT RIGHT ANGLES, SO THAT WE HAVE OUR MAXIMUM OR NEGATIVE PEAK VOLTAGE AT THIS INSTANT.

AS THE CONDUCTOR GRADUALLY APPROACHES POSITION "X" AGAIN, SO AS TO COMPLETE 360° OF TRAVEL OR ONE COMPLETE REVOLUTION, THE GENERATED VOLTAGE BECOMES LESS UNTIL AT "X" OR THE 360° MARK, IT FINALLY REACHES A ZERO VALUE. THIS EXPLAINS WHY THE VOLTAGE CURVE AGAIN STRIKES THE REFERENCE LINE OF ZERO VOLTAGE AT THE 360° MARK.

IN THIS CASE, THE CURRENT UNDERGOES THE SAME CHANGES IN RELATIVE VALUE AS DOES THE VOLTAGE AND FOR THIS REASON, THE SAME CURVE CAN REPRESENT EITHER THE VOLTAGE OR CURRENT VARIATION IN THIS PARTICULAR EXAMPLE. AS YOU WILL NOTE FROM THE RESULTING VOLTAGE CURVE, ONE A.C. CYCLE WILL BE COMPLETED DURING THE SINGLE REVOLUTION OF THIS CONDUCTOR AND AS THE ROTATION OF THE CONDUCTOR CONTINUES, WE WILL HAVE AN ENTIRE SERIES OF CYCLES.

THIS SAME CURVE OF FIG. 6 IS ALSO FREQUENTLY SPOKEN OF AS THE SINE CURVE AND SO NOW IF YOU SHOULD HEAR OR READ OF ANY OF THESE TERMS, YOU WILL KNOW JUST EXACTLY WHAT IS MEANT BY THEM.

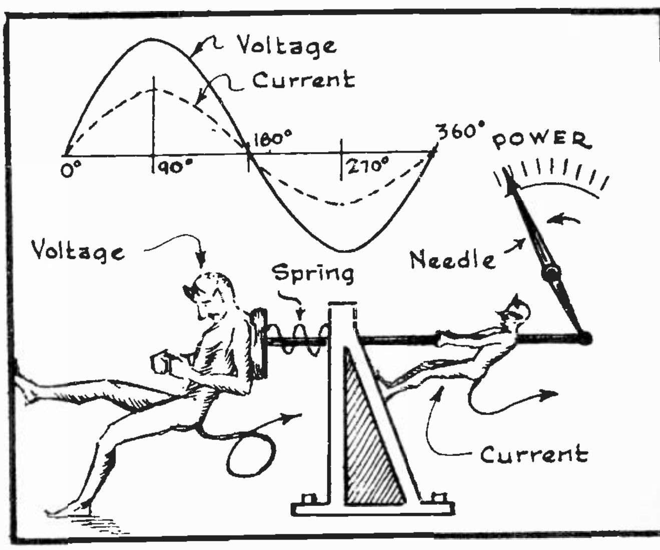

FIG. 7
Voltage and Current "In Phase".

THE DIFFERENT A.C. VALUES

AS YOU WILL OBSERVE FROM OUR VOLTAGE CURVE IN FIG. 6, THE VALUE OF THE VOLTAGE AND CURRENT IS CONTINUALLY VARYING DURING THE CYCLE AND AS A RESULT, A DIFFERENT VALUE IS OBTAINED AT EACH SUCCESSIVE INSTANT. FOR THIS REASON, WE SPEAK OF THREE DIFFERENT KINDS OF VALUES WHEN REFERRING TO ALTERNATING VOLTAGE OR CURRENT. THESE THREE VALUES ARE KNOWN AS THE PEAK VALUE, INSTANTANEOUS VALUE AND THE EFFECTIVE VALUE. FOR GENERAL PRACTICAL WORK, HOWEVER, ONLY THE PEAK AND EFFECTIVE VALUES ARE OF IMPORTANCE.

THE PEAK VALUES ARE CLEARLY ILLUSTRATED FOR YOU IN FIG. 6 AND OF COURSE THESE VALUES ARE JUST WHAT THEIR NAME INDICATES. THAT IS, THE PEAK VOLTAGE OR CURRENT IS THE MAXIMUM VOLTAGE OR CURRENT WHICH IS GENERATED AT SOME INSTANT OF THE CYCLE.

WHEN WE SPEAK OF A.C. CIRCUITS AS OPERATING AT A VOLTAGE OF 220 VOLTS, WE ARE REFERRING TO THE EFFECTIVE VOLTAGE VALUE AND NOT TO THE PEAK VALUE. THE TERM "EFFECTIVE VOLTAGE" IS ALWAYS UNDERSTOOD TO BE MEANT UNLESS WE ACTUALLY SPECIFY "PEAK VOLTAGE". THE PEAK VOLTAGE OF A 220 VOLT

CIRCUIT IS REALLY EQUAL TO APPROXIMATELY 311.17 VOLTS BECAUSE THE EFFECTIVE VOLTAGE IS APPROXIMATELY EQUAL TO .707 OF THE MAXIMUM OR PEAK VOLTAGE. IN LIKE MANNER, IF THE PEAK VOLTAGE IS 155.16 VOLTS, THEN THE EFFECTIVE VOLTAGE IS EQUAL TO APPROXIMATELY 110 VOLTS AND WE WOULD SPEAK OF THE SYSTEM AS BEING A 110 VOLT CIRCUIT. AN A.C. VOLTMETER REGISTERS THE EFFECTIVE VOLTAGE AND NOT THE PEAK VOLTAGE.

THE EFFECTIVE CURRENT OF AN A.C. CIRCUIT IS THE CURRENT WHICH HAS THE SAME HEATING EFFECT AS A DIRECT CURRENT OF SO MANY AMPERES. THE EFFECTIVE VALUE OF THE CURRENT IN AN A.C. CIRCUIT IS EQUAL TO APPROXIMATELY .707 TIMES THE MAXIMUM CURRENT OF THE CYCLE. IN OTHER WORDS, IF THE MAXIMUM CURRENT AT SOME INSTANT OF THE CYCLE IS 50 AMPERES, THEN THE EFFECTIVE CURRENT IS EQUAL TO .707 X 50 OR 35.35 AMPERES.

THE EFFECTIVE VOLTAGE THEN CAN ALSO BE CONSIDERED AS THE ALTERNATING VOLTAGE REQUIRED TO FORCE A CURRENT THRU A CIRCUIT HAVING THE SAME HEATING VALUE AS THE CURRENT WHICH IS PRODUCED BY A DIRECT VOLTAGE OF THIS SAME VALUE. THE EFFECTIVE VALUES ARE ALSO FREQUENTLY SPOKEN OF AS THE "ROOT MEAN SQUARE VALUE," WHICH IS GENERALLY ABREVIATED AS R.M.S. YOU WILL COME ACROSS THIS TERM QUITE OFTEN IN RADIO LITERATURE AND SO NOW YOU WILL ALREADY KNOW WHAT IT MEANS AND WILL HAVE NO REASON TO WONDER ABOUT IT IF YOU SHOULD FIND IT USED SOMEWHERE.

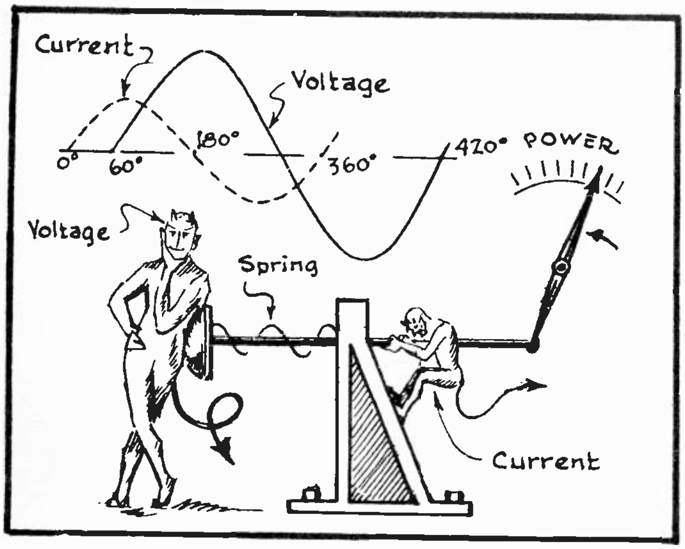

FIG. 8
Voltage and Current "out of Phase"

REMEMBER NOW, -- TO DETERMINE THE EFFECTIVE VOLTAGE IN TERMS OF THE PEAK VOLTAGE, SIMPLY MULTIPLY THE PEAK VOLTAGE BY .707. FOR INSTANCE, IF THE PEAK VOLTAGE IS 435 VOLTS, THEN THE EFFECTIVE VOLTAGE WILL BE EQUAL TO 435 X .707 OR 307.545 VOLTS. THE SAME RULE APPLIES TO CURRENT, FOR IN THIS CASE, THE EFFECTIVE CURRENT IS EQUAL TO THE PEAK CURRENT MULTIPLIED BY .707 . THAT IS TO SAY, IF THE PEAK CURRENT IS 55 AMPERES, THE EFFECTIVE CURRENT WILL BE EQUAL TO 55 X .707 OR 38.885 AMPERES.

ON THE OTHER HAND, TO DETERMINE PEAK VALUES IN TERMS OF EFFECTIVE VALUES, MULTIPLY THE EFFECTIVE VALUE BY THE CONSTANT 1.41. IN OTHER WORDS, IF THE EFFECTIVE VOLTAGE IS KNOWN TO BE 300 VOLTS, THEN THE PEAK VOLTAGE WILL BE EQUAL TO 300 X 1.41 OR 423 VOLTS. IN LIKE MANNER, IF THE EFFECTIVE CURRENT IS 30 AMPERES, THEN THE PEAK CURRENT WILL BE EQUAL TO 30 X 1.41 OR 42.3 AMPERES.

THESE RULES AS HERE GIVEN, HOWEVER, APPLY ONLY TO CIRCUITS IN WHICH THE ALTERNATING VOLTAGES AND CURRENTS ARE OF A TRUE SINE-WAVE FORM.

THE INSTANTANEOUS VALUES OF THE CURRENT OR VOLTAGE IN AN A.C. CIR-

CUIT ARE THE VALUES AT SOME PARTICULAR INSTANT OF THE CYCLE. THAT IS, THE VALUE AT THE 35° POINT OF THE CYCLE, AT THE 42° POINT ETC., BUT FOR PRACTICAL RADIO PURPOSES, YOU WILL HAVE NO USE FOR INSTANTANEOUS VALUES OF EITHER THE VOLTAGE OR CURRENT. HOWEVER, IN A LATER LESSON YOU WILL BE SHOWN HOW TO CALCULATE PROBLEMS INVOLVING INSTANTANEOUS VALUES.

