RADIO - TELEVISION
Practical • J. A. ROSENKRANZ, Pres. • Training
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LESSON NO. 1

PRINCIPLES OF SOUND

HERE YOU ARE -- READY TO START YOUR STUDY OF RADIO. IT IS QUITE POSSIBLE THAT YOU ARE MOST INTERESTED IN THAT RADIO ACTIVITY CALLED BROADCASTING, BY WHICH IS MEANT THE CONVERSION OF SOUND INTO ELECTRICAL IMPULSES KNOWN AS RADIO WAVES, THEIR "BROADCAST" INTO THE ATMOSPHERE, THEIR RECEPTION BY THE BROADCAST LISTENER (KNOWN TO RADIO MEN AS BCL). HIS "RECEIVER" RECONVERTS THESE WAVES INTO SOUND. THUS INFORMATION AND ENTERTAINMENT IS MADE AVAILABLE TO HUNDREDS OF MILLIONS OF PEOPLE WHO OTHERWISE WOULD MISS THIS EDUCATION AND AMUSEMENT.

SINCE BROADCASTING CONSISTS ENTIRELY OF TRANSMITTING THE SOUNDS OF VOICES, MUSICAL INSTRUMENTS, ETC., IT IS EVIDENT THAT THE VERY FIRST STEP IN THIS MOST REMARKABLE PROCESS IS TO PRODUCE THE SOUNDS.

OF COURSE, YOU ALREADY HAVE SOMETHING OF AN IDEA AS TO WHAT SOUND IS BECAUSE IT IS SUCH AN IMPORTANT PART OF YOUR DAILY LIFE. NEVERTHELESS, THERE ARE MANY CHARACTERISTICS ASSOCIATED WITH IT WHICH YOU PROBABLY NEVER REALIZED BEFORE. FOR EXAMPLE, THE LAST TIME THAT YOU LISTENED TO A RADIO PROGRAM, DID YOU STOP TO THINK JUST WHY IT IS THAT YOU ARE ACTUALLY ABLE TO HEAR SOUNDS? DO YOU KNOW JUST WHAT HAPPENS WHEN YOU STRIKE A DRUM, SO THAT A SENSATION IS PRODUCED THAT WE CALL SOUND? DO YOU KNOW WHY SOME SOUNDS APPEAR TO BE LOUDER THAN OTHERS, AND WHY SOME SOUNDS ARE HIGH IN PITCH WHILE OTHERS ARE LOW OR SO-CALLED DEEP TONES? THESE THINGS ARE SO COMMON THAT MOST PEOPLE SIMPLY TAKE THEM FOR GRANTED - NEVER STOPPING TO CONSIDER

Fig. 1
Singing Into An N.B.C.
Microphone.

THE WONDERS OF THIS THING THAT WE CALL "SOUND".

HOWEVER, YOU ARE DETERMINED TO BECOME A RADIO EXPERT, AND SO TO YOU SOUND IS VERY IMPORTANT. IN FACT, IT IS THE VERY BACK-BONE OF YOUR INTENDED PROFESSION, AND FOR THIS REASON IT IS NECESSARY THAT YOU HAVE A GOOD FUNDAMENTAL UNDERSTANDING OF IT. WHEN YOU HAVE COMPLETED THIS LESSON, ALL OF THE QUESTIONS IN THE PRECEDING PARAGRAPH, AS WELL AS MANY MORE, WILL HAVE BEEN ANSWERED IN A MANNER EASILY UNDERSTANDABLE BY YOU.

WE WANT YOU TO REALIZE THAT EVERY BIT OF THE INFORMATION THAT IS TO BE GIVEN TO YOU IN THIS LESSON IS ABSOLUTELY NECESSARY, AND THAT YOU ARE NOT BEING ASKED TO LEARN USELESS THEORY. EXPERIENCE HAS GIVEN US A DEFINITE REASON FOR TEACHING YOU THE PRINCIPLES OF SOUND AT THIS, THE VERY START OF YOUR TRAINING. ACCEPT OUR FRIENDLY ADVICE, AND STUDY EVERY WORD OF THE DISCUSSION WHICH IS TO FOLLOW. IN THIS WAY YOU WILL BE PROPERLY PREPARED TO LEARN HOW THESE VARIOUS CHARACTERISTICS OF SOUND AFFECT THE FIRST UNIT OF THE BROADCAST APPARATUS, THE "MICROPHONE", WHICH INSTRUMENT WILL BE EXPLAINED TO YOU IN THE NEXT LESSON.

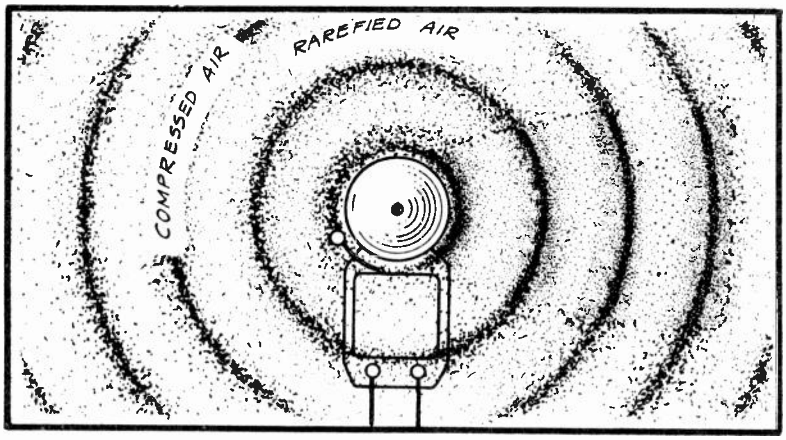

Fig. 2
Radiation Of Sound Waves From An Electric Bell.

GENERATING SOUND WAVES

TO START WITH SOMETHING EASY, LET US CONSIDER A SIMPLE EXPERIMENT WITH AN ELECTRIC BELL - ITS ARRANGEMENT IS ILLUSTRATED FOR YOU IN FIG.2.

WHEN THIS BELL RINGS, OUR EYES TELL US THAT THE LITTLE HAMMER STRIKES THE BELL MANY TIMES IN RAPID SUCCESSION, AND AT THE SAME TIME WE HEAR THE CHARACTERISTIC SOUND OF THE ELECTRIC BELL. THE QUESTION NOW IS - WHAT CAUSES THIS SOUND? - AND WE WILL SETTLE THIS POINT FIRST.

TO BEGIN WITH, LET US TOUCH THE BELL WITH A FINGER DURING THE TIME THAT IT IS RINGING: WE FIND THAT THE BELL IS VIBRATING AT A RAPID RATE, AND THAT IT IS THE RAPID SUCCESSION OF BLOWS BY THE LITTLE HAMMER WHICH CAUSES THIS VIBRATION. THIS IS THE FIRST IMPORTANT POINT TO REMEMBER.

THE BELL IS SURROUNDED COMPLETELY BY AN "ENVELOPE" OF AIR OR ATMOSPHERE, THE SAME AS WE ARE, AND AIR IS A GASEOUS COMBINATION HAVING AN ELASTIC NATURE. IT CAN BE SET IN MOTION BY APPLYING FORCE TO IT. FOR EXAMPLE, WHEN PUMPING UP AN AUTOMOBILE TIRE YOU FORCE AIR INTO THE TIRE UNDER PRESSURE, AND ACTUALLY CROWD THE AIR INTO A LIMITED SPACE. IN TECHNICAL TERMS THIS IS DESCRIBED AS COMPRESSING THE AIR.

SO, RETURNING AGAIN TO THE BELL, WE FIND THAT THE AIR PRESSES AGAINST THE BELL ON ALL SIDES. THE BELL'S SHAPE IS WHAT IN ORDINARY TERMS WE

WOULD CALL "ROUNDED" OR BOWL-SHAPED, AND THEREFORE, WHEN STRUCK, ITS NATURAL TENDENCY IS TO VIBRATE FROM ITS CENTER OUTWARD - EQUALLY IN ALL DIRECTIONS, AS THOUGH IT WERE EXPANDING AND CONTRACTING FROM ITS CENTER.