THE MEANING OF "PHASE"

NOW THERE IS ANOTHER ELECTRICAL EXPRESSION WHICH YOU WILL FIND USED A GREAT DEAL RELATIVE TO A.C. CIRCUITS IN RADIO AND THIS IS THE TERM "PHASE". NO DOUBT, FIG. 7 AND FIG. 8 WILL AID YOU CONSIDERABLY IN GRASPING THE MEANING OF THIS POPULAR TERM.

IN FIG. 7, FOR INSTANCE, WE HAVE AN EXAMPLE ILLUSTRATING THE FACT THAT THE VOLTAGE AND CURRENT IN AN A.C. CIRCUIT ARE "IN PHASE". HERE WE ARE PICTURING VOLTAGE AS THE LARGE AND MORE POWERFUL DEMON WHILE THE CURRENT IS THE SMALLER BUT ACTIVE HARD WORKING LITTLE FELLOW. BOTH ARE APPLYING THEIR UTMOST EFFORTS SIMULTANEOUSLY TOWARDS COMPRESSING THE SPRING, THEREBY CAUSING THE INDICATING NEEDLE TO SWING A CONSIDERABLE DISTANCE ACROSS THE SCALE. IN OTHER WORDS, THE VOLTAGE AND CURRENT ARE BOTH IN STEP WITH EACHOTHER, WORKING IN CLOSE "TEAM WORK."

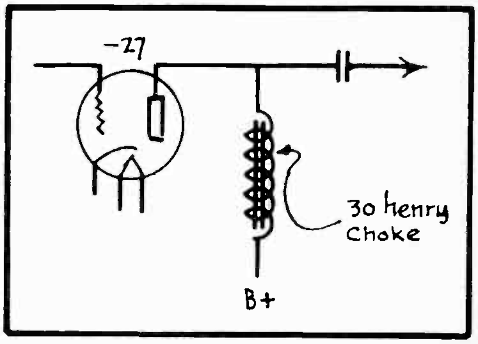

FIG. 9

Calculating Inductive Reactance.

NOW THEN, IF WE SHOULD SHOW BOTH THE VOLTAGE AND CURRENT SINE CURVES SIMULTANEOUSLY AT THIS TIME, THEY WOULD APPEAR AS ILLUSTRATED AT THE UPPER LEFT OF FIG. 7. AS YOU WILL NOTE, THE PEAK VALUES OF BOTH THE VOLTAGE AND CURRENT OCCUR AT THE SAME INSTANT AND THEY BOTH DROP TO A ZERO VALUE AT THE SAME INSTANT. THIS RELATION BETWEEN THE VOLTAGE AND CURRENT ALWAYS EXISTS WHENEVER THE VOLTAGE AND THE CURRENT ARE IN PHASE.

WHENEVER AN A.C. CIRCUIT CONTAINS RESISTANCE ALONE AND NEITHER INDUCTANCE OR CAPACITY, THEN THE VOLTAGE AND CURRENT ARE ALWAYS IN PHASE AS HERE SHOWN.

NOW IN FIG. 8, WE HAVE PICTURED A DIFFERENT CONDITION, FOR HERE VOLTAGE IS "LAYING DOWN ON THE JOB" AND DOESN'T REALLY COMMENCE WORKING AS HARD AS IT SHOULD UNTIL THE CURRENT HAS ALREADY COMMENCED TO BUILD UP. THE RESULT IS, THAT THE CURRENT REACHES ITS PEAK VALUE BEFORE THE VOLTAGE REACHES ITS PEAK VALUE. IN OTHER WORDS, THE VOLTAGE LAGS BEHIND THE CURRENT OR THE CURRENT LEADS THE VOLTAGE AND SO NATURALLY SINCE THE CURRENT AND VOLTAGE ARE NOW OUT OF STEP WITH EACHOTHER, WE USE THE ELECTRICAL EXPRESSION BY SAYING THAT THEY ARE "OUT OF PHASE".

AS YOU SHALL SEE A LITTLE LATER, THERE ARE ALSO TIMES WHERE THE VOLTAGE LEADS THE CURRENT IN AN A.C. CIRCUIT BUT IRRESPECTIVE OF WHICH OF THE TWO VALUES IS LEADING THE OTHER, THEY ARE OUT OF PHASE UNLESS INCREASING AND DECREASING IN VALUE SIMULTANEOUSLY. NOW THAT YOU UNDERSTAND WHAT IS MEANT BY THESE TWO ELECTRICAL TERMS "IN PHASE" AND "OUT OF PHASE", LET US NEXT INVESTIGATE THE MATTER OF INDUCTANCE A LITTLE MORE THOROUGHLY.

INDUCTIVE REACTANCE

IN ALL OF YOUR PRELIMINARY STUDIES, YOU LEARNED THAT AN INDUCTANCE OR COIL OFFERED AN OPPOSITION TO THE FLOW OF ALTERNATING CURRENT DUE TO THE SELF INDUCTION IN THE WINDING. YOU ALSO LEARNED THAT THE OPPOSITION OFFERED BY AN INDUCTANCE INCREASES WITH AN INCREASE IN FREQUENCY BUT NOW LET US CONSIDER THIS EFFECT IN GREATER DETAIL. TO BEGIN WITH, IT IS UNDERSTOOD THAT A STRAIGHT WIRE OFFERS A RESISTIVE EFFECT TO BOTH D.C. AND A.C. CURRENTS AND THE CONDUCTOR'S RESISTANCE IS DETERMINED BY THE MATERIAL, LENGTH, AREA AND TEMPERATURE OF THE CONDUCTOR. FURTHERMORE, YOU KNOW THAT THE CONDUCTOR'S RESISTANCE IS MEASURED IN OHMS.

SINCE A COIL OR INDUCTANCE OFFERS AN OPPOSITION TO THE FLOW OF AN A.C. CURRENT ON ACCOUNT OF ITS MAGNETIC QUALITIES, IT IS NO MORE BUT REASONABLE THAT WE ALSO MEASURE THIS TYPE OF OPPOSITION IN OHMS, BECAUSE THE EFFECT OF A GIVEN E.M.F. OF SELF INDUCTION IN IMPEDING OR RETARDING THE FLOW OF CURRENT IS EQUIVALENT TO A CERTAIN NUMBER OF OHMS RESISTANCE WHICH WOULD HAVE EXACTLY THE SAME EFFECT. NOW THE REAL ELECTRICAL NAME FOR THIS EFFECT OF SELF-INDUCTION TO OPPOSING THE FLOW OF ALTERNATING CURRENT IS CALLED INDUCTIVE REACTANCE. SO REMEMBER NOW, INDUCTIVE REACTANCE IS SIMPLY THE OPPOSITION OFFERED BY A COIL OR WINDING TO THE FLOW OF A.C. OR PULSATING D.C. CURRENTS DUE TO SELF-INDUCTION IN THE WINDING.

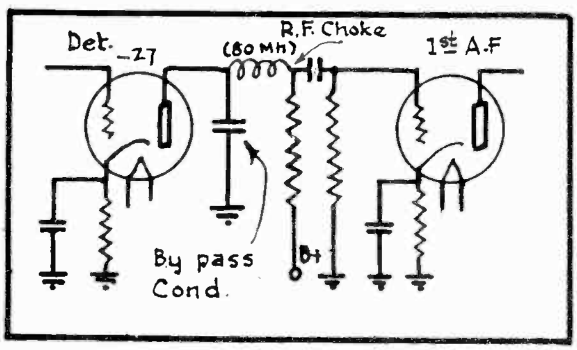

FIG. 10

Inductive Reactance of R. F. Choke.

CALCULATING INDUCTIVE REACTANCE

WE HAVE A SIMPLE FORMULA AVAILABLE FOR OUR USE, WHICH ENABLES US TO CALCULATE QUITE READILY THE INDUCTIVE REACTANCE OF ANY INDUCTANCE. TO DETERMINE THE INDUCTIVE REACTANCE OF ANY COIL, SIMPLY MULTIPLY TOGETHER 2 X 3.1416 X FREQUENCY IN CYCLES PER SECOND X THE INDUCTANCE OF THE COIL IN HENRIES. EXPRESSED AS A FORMULA WE HAVE $X_L = 2\pi f L$ WHERE X_L IS THE STANDARD SYMBOL FOR INDUCTIVE REACTANCE, π IS THE CONSTANT 3.1416, "f" IS THE FREQUENCY EXPRESSED IN CYCLES PER SECOND AND L IS THE SYMBOL FOR INDUCTANCE IN HENRIES.

SOMETIMES YOU WILL ALSO COME ACROSS THIS FORMULA WRITTEN IN THE FORM $X_L = 6.28 f L$. IN THIS CASE, THE APPROXIMATE VALUE OF π OR 3.14 HAS ALREADY BEEN DOUBLED OR MULTIPLIED BY 2 SO AS TO GIVE THE CONSTANT 6.28 IN THE LATTER FORM. OTHERWISE, BOTH FORMULAE ARE IDENTICAL AND YOU CAN USE EITHER. THE LATTER OR $X_L = 6.28 f L$ IS MOST USED FOR PRACTICAL PURPOSES BECAUSE IT REQUIRES LESS COMPUTATION AND IS SUFFICIENTLY ACCURATE EVEN THOUGH THE LAST TWO DECIMAL PLACES HAVE BEEN DROPPED FROM THE VALUE OF π.

IN FIG. 9, WE HAVE A PRACTICAL EXAMPLE FOR DETERMINING THE INDUCTIVE REACTANCE OF AN INDUCTANCE. IN THIS CASE, A 30 HENRY CHOKE OR IMPEDANCE COIL IS CONNECTED IN THE PLATE CIRCUIT OF A TYPE -27 TUBE. LET US NOW DETERMINE THE INDUCTIVE REACTANCE OF THIS CHOKE AT THE TIME THAT AUDIO

CURRENT VARIATIONS OF A 100 CYCLE FREQUENCY FLOW THROUGH IT.