EACH TIME THAT THE VIBRATING BELL MAKES AN OUTWARD IMPULSE IT COMPRESSES, TO A CERTAIN EXTENT, THE AIR THAT PRESSES ON IT FROM ALL SIDES. THAT IS, IT CROWDS THE SURROUNDING AIR PARTICLES TOGETHER, PUSHING THEM OUTWARD IN ALL DIRECTIONS. THEN, WHEN THE BELL UNDERGOES THE FOLLOWING CONTRACTING IMPULSE, IT REDUCES THE PRESSURE ON THE SURROUNDING AIR -- IN FACT, IT TENDS TO DRAW AWAY FROM THE AIR AND THE SURROUNDING AIR PARTICLES ARE THEN NO LONGER CROWDED TOGETHER, SO THAT THE AIR IS LESS DENSE THAN NORMAL. WE THEN SAY THAT AT THIS INSTANT THERE IS A "RAREFACTION OF AIR".

THIS SUCCESSIVE SERIES OF COMPRESSIONS AND RAREFACTIONS RADIATE OUTWARD FROM THE BELL, IN THE MANNER ILLUSTRATED IN FIG. 2, WHERE THE DARK RINGS REPRESENT AIR COMPRESSIONS AND THE LIGHTER SHADED PORTIONS, AIR RAREFACTIONS. HENCE, ALL OF THE SURROUNDING AIR IS AGITATED OR SET IN MOTION, AND WE SPEAK OF THIS PARTICULAR TYPE OF AIR MOTION OR VIBRATION AS SOUND WAVES.

THE "SPREADING" OF SOUND WAVES

THE MANNER IN WHICH SOUND WAVES SPREAD OUTWARD FROM THE VIBRATING BELL WILL BECOME MORE CLEAR TO YOU IF YOU CONSIDER THE ACTION ILLUSTRATED IN FIG. 3. HERE IS SHOWN A LAKE IN WHICH THE WATER SURFACE IS PERFECTLY CALM AND SMOOTH. SHOULD WE THROW A STONE INTO THE QUIET WATER, WE WOULD IMMEDIATELY OBSERVE CONCENTRIC WAVES RADIATING OUTWARD OVER THE SURFACE, FROM THE POINT AT WHICH THE STONE PENETRATED IT. IN THE CASE OF SOUND WAVES THE ACTION IS SIMILAR, FOR THE WAVES RADIATE OUTWARD FROM THE BELL.

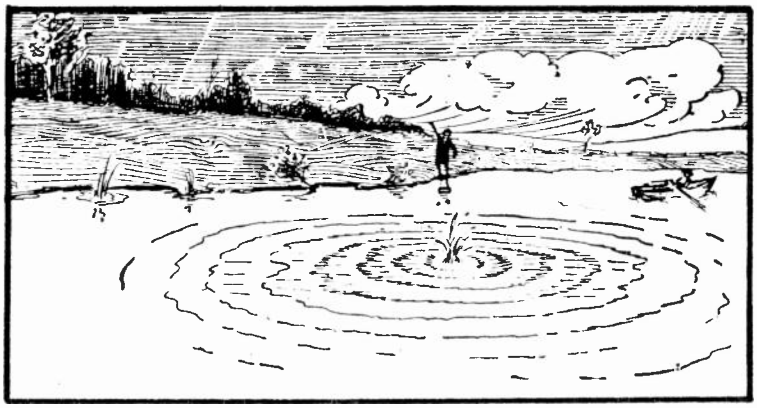

Fig. 3
Wave Motion On The Surface Of A Lake.

BEFORE WE GO INTO GREATER DETAIL IN RESPECT TO THE NATURE OF THE SOUND WAVES, LET US FIRST SEE IN WHAT WAY THAT THESE AIR WAVES, AS RADIATED BY THE BELL, ENABLE US TO HEAR THE BELL. TO DO THIS, WE MUST KNOW HOW THE EAR OPERATES, AND IN FIG. 4 YOU ARE SHOWN A SECTIONAL VIEW OF THE HUMAN EAR. STUDY THIS ILLUSTRATION CAREFULLY, TO BECOME ACQUAINTED WITH THE VARIOUS PARTS WHICH MAKE UP ITS STRUCTURE.

THE HUMAN EAR

THE EAR CONSISTS OF THREE GENERAL DIVISIONS WHICH CAN BE CLASSIFIED AS THE EXTERNAL, MIDDLE, AND INTERNAL PORTIONS OF THE EAR. THE SO-CALLED EXTERNAL PORTION CONSISTS, FIRST, OF THE FLAP OF THE EAR, THE EXTERNAL

PORTION, WHICH ACTS AS A COLLECTOR OF SOUND WAVES. IT IS INDICATED BY THE LETTER "P" IN FIG.4. THE SECOND EXTERNAL SECTION OF THE EAR IS THE DUCT OR CHANNEL "C", LEADING FROM THE EAR FLAP TO THE MIDDLE SECTION OF THE EAR. THE INNER END OF CHANNEL "C" IS SEALED BY A THIN MEMBRANE OR DIAPHRAGM "D", WHICH WE GENERALLY SPEAK OF AS THE "EAR DRUM".

OF THE SOUND WAVES THAT SPREAD OUTWARD FROM THE BELL, A PORTION WILL ENTER THE EXTERNAL OPENING OF THE EAR CHANNEL "C",THEREBY ENABLING THE AIR-PRESSURE VIBRATIONS TO ACT UPON THE THIN AND ELASTIC EAR DRUM. THESE VARIATIONS OF AIR WAVES CAUSE THE EAR DRUM TO VIBRATE AT A DEFINITE RATE WHICH WILL BE IN EXACT STEP WITH THE AIR-PRESSURE VARIATIONS THAT STRIKE IT.

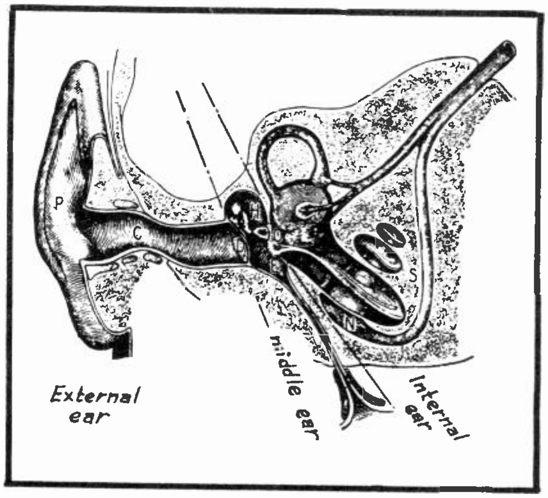

Fig. 4
Sectional View Of The Ear.

NOW, THESE VIBRATIONS OF THE EAR DRUM ARE TRANSMITTED DIRECTLY TO A GROUP OF THREE BONES WHICH FORM A MECHANICAL LEVER SYSTEM, SHOWN AT "H" IN FIG. 4, AND THEY TRANSMIT THE MOTION OF THE EAR DRUM TO A SECOND DIAPHRAGM "O" LOCATED IN THE INNER EAR. THE VIBRATIONS OF THIS SECOND DIAPHRAGM ARE IMPRESSED UPON A FLUID THAT IS CONTAINED IN A SPIRAL-SHAPED CHAMBER FORMED IN THE BONEY STRUCTURE OF THE HEAD.

THOUSANDS OF TINY, FLEXIBLE, HAIRS OF VARIOUS SIZES AND LENGTHS PROJECT INTO THIS FLUID, AND THE AUDITORY NERVE, WHICH IS LABELED "N" IN FIG. 4, BRANCHES OFF INTO TINY NERVE FIBRES, EACH OF WHICH IS ATTACHED TO ONE OF THE HAIRS. THUS, THE VIBRATING AGITATION OF THE LIQUID IN THE INNER EAR ACTS UPON THE TINY HAIRS TO WHICH THE NERVE FIBRES ARE ATTACHED, STIMULATING THEM SO THAT THEY TRANSMIT THE IMPRESSIONS TO THE BRAIN IN SUCH A MANNER THAT WE RECOGNIZE THE SENSATION AS"SOUND".

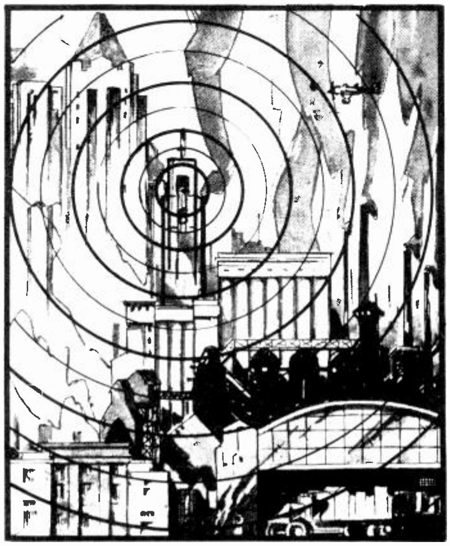

Fig. 5
Sound Waves Spread Out
In Spherical Form.