OUR FORMULA FOR THIS CALCULATION IS OF COURSE $X_L = 6.28 f L$, SO OUR FIRST STEP IS TO SUBSTITUTE OUR VALUES INTO THE FORMULA. SINCE THE FREQUENCY, WITH WHICH WE ARE DEALING AT THIS PARTICULAR TIME, IS 100 CYCLES AND THE INDUCTANCE OF THE CHOKE IS 30 HENRIES, WE SIMPLY INSERT THESE VALUES FOR "f" AND "L" IN THE FORMULA. WE THEN HAVE THE EXPRESSION THAT $X_L = 6.28 \times 100 \times 30$ AND HENCE BY MULTIPLYING TOGETHER 6.28 BY 100 BY 30, WE FIND THAT THE INDUCTIVE REACTANCE FOR THIS 30 HENRY CHOKE AT 100 CYCLES IS 18,840 OHMS. AS YOU WILL NOTE, THIS CHOKE WILL OFFER A CONSIDERABLE LOAD IN THE PLATE CIRCUIT OF THIS TUBE AT 100 CYCLES IN SPITE OF THE FACT THAT THE D.C. OR OHMIC RESISTANCE OF THE WIRE MAKING UP THE CHOKE IS RELATIVELY LOW.

FOR THE SAKE OF EXPLANATION, LET US SEE WHAT HAPPENS WHEN THE FREQUENCY OF THE CURRENT PASSING THROUGH THIS SAME CHOKE IS INCREASED. FOR EXAMPLE, WE WILL ASSUME THAT AN AUDIO FREQUENCY OF 2000 CYCLES IS ACTING UPON IT AT ONE INSTANT. AT THIS TIME, WE HAVE TO SUBSTITUTE THE VALUE OF 2000 FOR "f" IN OUR FORMULA AND THE EXPRESSION THEN BECOMES $X_L = 6.28 \times 2000 \times 30$. WORKING OUT THIS CALCULATION, WE FIND THE INDUCTIVE REACTANCE FOR THIS CHOKE AT 2000 CYCLES TO BE 376,800 OHMS. THIS SHOWS YOU THAT THE INDUCTIVE REACTANCE INCREASES VERY RAPIDLY AS THE OPERATING FREQUENCY IS INCREASED.

QUITE OFTEN IN YOUR RADIO WORK, YOU WILL HAVE TO DEAL WITH COILS ETC; WHOSE INDUCTANCE IS SO SMALL THAT THE UNIT "MILLIHENRY" OR "MICROHENRY" IS USED, SUCH AS IN THE CASE OF R.F. CHOKES AND R.F. TRANSFORMER WINDINGS. IN THIS INSTANCE, YOU WILL HAVE TO BE CAREFUL WHEN CALCULATING THE COIL'S INDUCTIVE REACTANCE WITH OUR FORMULA, FOR THE VALUE OF THE INDUCTANCE WILL FIRST HAVE TO BE CHANGED TO HENRIES. THAT IS, IF THE COIL'S INDUCTANCE IS GIVEN AS 80 MILLIHENRIES, THIS IS, EQUIVALENT TO .080 HENRIES. IF THE INDUCTANCE IS GIVEN AS 100 MICROHENRIES, THEN THIS IS EQUIVALENT TO .0001 HENRIES ETC.

TO BE SURE THAT YOU UNDERSTAND HOW TO TACKLE A PROBLEM WHERE VALUES MUST FIRST BE CHANGED TO DIFFERENT UNITS, LET US WORK OUT THE PROBLEM ILLUSTRATED IN FIG. 10. HERE WE HAVE AN 80 MILLIHENRY CHOKE CONNECTED IN THE PLATE CIRCUIT OF A TYPE -27 DETECTOR TUBE. NOW LET US DETERMINE THE INDUCTIVE REACTANCE OR THE OPPOSITION OFFERED BY THIS CHOKE TO A RADIO FREQUENCY OF 500 KC.

OUR FIRST STEP IS TO CHANGE THE VALUE OF THE CHOKE FROM 80 MILLIHENRIES TO ITS EQUIVALENT OF .080 HENRIES. THE RADIO FREQUENCY OF 500 KC. MUST NEXT BE CHANGED TO ITS EQUIVALENT OF 500,000 CYCLES. THIS DONE, WE ARE NOW READY TO SUBSTITUTE THESE NEW VALUES INTO OUR FORMULA OF INDUCTIVE REACTANCE. THAT IS, $X_L = 6.28 f L$ OR $X_L = 6.28 \times 500{,}000 \times .080 = 251{,}200$ OHMS.

AS YOU WILL NOTE FROM THE RESULTS OF THIS CALCULATION, AN ORDINARY R.F. CHOKE OFFERS A GREAT DEAL OF OPPOSITION OR INDUCTIVE REACTANCE TO RADIO FREQUENCIES.

ANOTHER GROUP OF HANDY FORMULAS FOR EASY DETERMINATION OF THE INDUCTIVE REACTANCE OF A GIVEN INDUCTANCE ARE AS FOLLOWS:

IF THE FREQUENCY IS GIVEN IN CYCLES AND THE INDUCTANCE IN HENRIES,

THEN THE REACTANCE IN OHMS $= \frac{\text{CYCLES} \times \text{HENRIES} \times 1000}{159}$. THAT IS, MULTIPLY TOGETHER THE FREQUENCY IN CYCLES, INDUCTANCE IN HENRIES AND MULTIPLY THIS PRODUCT BY 1000. FINALLY, DIVIDE THIS RESULT BY 159 AND THE ANSWER WILL BE THE REACTANCE IN OHMS.

IF THE FREQUENCY IS GIVEN IN KILOCYCLES AND THE INDUCTANCE IN MILLIHENRIES, THEN THE INDUCTIVE REACTANCE IN OHMS IS EXPRESSED AS FOLLOWS: $\frac{\text{KILOCYCLES} \times \text{MILLIHENRIES} \times 1000}{159}$. THESE ARE ONLY APPROXIMATE FORMLAE BUT OFFER SUFFICIENTLY ACCURATE RESULTS FOR ORDINARY PRACTICAL PURPOSES.

IN THIS LESSON, YOU HAVE RECEIVED CONSIDERABLE INFORMATION OF IMPORTANCE RELATIVE TO A.C. CIRCUITS AND YOU ARE URGED TO STUDY THIS LESSON VERY CAREFULLY. WE SHALL CONTINUE OUR INVESTIGATION OF MANY MORE INTERESTING PHENOMENA CONCERNING ALTERNATING CURRENTS IN THE FOLLOWING LESSONS. THEN WHEN YOU HAVE MASTERED THE COMING LESSONS. YOU ARE GOING TO ENTER THE MOST FASCINATING PORTION OF YOUR RADIO TRAINING, NAMELY THAT OF DESIGNING AND CONSTRUCTING RADIO EQUIPMENT SUCH AS R.F. COILS, POWER TRANSFORMERS, COMPLETE POWER PACKS ETC.

Examination Questions

ans 9/10 WP

1. – EXPLAIN HOW A GENERATOR PRODUCES AN ALTERNATING VOLTAGE.

2. – DESCRIBE THE "SINE CURVE".

3. – WHAT DO WE MEAN BY THE TERMS PEAK VALUE, INSTANTANEOUS VALUE, AND EFFECTIVE VALUE?

4. – IF THE PEAK VOLTAGE OF A CERTAIN A.C. CIRCUIT IS 600 VOLTS, WHAT IS THE EFFECTIVE VOLTAGE?

5. – IF THE EFFECTIVE VOLTAGE OF A CERTAIN A.C. CIRCUIT IS 256 VOLTS, WHAT IS THE PEAK VOLTAGE?

6. – WHAT DO WE MEAN BY THE EXPRESSIONS "IN PHASE" AND "OUT OF PHASE" WITH RESPECT TO A.C. CIRCUITS?

7. – WHAT IS MEANT BY THE TERM INDUCTIVE REACTANCE?

8. – A CERTAIN A.F. CHOKE HAS AN INDUCTANCE OF 30 HENRIES. WHAT WILL BE ITS INDUCTIVE REACTANCE TOWARDS A.F. CURRENTS HAVING A FREQUENCY OF 1500 CYCLES PER SECOND?

9. – WHAT INDUCTIVE REACTANCE WILL AN 85 MILLIHENRY R.F. CHOKE OFFER TOWARDS RADIO FREQUENCY CURRENTS OF 600 Kc?

10. – WHENEVER AN A.C. CIRCUIT CONTAINS RESISTANCE ALONE AND NO INDUCTANCE OR CAPACITY, WILL THE VOLTAGE AND CURRENT BE IN PHASE OR OUT OF PHASE?

RADIO - TELEVISION

Practical Training

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J. A. ROSENKRANZ, Pres.

LESSON NO. 40

INDUCTANCE-CONDENSER CALCULATIONS IN A.C. CIRCUITS IMPEDANCE

ONE OF THE MOST IMPORTANT THINGS ABOUT A THOROUGH RADIO TRAINING IS THAT IT PUTS YOU INTO A POSITION WHERE YOU HAVE A LARGE VARIETY OF JOBS TO CHOOSE FROM. IN OTHER WORDS, YOU CAN BECOME AN EXPERT RADIO SERVICE ENGINEER, A RADIO DEALER, A TESTER FOR A RADIO MANUFACTURING CONCERN SUCH AS THOSE MEN SHOWN IN FIG. 1, A DESIGNER ETC.

THIS FACT, OF COURSE, MEANS A GREATER CHANCE FOR EMPLOYMENT IN THE ACTIVE RADIO FIELD AND YOU WILL FIND THAT EACH OF ITS BRANCHES OFFERS YOU MANY OPPORTUNITIES WITH GOOD SALARIES THAT ARE DUE TO SUCH MEN AS YOU, WHO ARE EQUIPPED WITH THOROUGH TRAINING.

FIG. 1
Testing Radio Equipment.

SET YOURSELF A HIGH GOAL AND KEEP THIS GOAL CONSTANTLY IN MIND, SO THAT YOU WILL BE INSPIRED TO STUDY HARD IN ORDER TO ATTAIN THE SUCCESS THAT IS BOUND TO COME TO YOU. REMEMBER, THAT EACH LESSON IS NOTHING MORE THAN A STEPPING STONE, WHICH IS BRINGING YOU CLOSER AND CLOSER TO THAT GOOD RADIO JOB.

NOW LET US CONTINUE WITH THE SECOND PORTION OF OUR STUDY, WHICH CONCERNS THE ESSENTIALS OF A.C. CIRCUITS.