EQUALITY OF SOUND PROPAGATION

FROM YOUR OWN EXPERINECE, YOU WILL BE AWARE OF THE FACT THAT THE FARTHER YOU ARE FROM THE SOURCE OF THE SOUND, THE WEAKER WILL BE THE SOUND THAT REACHES YOU,FOR THE REASON THAT AS THE SOUND WAVES RADIATE OUTWARD, A CONTINUALLY INCREASING VOLUME OF AIR MUST BE ACTED UPON, WITH THE RESULT THAT MORE ENERGY IS REQUIRED TO MAINTAIN THEIR AMPLITUDE. THEREFORE, IT IS OBVIOUS THAT MORE AND MORE OF THE ORIGINAL ENERGY IMPARTED TO THE WAVES IS BEING CONSUMED IN AGITATING AN EVER-INCREASING AMOUNT OF AIR, AS THE DISTANCE FROM THE SOURCE OF THE

SOUND INCREASES, UNTIL WE FINALLY COME TO A POINT WHERE THE AIR WAVES CEASE, AND THEREFORE, NO SOUND IS HEARD.

THE EXPERIMENT AT THE LAKE (FIG. 3) WILL HELP TO MAKE THIS EXPLANATION STILL CLEARER, FOR WHEN THE STONE IS THROWN INTO THE WATER, WE FIND THAT THE WAVE MOTION SO PRODUCED WILL BE MOST VIOLENT NEAR THE POINT AT WHICH THE STONE PENETRATES THE WATER'S SURFACE. THEN, AS THE WAVE MOTION SPREADS OUTWARD OVER THE CALM SURFACE OF THE WATER, THE WAVES GRADUALLY BECOME LOWER, AND IF THE LAKE IS LARGE ENOUGH THEY WILL FINALLY DISAPPEAR. SO ALSO WITH SOUND WAVES, FOR AT GREATER DISTANCES THERE IS NOT ENOUGH WAVE MOTION REMAINING IN THE AIR TO ACTUATE THE EAR DRUM.

WATER ANALOGY OF SOUND WAVES

SINCE SOUND IS SO EXTENSIVELY USED IN RADIO WORK, IT IS NECESSARY TO ADOPT SOME METHOD WHEREBY SOUND WAVES CAN BE REPRESENTED IN PICTURE FORM, SIMPLY AS A MEANS OF CONVENIENCE. THIS MAY APPEAR RATHER ODD, BUT YOU WILL QUICKLY BECOME ACQUAINTED WITH THIS SYSTEM, SO THAT BEFORE LONG YOU WILL NOT CONSIDER DRAWING SOUND CURVES AS MORE PECULIAR THAN WRITING YOUR OWN NAME. NOT ONLY DO CURVES SUCH AS THIS SIMPLIFY THEIR DRAWING FOR EXPLANATORY PURPOSES, BUT IN ADDITION, THEY TELL A COMPLETE STORY OF THE PARTICULAR WAVEFORM IN QUESTION.

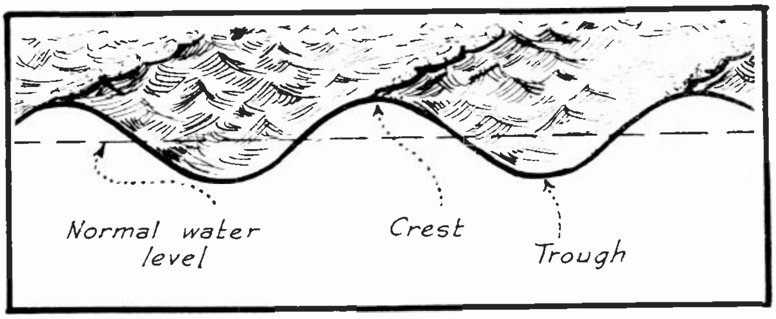

Fig. 6
Picturing Water Waves As A "Curve".