THE PHASE RELATION IN INDUCTIVE CIRCUITS

FIRST, WE SHALL INVESTIGATE THE MATTER OF THE PHASE RELATION IN A CIRCUIT CONTAINING INDUCTANCE ALONE AND NO RESISTANCE OR CAPACITY. OF COURSE, SUCH A CONDITION IS REALLY IMPOSSIBLE IN A PRACTICAL SENSE BUT NEVERTHELESS, AN UNDERSTANDING OF IT WILL AID YOU IN MORE READILY UNDERSTANDING THE PHASE RELATION IN INDUCTIVE CIRCUITS THAN IF WE SHOULD ALREADY CONSIDER A COMPLEX CON-

DITION AS REALLY EXISTS IN ACTUAL PRACTICE.

THE VOLTAGE AND CURRENT FOR A PURE INDUCTIVE CIRCUIT ARE SHOWN TOGETHER IN FIG. 2. HERE YOU WILL NOTE THAT THE VOLTAGE COMMENCES TO INCREASE RAPIDLY BEFORE THE CURRENT ACTUALLY STARTS TO FLOW THROUGH THE CIRCUIT. THIS PECULIAR EFFECT IS DUE TO THE COUNTER ELECTROMOTIVE FORCE DEVELOPED BY THE INDUCTANCE AS A VOLTAGE IS FIRST APPLIED ACROSS IT. THE VOLTAGE, YOU WILL NOTE IN FIG. 2, REACHES ITS PEAK VALUE AT 90° AND AT THIS SAME INSTANT, THE CURRENT JUST STARTS ITS INCREASE IN VALUE. IN OTHER WORDS, THE CURRENT LAGS BEHIND THE VOLTAGE BY 90°, OR THE VOLTAGE LEADS THE CURRENT BY 90°. CONTINUALLY, THE CURRENT REACHES ITS PEAK VALUE WHEN THE VOLTAGE IS ZERO AND THE VOLTAGE REACHES ITS PEAK VALUE WHEN THE CURRENT IS AT ZERO. THUS WE CONCLUDE, THAT IN CIRCUITS CONTAINING INDUCTANCE ALONE, THE VOLTAGE AND CURRENT ARE 90° OUT OF PHASE, WITH THE VOLTAGE LEADING THE CURRENT.

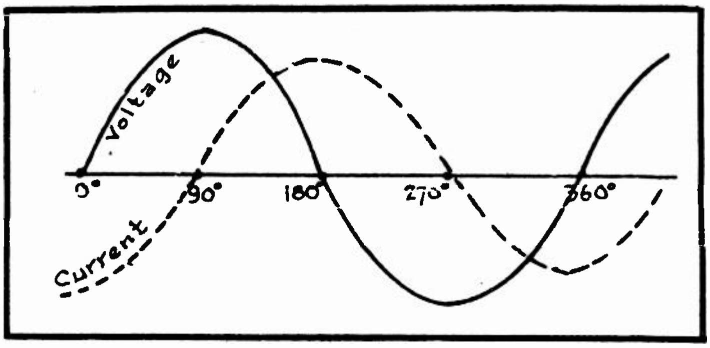

FIG. 2
Voltage Leads Current in Inductive Circuits.

SERIES CONNECTED INDUCTANCES

NOW LET US CONSIDER THE EFFECT WHICH IS PRODUCED WHEN INDUCTANCES ARE CONNECTED IN SERIES. THIS IS ILLUSTRATED FOR YOU IN FIG. 3 AND IT IS INTERESTING TO NOTE THAT WE TREAT SERIES CONNECTED INDUCTANCES THE SAME AS SERIES CONNECTED RESISTORS. THAT IS, AT THE TOP OF FIG. 3, WE HAVE A 300 OHM, 200 OHM AND 400 OHM RESISTOR CONNECTED IN SERIES. THE TOTAL RESISTANCE OF THIS COMBINATION THUS BECOMES EQUAL TO THEIR SUM (300 + 200 + 400 OR 900 OHMS.)

WHEN INDUCTANCES ARE CONNECTED IN SERIES, WE FIGURE THE TOTAL INDUCTANCE THE SAME WAY. THAT IS, IN THE CASE OF FIG. 3, THE 300 MICROHENRY (THE SYMBOL "μh" DENOTES "MICROHENRY"), 200 MICHROHENRY AND 400 MICHROHENRY COILS ARE CONNECTED TOGETHER IN SERIES. THE TOTAL INDUCTANCE OF THE COMBINATION THUS BECOMES 300 + 200 + 400 OR 900 MICHROHENRIES. IN LIKE MANNER, THE TOTAL INDUCTIVE REACTANCE OF THESE THREE COILS TOWARDS THE FLOW OF AN A.C. CURRENT OF GIVEN FREQUENCY WOULD BE EQUAL TO THE SUM OF THE REACTANCES OF THE THREE COILS.

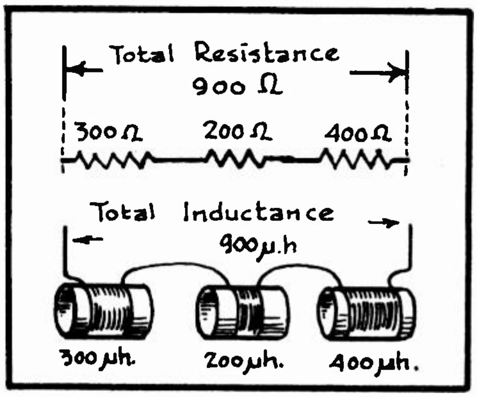

FIG. 3
Inductances Connected In Series.

PARALLEL CONNECTED INDUCTANCES

IN FIG. 4, WE HAVE PICTURED THE CONDITION WHERE THREE COILS, OR INDUCTANCES ARE CONNECTED IN PARALLEL AND IN THIS CASE, THE COMPUTATION FOR THE TOTAL OR COMBINED INDUCTANCE CAN BE COMPARED TO THAT OF CALCULATING THE COMBINED RESISTANCE OF A PARALLEL CONNECTED GROUP OF RESISTORS. FOR

EXAMPLE, AT THE TOP OF FIG. 4, WE HAVE A 300, 200 AND 400 OHM RESISTOR CONNECTED IN PARALLEL AND AS YOU LEARNED IN A PREVIOUS LESSON, THE RECIPROCAL OF THE COMBINED RESISTANCE OF THIS COMBINATION IS FOUND BY ADDING THE RECIPROCALS OF THE INDIVIDUAL RESISTORS. THAT IS, $\frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}$ OR $\frac{1}{R}=\frac{1}{300}+\frac{1}{200}+\frac{1}{400}$ OR $1/R=\frac{4}{1200}+\frac{6}{1200}+\frac{3}{1200}$ OR $R=92.3$ OHMS.

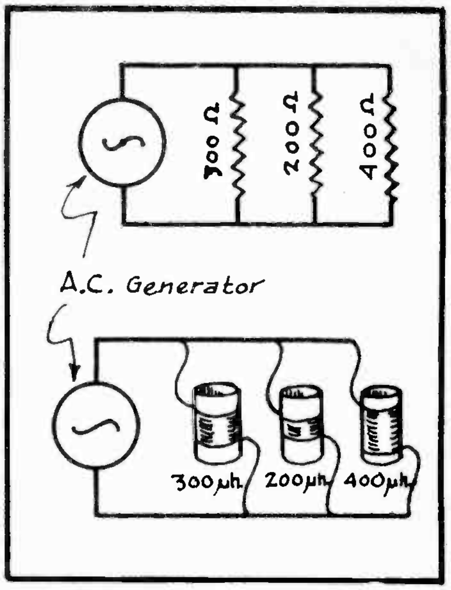

FIG. 4
Inductances Connected In Parallel.

IN LIKE MANNER, THE RECIPROCAL OF THE TOTAL INDUCTANCE OF A GROUP OF PARALLEL CONNECTED INDUCTANCES, BECOMES EQUAL TO THE SUM OF THE RECIPROCALS OF THE INDIVIDUAL INDUCTANCES. FOR EXAMPLE, IN THE CASE OF FIG. 4, $\frac{1}{L}=\frac{1}{L_1}+\frac{1}{L_2}+\frac{1}{L_3}$ WHERE L REPRESENTS INDUCTANCE. CONTINUING, WE HAVE THAT $\frac{1}{L}=\frac{1}{300}+\frac{1}{200}+\frac{1}{400}$ OR $\frac{1}{L}=\frac{4}{1200}+\frac{6}{1200}+\frac{3}{1200}$, WHENCE L OR THE COMBINED INDUCTANCE BECOMES 92.3 MICROHENRIES. IT THUS ALSO FOLLOWS THAT THE TOTAL INDUCTIVE REACTANCE OF THESE THREE COILS TOWARDS THE FLOW OF AN A.C. CURRENT OF GIVEN FREQUENCY WOULD BE FIGURED WITH THE AID OF RECIPROCALS. IN OTHER WORDS, IF THREE PARALLEL CONNECTED COILS AT A GIVEN FREQUENCY RESPECTIVELY HAVE AN INDUCTIVE REACTANCE OF 2000 OHMS, 1500 OHMS AND 3000 OHMS, THE THREE TOGETHER WOULD HAVE A COMBINED REACTANCE OF 666.66 OHMS ($\frac{1}{X_L}=\frac{1}{2000}+\frac{1}{1500}+\frac{1}{3000}$ OR $X_L=666.66$ OHMS).

CAPACITIVE REACTANCE

NOW LET US TURN OUR ATTENTION TO A DIFFERENT TYPE OF REACTANCE. THIS TIME, IT IS GOING TO BE CAPACITIVE REACTANCE AND THIS IS THE REAL NAME FOR THE OPPOSING EFFECT THAT A CONDENSER OFFERS TO THE FLOW OF AN ALTERNATING CURRENT. YOU ARE ALREADY SOMEWHAT FAMILIAR WITH THIS INTERESTING PHENOMENA BUT AT THIS TIME, WE ARE GOING TO CONSIDER IT IN A MORE ADVANCED FORM.

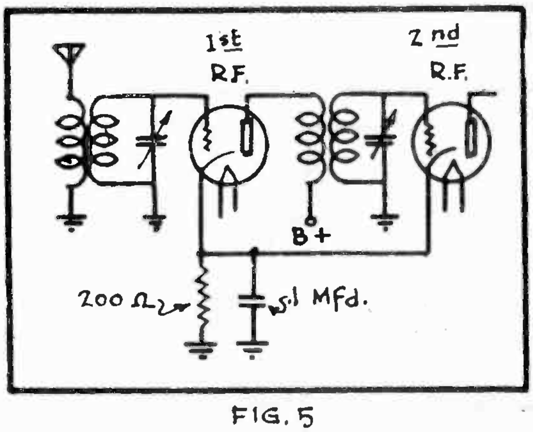

FIG. 5
Calculating Capacitive Reactance.

TO BEGIN WITH, CAPACITIVE REACTANCE IS ALSO MEASURED IN OHMS, THE SAME AS RESISTANCE AND INDUCTIVE REACTANCE. THE METHOD OF CALCULATING THE CAPACITIVE REACTANCE, HOWEVER, IS SOMEWHAT DIFFERENT, AND WE MAKE USE OF THE FOLLOWING FORMULA: $X_c=\frac{1}{2\pi fC}$ OR $X_c=\frac{1}{6.28\,f\,C}$ WHERE X_c IS THE SYMBOL FOR CAPACITIVE REACTANCE, "2π" IS THE CONSTANT 6.28 (APPROXIMATE) "f" IS THE FREQUENCY IN CYCLES PER SECOND AND "C" IS THE CAPACITY OF THE GIVEN CONDENSER EXPRESSED IN FARADS.

A PRACTICAL CAPACITIVE REACTANCE PROBLEM

LET US WORK OUT A PRACTICAL PROBLEM INCLUDING CAPACITIVE REACTANCE AND SEE JUST WHERE WE STAND. IN FIG. 5, YOU ARE SHOWN TWO R.F. AMPLIFYING STAGES WHICH HAVE A 200 OHM GRID BIAS RESISTOR INSTALLED IN THEIR COMMON CATHODE CIRCUIT. THIS 200 OHM RESISTOR IS BY PASSED BY A .1 MFD. CONDENSER.

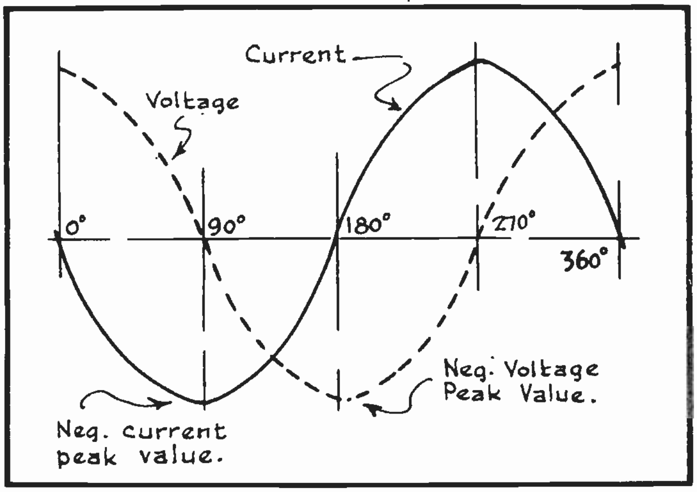

FIG. 6
Current Leads the Voltage in a Capacitive Circuit.

AS YOU ALREADY KNOW, THE PURPOSE OF THIS BY-PASS CONDENSER IS TO PASS THE RADIO FREQUENCIES TO GROUND SO THAT THEY WON'T PASS THROUGH THIS RESISTOR BUT NOW LET US SEE HOW THIS CONDITION IS GOING TO WORK OUT MATHEMATICALLY.

SINCE WE ALREADY KNOW THAT A CONDENSER OFFERS LESS OPPOSITION OR LESS REACTANCE TO ALTERNATING CURRENTS AS THE FREQUENCY INCREASES, LET US CHOOSE A LOW RADIO BROADCAST FREQUENCY AND SEE WHAT IS GOING TO HAPPEN. WE SHALL ASSUME AN R.F. OF 550 KC. THE CAPACITIVE REACTANCE OF THIS .1 MFD. CONDENSER TO A RADIO FREQUENCY OF 500 KC. IS EXPRESSED BY THE FORMULA AS $X_c = \frac{1}{6.28 \times 500{,}000 \times .0000001}$ (NOTE THAT 550,000 CYCLES = 550 KC. AND .0000001 FARAD = .1 MFD). THIS FORMULA WORKS OUT AS $X_c = \frac{1}{.314}$ OR THE CAPACITIVE REACTANCE OF THE .1 MFD. CONDENSER AT 550 KC. IS 3.18 OR APPROXIMATELY 3 OHMS.

THE BIAS RESISTOR OFFERS APPROXIMATELY 200 OHMS OF RESISTANCE IRRESPECTIVE OF THE FREQUENCY AND SINCE WE FOUND THAT THE .1 MFD. BY-PASS CONDENSER ONLY HAS A CAPACITIVE REACTANCE OF APPROXIMATELY 3 OHMS AT 500 KC., IT IS OBVIOUS THAT CURRENTS OF THIS FREQUENCY WILL MOST NATURALLY PASS THROUGH THE CONDENSER IN PREFERANCE TO THE RESISTOR BECAUSE THE OPPOSITION OFFERED BY THE RESISTOR TO THESE CURRENTS IS NEARLY 70 TIMES AS GREAT AS THAT OFFERED BY THE CONDENSER.

AS THE FREQUENCY BEING HANDLED BECOMES GREATER, THE CAPACITIVE REACTANCE BECOMES LESS AT A RAPID RATE, SO THAT THE EFFECT OF THE BY-PASS CONDENSER BECOMES STILL MORE PRONOUNCED. FOR EXAMPLE, AT 1500 KC. THE REACTANCE OF THE BY-PASS CONDENSER IN FIG. 5 BECOMES AS FOLLOWS: $X_c = \frac{1}{6.28 \times 1{,}500{,}000 \times .0000001}$ OR $X_c = 1.06$ OR APPROXIMATELY 1 OHM. IN OTHER WORDS, AT A FREQUENCY OF 1500 KC., THE BIAS RESISTOR OF-

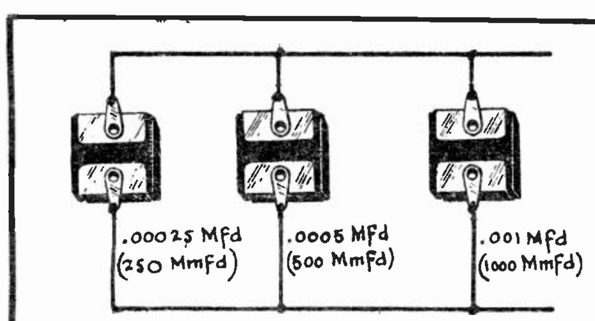

FIG. 7
Capacity Increased by Parallel Connection.

FERS ABOUT 200 TIMES AS MUCH OPPOSITION TO THESE HIGH FREQUENCIES AS DOES THE CONDENSER AND SO THESE CURRENTS HAVE A STILL GREATER TENDENCY TO PASS THROUGH THE CONDENSER IN PREFERANCE TO PASSING THROUGH THE 200 OHM RESISTOR.

THIS PRACTICAL PROBLEM IN ITSELF SHOWS YOU JUST EXACTLY WHAT A BY-PASS CONDENSER ACCOMPLISHES, THEREBY EMPHASIZING ITS IMPORTANCE STILL MORE.

ANOTHER FORMULA WHICH YOU CAN USE IN ORDER TO DETERMINE THE CAPACITIVE REACTANCE OF A GIVEN CONDENSER AT A SPECIFIED FREQUENCY IS AS FOLLOWS:

$$\text{CAPACITIVE REACTANCE IN OHMS} = \frac{159,155}{\text{FREQUENCY IN CYCLES} \times \text{CAPACITY IN MFD.}}$$

THIS FORMULA CHECKS CLOSELY WITH THE ONE GIVEN YOU PREVIOUSLY. FOR EXAMPLE, WHEN USED TO CALCULATE THE CAPACITIVE REACTANCE OF THE BY-PASS CONDENSER IN FIG. 14 AT 550 KC., THIS SECOND FORMULA WORKS OUT AS: $X_c =$

$$\frac{159,155}{550,000 \times .1} = 2.89 \text{ OHMS}$$

OR APPROXIMATELY 3 OHMS, THE SAME AS OBTAINED FROM THE PREVIOUS COMPUTATION.

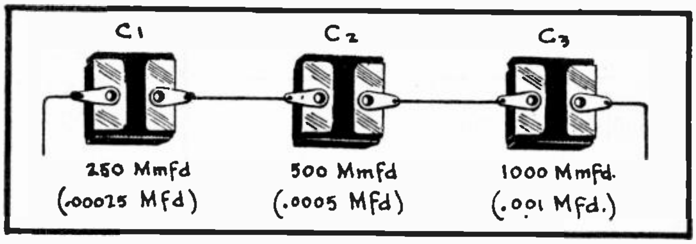

FIG. 8
Capacity Reduced by Series Connection.

THE PHASE RELATION IN CAPACITIVE CIRCUITS

NOW THAT YOU ARE FAMILIAR WITH CAPACITIVE REACTANCE, LET US NEXT INVESTIGATE THE MATTER OF THE PHASE RELATION IN AN ELECTRICAL CIRCUIT CONTAINING CAPACITY ONLY. IN THIS CASE, THE VOLTAGE AND CURRENT CURVES WOULD APPEAR AS ILLUSTRATED IN FIG. 6. NOTICE IN THIS GRAPH HOW DURING THIS ONE CYCLE, THE CURRENT REACHES ITS MAXIMUM OR PEAK VALUE 90° BEFORE THE VOLTAGE REACHES ITS PEAK VALUE. IN OTHER WORDS, IN A PURELY CAPACITIVE CIRCUIT, THE VOLTAGE AND CURRENT ARE 90° OUT OF PHASE BUT THE CURRENT LEADS THE VOLTAGE IN THIS CASE. THIS IS JUST THE REVERSE OF WHAT TAKES PLACE IN A PURE INDUCTIVE CIRCUIT.

WITH THIS POINT SETTLED, WE WILL PROCEED WITH THE MATTER CONCERNING SERIES AND PARALLEL CONDENSER CONNECTIONS, DISCUSSING THE PARALLEL ARRANGEMENT FIRST.

CONDENSERS CONNECTED IN PARALLEL

IN FIG. 7, YOU WILL SEE AN ILLUSTRATION WHERE THREE FIXED CONDENSERS OF DIFFERENT VALUES ARE CONNECTED IN PARALLEL. THESE CONDENSERS HAVE THE RESPECTIVE VALUES OF .00025 MFD. (250 MMFD.); .0005 MFD.(500 MMFD.) AND .001 MFD. (1000 MMFD.).