WE DRAW SOUND WAVES IN JUST THE SAME WAY AS WE WOULD DRAW WATER WAVES. FOR EXAMPLE, LET US SUPPOSE THAT WE HAVE A LARGE, SQUARE, GLASS TANK NEARLY FILLED WITH WATER. WITH THE WATER AT REST, WE FIND THAT IF WE PLACE OUR EYES AT THE WATER LEVEL, THE FLAT SURFACE OF THE WATER WILL APPEAR TO US AS A STRAIGHT HORIZONTAL LINE, WHICH WE COULD REPRESENT ON PAPER AS IN FIG. 6. WE CAN DESIGNATE THIS LINE AS REPRESENTING THE NORMAL WATER LEVEL.

NOW, SUPPOSE THAT WE AGITATE THE WATER, SO THAT WAVES ARE PRODUCED UPON ITS SURFACE. STILL FOCUSING OUR EYES AT THE SAME LEVEL AS BEFORE, WE FIND THAT THE WATER LINE NO LONGER APPEARS AS A HORIZONTAL LINE, BUT INSTEAD, AS A SERIES OF PEAKS AND VALLEYS WHICH WE CALL RESPECTIVELY THE "CRESTS" AND "TROUGHS" OF THE WAVE. THIS IS ILLUSTRATED BY THE HEAVY BLACK, WAVY LINE IN FIG. 6, AND BY REMOVING THE ARTISTIC REPRESENTATION OF WATER FROM THE DRAWING WE HAVE LEFT THE SIMPLE WAVE-FORM AS PICTURED IN FIG. 7. THIS IS THE WAY IN WHICH WE REPRESENT SOUND WAVES, AS WELL AS OTHER TYPES OF WAVES THAT ARE USED IN RADIO, AND WITH WHICH YOU WILL BECOME ACQUAINTED A LITTLE LATER.

WAVELENGTH

THERE ARE SOME IMPORTANT TERMS RELATIVE TO WAVES WHICH IT WILL BE NECESSARY FOR YOU TO LEARN, AND SEVERAL OF THEM ARE POINTED OUT IN FIG. 7.

THE FIRST OF THESE TERMS IS WAVELENGTH. IN FIG. 7 THE WAVELENGTH IS DISTANCE BETWEEN TWO SUCCESSIVE CRESTS OF THE WAVE, AND IT IS ALSO THE DISTANCE AS MEASURED BETWEEN TWO SUCCESSIVE TROUGHS OF THE SAME WAVE.

AMPLITUDE

THE OTHER TERM IN FIG.7 THAT YOU SHOULD LEARN IS AMPLITUDE, WHICH IS THE DISTANCE OF THE WAVE'S CREST ABOVE THE NORMAL LEVEL, AS POINTED OUT IN FIG. 7. IT IS ALSO THE DISTANCE OF THE WAVE'S TROUGH BELOW THE NORMAL LEVEL.

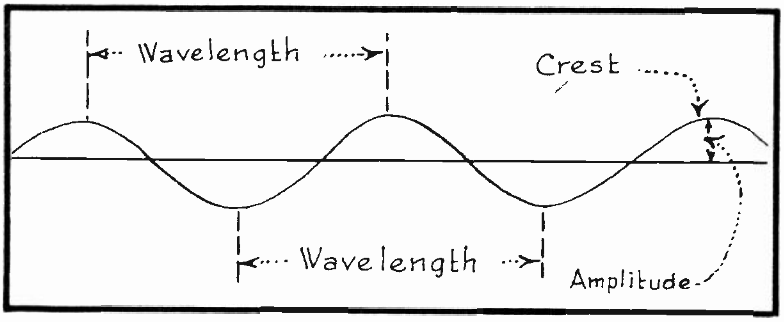

Fig. 7
"Drawing A Wave" For Radio Purposes.

FREQUENCY

A THIRD TERM, AND ONE OF EXTREME IMPORTANCE, IS FREQUENCY. SUPPOSE, FOR EXAMPLE, THAT WE CONSTRUCT A PLATFORM ABOVE THE SURFACE OF THE WATER, AND DRILL A HOLE THRU THE TOP OF THIS PLATFORM. IF WE SHOULD ATTACH A ROD TO A GOOD FLOAT, SUCH AS A BLOCK OF WOOD OR CORK, AND REST THE CORK UPON THE WATER'S SURFACE, WITH THE ROD PROTRUDING UP THROUGH THE HOLE IN THE PLATFORM, THEN WHENEVER A WAVE CREST PASSES THIS POINT,RAISING AND DROPPING IT IN ALTERNATION THE ACTION OF THE ROD WILL SHOW US WHENEVER A WAVE CREST PASSES THIS POINT.