THE COMBINED CAPACITY OF A PARALLEL CAPACITY COMBINATION IS EQUAL TO THE SUM OF THE INDIVIDUAL CAPACITIES. THAT IS, IN THE CASE OF FIG. 7, THE COMBINED CAPACITY OF THE GROUP IS EQUAL TO 250+500+1000 MMFD. OR 1750 MMFD. IN TERMS OF MICROFARADS, THIS TOTAL CAPACITY WOULD AMOUNT TO .00025+.0005+.001 OR .00175 MFDS. NOTICE THAT THE COMBINED CAPACITY

INCREASES AS THE NUMBER OR VALUE OF THE PARALLEL CAPACITIES IS INCREASED.

NOW IN FIG. 8, WE SEE THESE SAME THREE CONDENSERS CONNECTED IN SERIES. TO DETERMINE THE TOTAL CAPACITY OF THIS COMBINATION, WE USE THE FORMULA $\frac{1}{C}=\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}$, WHERE C = TOTAL CAPACITY AND C_1; C_2 AND C_3 THE VARIOUS INDIVIDUAL CAPACITIES. THUS IN THE CASE OF FIG. 8, THE CAPACITY OF THE COMBINATION BECOMES $\frac{1}{C}=\frac{1}{250}+\frac{1}{500}+\frac{1}{1000}$ OR $\frac{1}{C}=\frac{4}{1000}+\frac{2}{1000}+\frac{1}{1000}=\frac{7}{1000}$. SINCE $\frac{1}{C}=\frac{7}{1000}$, WE ALSO HAVE $7C=1000$ OR $C=142.859$ MMFDS. OR APPROXIMATELY 143 MMFDS. IN TERMS OF MICROFARADS, THIS VALUE WOULD BE EQUIVALENT TO .000143 MFDS.

FROM THE FOREGOING CALCULATIONS, YOU HAVE DEFINITE PROOF THAT AS CAPACITIES ARE CONNECTED IN SERIES, THE TOTAL CAPACITY BECOMES LESS. IT IS INTERESTING TO NOTE THAT WHEN DEALING WITH SERIES AND PARALLEL CAPACITIES, WE HAVE JUST THE EXACT OPPOSITE EFFECT AS WHEN DEALING WITH RESISTORS IN THESE SAME COMBINATIONS.

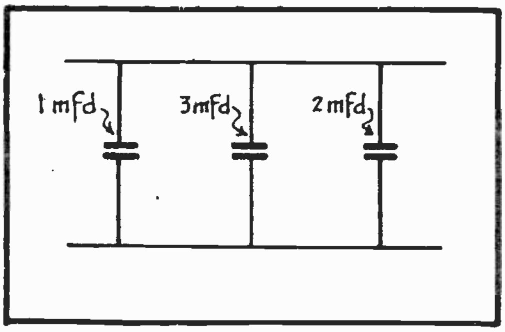

FIG. 9
Group of Parallel Connected Condensers.

CAPACITIVE REACTANCE IN PARALLEL CAPACITIVE CIRCUITS

FIRST, LET US LOOK AT FIG. 9. HERE WE HAVE 3 CONDENSERS CONNECTED IN PARALLEL AND THEIR VALUES ARE RESPECTIVELY 1 MFD, 3 MFD, AND 2 MFD. FROM WHAT YOU LEARNED IN YOUR PREVIOUS LESSON, YOU WILL REALIZE IMMEDIATELY THAT THE CAPACITY OF THIS ENTIRE PARALLEL ARRANGEMENT BECOMES EQUAL TO 1 MFD. + 3 MFD. + 2 MFD. OR 6 MFD.

THE REACTANCE OF THIS EFFECTIVE 6 MFD. CAPACITY TO A RADIO FREQUENCY OF 1600 KC. CAN BE DETERMINED BY THE FORMULA $X_c=\frac{159,155}{\text{FREQUENCY IN CYCLES} \times \text{CAP. IN MFD.}}$ OR $X_c=\frac{159,155}{1,600,000 \times 6}$ OR $X_c=.016$ OHMS (APPROXIMATELY). YOU CAN GET THIS SAME RESULT BY FIRST DETERMINING THE CAPACITIVE REACTANCE OF EACH OF THE INDIVIDUAL CONDENSERS TOWARDS THIS FREQUENCY. THESE SEPARATE REACTANCES CAN THEN BE ADDED TOGETHER BY RECIPROCALS THE SAME AS THOUGH THEY WERE PARALLELED RESISTORS BUT THIS METHOD OF SOLVING THE PROBLEM IS MUCH MORE COMPLICATED THAN THE SIMPLER METHOD JUST GIVEN YOU.

THE MAIN THING TO REMEMBER IS THAT THE CAPACITIVE REACTANCE OF THE GROUP OF PARALLEL CONDENSERS IN FIG. 2 TO ANY GIVEN FREQUENCY IS LESS THAN THE REACTANCE OFFERED BY ANY ONE OF THE INDIVIDUAL CONDENSERS TO THIS SAME FREQUENCY.

CAPACITIVE REACTANCE WITH SERIES CAPACITIES

NOW LET US PROCEED WITH THE CASE WHERE WE HAVE TO DEAL WITH THE CAPACITIVE REACTANCE OF A SERIES CONNECTED GROUP OF CONDENSERS. IN FIG. 10

For example, we have three condensers connected in series and their respective values are again 1 mfd., 3 mfd. and 2 mfd.

The combined capacity of this circuit will be found with the aid of the formula: $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ or $\frac{1}{C} = \frac{1}{1} + \frac{1}{3} + \frac{1}{2}$ whence $\frac{1}{C} = \frac{6}{6} + \frac{2}{6} + \frac{3}{6}$ or $\frac{1}{C} = \frac{11}{6}$. or $C = .545$ mfd. Thus the capacitive reactance of this series combination to a 1600 Kc. will be:- $X_c = \frac{159,155}{1600000 \text{ X } .545}$ or $X_c = \frac{159,155}{872,000} =$ .182 ohms.

You could get the same result by determining the capacitive reactance for each of these three condensers separately and then adding the results together so as to find the total reactance of this combination. But here again, this process would be longer than the method of solving this problem as explained above.

The important thing to remember about this type of circuit is that the capacitive reactance becomes GREATER as the number of series connected capacities is increased.

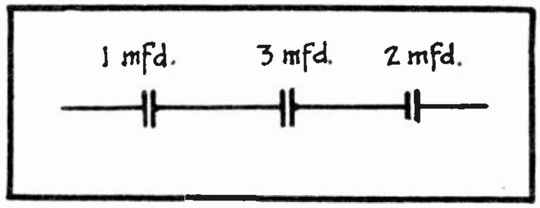

FIG. 10
Group of Series Connected Condensers.

IMPEDANCE

So far, we have considered circuits containing solely capacity or inductance. In practice, however, we generally have to deal with a combination of capacity and resistance, of inductance and resistance or even with combinations containing all three of these conditions. That is, inductance, capacity and resistance.

To begin with, let us look at Fig. 11, where we have a coil or inductance connected in series with a resistance. In fact, this resistance can even be considered as being the ohmic resistance of the wire making up the coil, for it is impossible to construct a coil which has inductance only without any resistance.

In this illustration, we will have to consider the opposition offered to the current flow by both the inductance and the resistance and the combined effect of all the reactance and all of the resistance in a circuit is called the IMPEDANCE and the impedance is representated by the letter "Z". In order to determine the total opposition or the impedance of the circuit in Fig. 11 toward the 60 cycle A.C. current, we use the formula $Z = \sqrt{R^2 + X_L^2}$. That is, the impedance is equal to the square root of the resistance squared plus the inductive reactance squared of the coil at 60 cycles.

In other words, the inductive reactance of this coil to a 60 cycle current will be $X_L = 2\pi f L$ or $X_L = 6.28 \text{ X } 60 \text{ X } 15 = 5652$ ohms. The impedance will than be $Z = \sqrt{2000^2 + 5652^2} = \sqrt{4,000,000 + 31,945,104} = \sqrt{35,945,104} =$ 6778 Ohms (approximately)

THE IMPEDANCE TRIANGLE FOR INDUCTANCE AND RESISTANCE

Impedance problems involving inductance and resistance can also be

WORKED OUT BY MEANS OF THE IMPEDANCE TRIANGLE. THIS IS A VERY SIMPLE METHOD AS YOU SHALL PRESENTLY SEE. IN FIG. 12, FOR EXAMPLE, WE HAVE A RESISTANCE-INDUCTANCE COMBINATION IN WHICH THE RESISTANCE HAS A VALUE OF 10 OHMS AND THE INDUCTANCE AT THE FREQUENCY BEING HANDLED HAS A REACTANCE OF 12 OHMS.

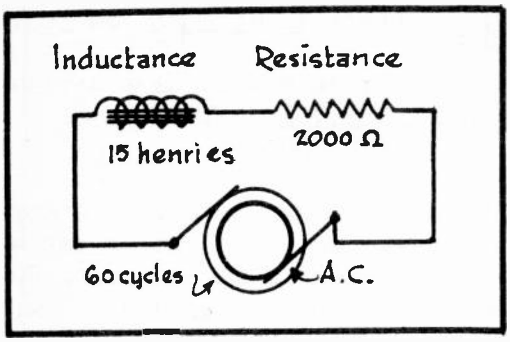

FIG. 11
Circuit With Inductance and Resistance.

TO FIND THE IMPEDANCE OF THIS CIRCUIT BY MEANS OF THE IMPEDANCE TRIANGLE, PROCEED AS ILLUSTRATED IN FIG. 13. THAT IS, FIRST DRAW A HORIZONTAL LINE. THIS LINE REPRESENTS RESISTANCE AND SINCE THE VALUE OF THE RESISTANCE IN OUR PRESENT PROBLEM IS 10 OHMS, DRAW THIS LINE 10 UNITS LONG. THE UNIT USED IS A MATTER OF CHOICE AND MAY BE 1/8", 1/4", 1/2", 1" OR ANY OTHER SUITABLE UNIT. IN THE CASE OF FIG. 13, 1/8" WAS CHOSEN AS THE UNIT AND CONSEQUENTLY THE RESISTANCE LINE IS 10/8" OR 1 1/4" LONG. THIS FORMS THE BASE FOR THE IMPEDANCE TRIANGLE. THE NEXT STEP IS TO DRAW THE INDUCTIVE REACTANCE LINE. THIS IS A VERTICAL LINE DRAWN AT RIGHT ANGLES TO THE END OF THE RESISTANCE LINE AND SINCE THE INDUCTIVE REACTANCE IN OUR PRESENT PROBLEM IS 12 OHMS, THIS LINE SHOULD BE DRAWN 12 UNITS LONG. (THE SAME UNIT MUST BE USED AS THAT USED FOR THE RESISTANCE LINE.)

THIS DONE, THE NEXT STEP IS TO CONNECT TOGETHER THE ENDS OF THESE TWO LINES BY A THIRD LINE WHICH IS DESIGNATED AS THE IMPEDANCE LINE IN FIG. 13. NOW MEASURE THIS LINE AND SEE HOW MANY UNITS IT CONTAINS AND THE RESULT WILL BE THE IMPEDANCE OF THE CIRCUIT IN OHMS. IN THE CASE OF THE PROBLEM GIVEN IN FIG. 12, THE IMPEDANCE LINE IN FIG. 13 WILL BE FOUND TO BE APPROXIMATELY $15\frac{1}{2}$ UNITS LONG. HENCE THE IMPEDANCE OF THIS CIRCUIT TO THE FREQUENCY BEING CONSIDERED IS ABOUT $15\frac{1}{2}$ OHMS.

IT IS INTERESTING TO NOTE HOW CLOSE IMPEDANCE VALUES AS DETERMINED BY THE IMPEDANCE TRIANGLE METHOD APPROACH THE CALCULATED IMPEDANCE VALUE. FOR EXAMPLE, SINCE $Z=\sqrt{R^2+X_L^2}$, WE FIND THAT BY SUBSTITUTING INTO IT THE RESISTANCE AND INDUCTIVE REACTANCE VALUES GIVEN IN FIG. 12, WE HAVE $Z=\sqrt{10^2+12^2}=\sqrt{100+144}=\sqrt{244}=15.62$ OHMS.

AS YOU WILL NOTICE THIS VALUE IS NOT SO VERY FAR OFF FROM THE MORE APPROXIMATE METHOD AS EMPLOYED IN FIG. 13.

IMPEDANCE OFFERED BY A RESISTANCE-CAPACITY COMBINATION

NOW LET US CONSIDER A CIRCUIT CONTAINING CAPACITY AND RESISTANCE. THIS IS ILLUSTRATED FOR YOU IN FIG. 14 AND THE VALUES ARE 20 OHMS FOR THE RESISTOR AND 1 MFD. FOR THE CONDENSER. OUR PROBLEM IS TO FIND THE TOTAL OPPOSITION OR IMPEDANCE OFFERED BY THIS CIRCUIT TO A CURRENT AT 600 CYCLES. IN THIS CASE, WE USE THE FORM

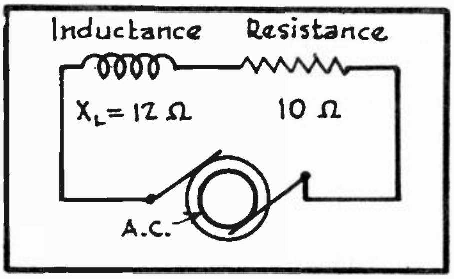

FIG. 12
Another Impedance Problem.

ULA $Z=\sqrt{R^2+X_c^2}$. THAT IS, THE IMPEDANCE IS EQUAL TO THE SQUARE ROOT OF THE RESISTANCE SQUARED PLUS THE CAPACITIVE REACTANCE SQUARED.

THE CAPACITIVE REACTANCE OF THE 1 MFD. CONDENSER TO THE 600 CYCLE CURRENT AS DETERMINED BY THE FORMULA $X_c = \frac{159,155}{\text{FREQ. IN CYCLES} \times \text{CAPACITY IN MFD.}}$ IS

$$X_c = \frac{159,155}{600 \times 1} = \frac{159,155}{600} = 265.26 \text{ OHMS.}$$

THE IMPEDANCE WILL THUS BE EQUAL TO $\sqrt{20^2+265.26^2}=\sqrt{70,762.8}$ OR APPROXIMATELY 266 OHMS.

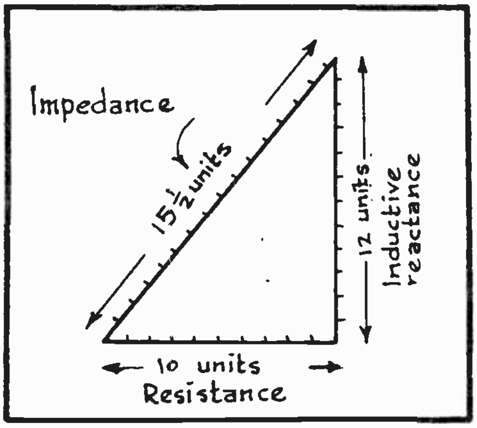

FIG. 13
Impedance Triangle for Inductance and Resistance.

IT IS ALSO POSSIBLE TO WORK OUT IMPEDANCE PROBLEMS INVOLVING RESISTANCE AND CAPACITIVE REACTANCE BY MEANS OF THE IMPEDANCE TRIANGLE. FOR EXAMPLE, AT THE TOP OF FIG. 15, WE HAVE AN A.C. CIRCUIT CONTAINING A 15 OHM RESISTANCE AND THE REACTANCE OF THE CONDENSER AT THE FREQUENCY BEING HANDLED IS 6 OHMS.

IN THE LOWER PORTION OF FIG. 15, WE ARE REPRESENTING THE RELATION BETWEEN THIS RESISTANCE AND CAPACITIVE REACTANCE IN THE FORM OF THE IMPEDANCE TRIANGLE. SUCH A TRIANGLE IS ALSO FREQUENTLY SPOKEN OF AS THE VECTOR RELATION OF RESISTANCE AND CAPACITIVE REACTANCE.

NOTE IN FIG. 15 THAT THE HORIZONTAL RESISTANCE LINE OF THE TRIANGLE IS DRAWN 15 UNITS LONG, SO AS TO REPRESENT 15 OHMS. THE CAPACITIVE REACTANCE LINE IS 6 UNITS LONG SO AS TO REPRESENT 6 OHMS OF CAPACITIVE REACTANCE BUT THIS LINE EXTENDS DOWNWARD AT RIGHT ANGLES TO THE EXTREMETY OF THE RESISTANCE LINE, OR IN A DIRECTION OPPOSITE TO THAT OF THE INDUCTIVE REACTANCE LINE WHICH WAS SHOWN YOU IN A PREVIOUS PROBLEM.

THE TWO EXTREMETIES OF THE RESISTANCE AND CAPACITIVE REACTANCE LINES ARE THEN CONNECTED TOGETHER BY THE THIRD LINE OF THE TRIANGLE AND UPON MEASUREMENT WITH A RULE, IT WILL BE FOUND THAT THIS LINE IS 16 UNITS LONG. HENCE, THE IMPEDANCE OF THIS CIRCUIT IS 16 OHMS.

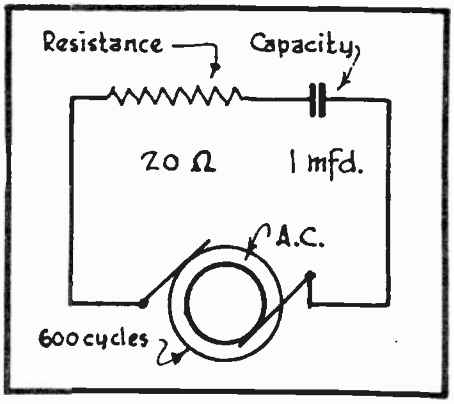

FIG. 14
Circuit With Capacity and Resistance.

PROBLEMS INVOLVING RESISTANCE, CAPACITY AND INDUCTANCE

NOW LET US CONSIDER THE CASE WHERE WE HAVE A CIRCUIT CONTAINING RESISTANCE, INDUCTANCE AND CAPACITY. HERE THE IMPEDANCE WILL BE EXPRESSED BY THE FORMULA $Z=\sqrt{R^2+X^2}$ IN WHICH "X" IS THE NET REACTANCE OR THE ARITHMETICAL DIFFERENCE BETWEEN THE INDUCTIVE REACTANCE AND THE CAPACITIVE REACTANCE.

TO ILLUSTRATE THIS IMPORTANT POINT, LET US LOOK AT FIG. 16, WHERE WE HAVE A CIRCUIT IN WHICH A 10 HENRY CHOKE IS CONNECTED

IN SERIES WITH A 50 MFD. CONDENSER. THE WIRE OF THIS SAME CHOKE IS OF SUCH CROSS-SECTION AND LENGTH AS TO OFFER A RESISTANCE OF 5 OHMS. THIS 5 OHMS OF RESISTANCE CAN BE CONSIDERED AS A RESISTANCE INSERTED IN SERIES WITH THE CIRCUIT AS HERE PICTURED.

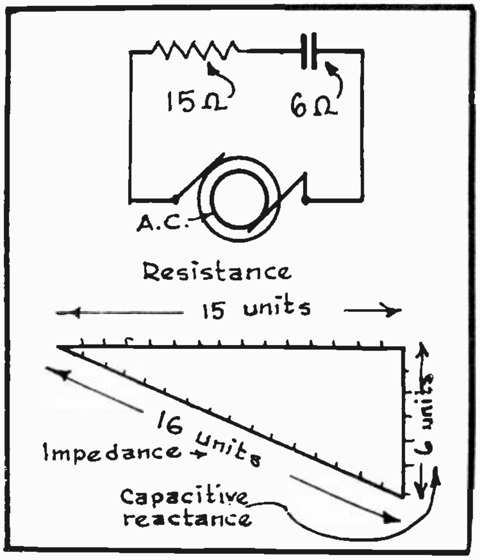

FIG. 15
Impedance Triangle for Resistance and Capacity.

OUR FIRST STEP IN DETERMINING THE IMPEDANCE OF THIS CIRCUIT TO A 1000 CYCLE CURRENT IS TO FIRST CALCULATE THE INDUCTIVE AND CAPACITIVE REACTANCE TO THIS FREQUENCY. TO FIND THE INDUCTIVE REACTANCE, USE THE FORMULA $X_L = 2\pi f L$ WHENCE $X_L = 6.28 \times 1000 \times 10 = 62,800$ OHMS.

THE CAPACITIVE REACTANCE OF THE 50 MFD. CONDENSER TOWARD THE 1000 CYCLE CURRENT WILL BE FOUND WITH THE FORMULA $X_c = \frac{1}{2\pi f C} = \frac{1}{6.28 \times 1000 \times .00005} = \frac{1}{.314} = 3.2$ OHMS.

THE NET OR EFFECTIVE REACTANCE OF THE CIRCUIT THENCE BECOMES 62,800 − 3.2 OR 62796.8 OHMS. THE IMPEDANCE FORMULA WILL THEN BE EXPRESSED AS $Z = \sqrt{R^2 + X^2}$ OR $Z = \sqrt{5^2 + 62796.8^2}$ OR $Z = 62796$ OHMS.

IN THIS PARTICULAR PROBLEM, WE SUBTRACTED THE CAPACITIVE REACTANCE FROM THE INDUCTIVE REACTANCE IN ORDER TO DETERMINE THE NET REACTANCE. HOWEVER, IN SUCH CASES WHERE THE CAPACITIVE REACTANCE IS GREATER THAN THE INDUCTIVE REACTANCE, THEN THE INDUCTIVE REACTANCE IS SUBTRACTED FROM THE CAPACITIVE REACTANCE IN ORDER TO DETERMINE THE NET REACTANCE. THE REST OF THE CALCULATIONS, HOWEVER, WOULD BE CARRIED OUT IN THE SAME MANNER AS ALREADY SHOWN YOU.

IN THIS PROBLEM, A VERY INTERESTING CONDITION OCCURS AND THAT IS THAT THE IMPEDANCE OF THE CIRCUIT UNDER CONSIDERATION IS PRACTICALLY EQUAL TO THAT OF THE INDUCTIVE REACTANCE ALONE. THE REASON FOR THIS IS THAT THE INDUCTIVE REACTANCE IS SO VERY LARGE IN RELATION TO THE PURE RESISTANCE AND CAPACITIVE REACTANCE THAT THE CIRCUIT AS A WHOLE ACTUALLY ASSUMES THE CHARACTERISTICS OF A PURE INDUCTIVE CIRCUIT.

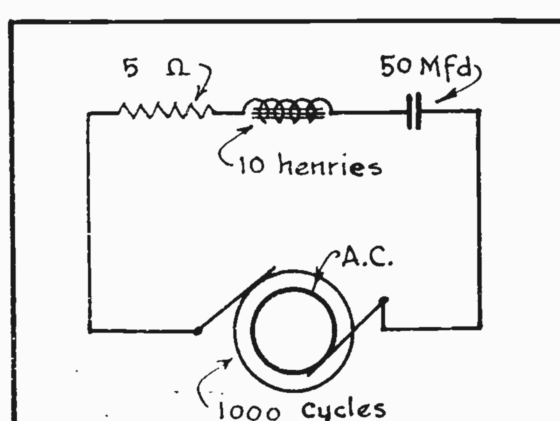

FIG. 16
A Circuit With Resistance, Inductance and Capacity.

IN PRACTICE, WHERE SUCH CONDITION OCCUR THAT THE INDUCTIVE REACTANCE IS SO VERY LARGE IN RESPECT TO THE PURE RESISTANCE, ONE GENERALLY ASSUMES THE NET REACTANCE AS OFFERING THE TOTAL OPPOSITION TO CURRENT FLOW AND THE PURE RESISTANCE IS CONSIDERED AS NEGLIGIBLE.

REMEMBER, HOWEVER, THAT WHEN AN APPRECIABLE PURE RESISTANCE IS PRESENT IN THE CIRCUIT, IT WILL AFFECT THE IMPEDANCE OF SUCH A CIRCUIT MATERIALLY AND MUST THEREFORE, BE ACCOUNTED FOR IN THE FORMULA FOR THE CALCULATION OF THE CIRCUIT'S TOTAL IMPEDANCE.

SIMILAR CONDITIONS AS THIS ALSO ARISE WHEN THE CAPACITIVE REACTANCE OF A CIRCUIT IS VERY LARGE IN PROPORTION TO ITS PURE RESISTANCE. IN THIS CASE, THE IMPEDANCE OF THE CIRCUIT WILL ASSUME THE CHARACTERISTICS OF A PURE CAPACITIVE CIRCUIT AND THE PURE RESISTANCE CAN BE CONSIDERED AS NEGLIGIBLE.

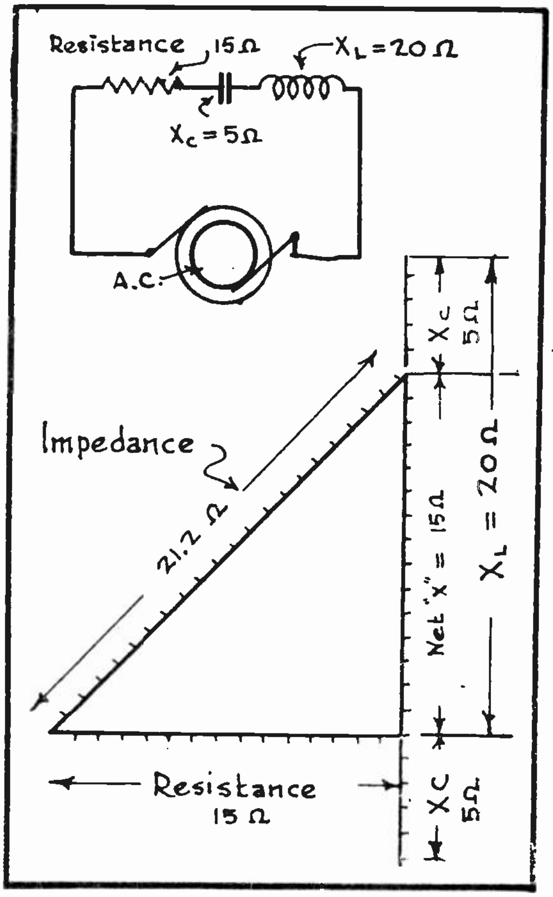

FIG.17
Vector Relation of Resistance, Capacitive Reactance and Inductive Reactance.

PROBLEMS OF THIS NATURE CAN ALSO BE REPRESENTED BY A VECTOR DIAGRAM AND SOLVED THEREBY. FOR EXAMPLE, IN FIG. 17, YOU WILL SEE A CIRCUIT COMPOSED OF INDUCTANCE, CAPACITY AND RESISTANCE. THE VECTOR RELATION FOR THIS PROBLEM IS ALSO SHOWN IN FIG. 17.

IN THIS PARTICULAR CASE, THE RESISTANCE HAS A VALUE OF 15 OHMS, AND THE INDUCTIVE REACTANCE IS 20 OHMS. OBSERVE IN THE LOWER PORTION OF FIG. 17 THAT THE HORIZONTAL RESISTANCE LINE IS DRAWN 15 UNITS LONG. THE VERTICAL OR INDUCTIVE REACTANCE LINE EXTENDS UPWARD FROM THE RESISTANCE LINE FOR 20 UNITS, THEREBY REPRESENTING THE VALUE OF 20 OHMS.

THE CAPACITIVE REACTANCE LINE, WHICH REPRESENTS 5 OHMS, IS DRAWN STRAIGHT DOWNWARDS FROM THE RESISTANCE LINE FOR A DISTANCE OF 5 UNITS. UPON SUBTRACTING THE X_C-5 OHM LINE FROM THE 20 OHM INDUCTIVE REACTANCE LINE, WE HAVE LEFT THE NET REACTANCE LINE WHICH IS ONLY 15 UNITS LONG. THIS REPRESENTS A NET REACTANCE OF 15 OHMS.

NOW BY CONNECTING TOGETHER THE END OF THE RESISTANCE LINE WITH THE 15TH MARK OF THE NET REACTANCE LINE, WE OBTAIN THE IMPEDANCE. UPON MEASUREMENT WITH A RULE, THIS IMPEDANCE LINE WILL BE FOUND TO BE 21.2 UNITS LONG, THUS SHOWING THAT THE IMPEDANCE FOR THIS CIRCUIT IS APPROXIMATELY 21 OHMS.

YOU ARE GRADUALLY DEVELOPING A GOOD UNDERSTANDING OF A.C. CIRCUITS AND IN THE FOLLOWING LESSON, YOU ARE GOING TO EXPAND THIS KNOWLEDGE STILL MORE BY LEARNING THE MATHEMATICAL LAWS WHICH GOVERN RESONANT CIRCUITS AND MANY OTHER INTERESTING FEATURES OF IMPORTANCE.

Examination Question

LESSON NO. 40

"When a man really finds himself at the top of the ladder of success, he is never alone. No man can climb to genuine success without taking others along with him."

1. - EXPLAIN THE PHASE RELATION WHICH EXISTS BETWEEN THE VOLTAGE AND CURRENT IN A PURE INDUCTIVE CIRCUIT.

2. - EXPLAIN THE PHASE RELATION WHICH EXISTS BETWEEN THE VOLTAGE AND CURRENT IN A PURE CAPACITIVE CIRCUIT.

3. - IF INDUCTANCES OF 30, 25 AND 15 HENRIES RESPECTIVELY ARE ALL CONNECTED IN SERIES, WHAT WILL BE THE TOTAL INDUCTANCE OF THIS COMBINATION?

4. - IF INDUCTANCES OF 100; 200 AND 50 MICROHENRIES RESPECTIVELY ARE ALL CONNECTED IN PARALLEL, WHAT WILL BE THE TOTAL INDUCTANCE OF THIS COMBINATION?

5. - WHAT CAPACITIVE REACTANCE WILL A CONDENSER OF .25 MFD. OFFER TOWARDS AN R.F. SIGNAL CURRENT OF 600 KC.?

6. - IF THREE CONDENSERS HAVING A CAPACITY RATING OF 2; 4 AND 8 MFD. RESPECTIVELY ARE ALL CONNECTED IN PARALLEL, WHAT REACTANCE WILL THIS COMBINATION OFFER TOWARDS A 60 CYCLE CURRENT?

7. - EXPLAIN WHAT IS MEANT BY THE TERM IMPEDANCE?

8. - IF AN INDUCTANCE OF 15 HENRIES IS CONNECTED IN SERIES WITH A RESISTANCE OF 2000 OHMS, WHAT IMPEDANCE WILL THIS CIRCUIT OFFER TOWARDS A 120 CYCLE CURRENT?

9. - IF A CONDENSER OF 8 MFD. CAPACITY RATING IS CONNECTED IN SERIES WITH A RESISTANCE OF 1000 OHMS AND AN INDUCTANCE OF 30 HENRIES, WHAT IMPEDANCE WILL THIS CIRCUIT OFFER TOWARDS A 60 CYCLE CURRENT?

10. - ILLUSTRATE HOW THE IMPEDANCE MAY BE DETERMINED BY MEANS OF THE "IMPEDANCE TRIANGLE" IF THE D.C. RESISTANCE OF A CERTAIN CIRCUIT IS 10 OHMS AND ITS INDUCTIVE REACTANCE 15 OHMS.