SHOULD THIS SIMPLE ARRANGEMENT SHOW THAT 4 WAVE CRESTS PASS THIS POINT IN ONE MINUTE WE WOULD THEN SAY THAT THE FREQUENCY OF THIS MOTION IS 4 WAVES PER MINUTE. THIS CONDITION CAN BE ILLUSTRATED IN A VERY SIMPLE FORM, AS SHOWN IN FIG. 8. NOTICE THAT THERE IS LAID OFF A HORIZONTAL DISTANCE REPRESENTING ONE MINUTE OF TIME, AND THE WAVE FORM IS SO DRAWN THAT WE HAVE FOUR WAVE CRESTS DURING THIS INTERVAL.

BE SURE THAT YOU HAVE THESE THREE TERMS, WAVELENGTH, AMPLITUDE, AND FREQUENCY, WELL IN MIND, AND IF NECESSARY, READ THE LAST FEW PARAGRAPHS AGAIN, SO THAT THERE WILL BE NO DOUBT IN YOUR MIND AS TO WHAT EACH OF THESE EXTENSIVELY USED TERMS MEANS.

GRAPHIC REPRESENTATION OF SOUND WAVES

OUR REPRESENTATIONS OF WAVES HAVE THUS FAR BEEN CONFINED SOLELY TO WATER WAVES,BUT EACH OF THE POINTS DISCUSSED CONCERNING THEM APPLIES AS WELL TO SOUND WAVES. YOUR FIRST EXAMPLE OF SOUND WAVE IS LAID OUT FOR YOU IN FIG.9, AND YOU WILL IMMEDIATELY OBSERVE THAT THE WAVE-FORM LOOKS THE SAME AS THAT OF THE WATER WAVES THAT YOU STUDIED A FEW MOMENTS AGO.

FOR YOUR CONVENIENCE, WE ARE SHOWING YOU IN THE UPPER PORTION OF FIG. 9 A REPRESENTATION OF HOW THE AIR COMPRESSION AND RAREFACTIONS WOULD ACTUALLY APPEAR, IF THEY COULD BE SEEN,AS THE WAVE MOTION SPREADS OUTWARD THRU THE AIR, WHILE DIRECTLY BELOW IT IS SHOWN THE "CURVE"WHICH REPRESENTS THIS SAME WAVE MOTION.

THE HORIZONTAL LINE DRAWN THRU THE CENTRAL PORTION OF THIS CURVE REPRESENTS THE CONDITION OF THE ATMOSPHERE OR AIR WHEN AT REST OR IN ITS NATURAL STATE -- THAT IS, AT THE TIME WHEN NO SOUND WAVES EXIST. THAT PART OF THE CURVE WHICH EXTENDS ABOVE THE HORIZONTAL LINE REPRESENTS THE COMPRESSED PORTION OF THE AIR.

NOTICE IN FIG. 9 THAT THE WAVELENGTH OF THE SOUND WAVE IS INDICATED AS BEING EQUAL TO THE DISTANCE BETWEEN TWO ADJACENT COMPRESSED SECTIONS, OR THE DISTANCE BETWEEN TWO CRESTS OF THE WAVE FORM. THE WAVE LENGTH OF THAT PARTICULAR SOUND WAVE CAN, OF COURSE, ALSO BE CONSIDERED AS EQUAL TO THE DISTANCE BETWEEN TWO ADJACENT TROUGHS OR RAREFIED REGIONS OF THE AIR. SO YOU CAN SEE THAT SOUND WAVES AND WATER WAVES CAN BE COMPARED QUITE CLOSELY.

IN FIG. 9, ALSO OBSERVE THAT THE AMPLITUDE OF THIS PARTICULAR SOUND WAVE IS INDICATED AS BEING THE DISTANCE OF THE CREST ABOVE THE HORIZONTAL LINE, OR THE DISTANCE OF THE TROUGH BELOW THE HORIZONTAL LINE. AS IN WATER WAVES, THE AMPLITUDE OF THE SOUND WAVES CONSTITUTES THE VIOLENCE OF THE WAVE, AND THE GREATER THE AMPLITUDE OF THE SOUND WAVES -- OR THE MORE VIOLENT THE WAVE MOTION, THE LOUDER WILL BE THE SOUND.

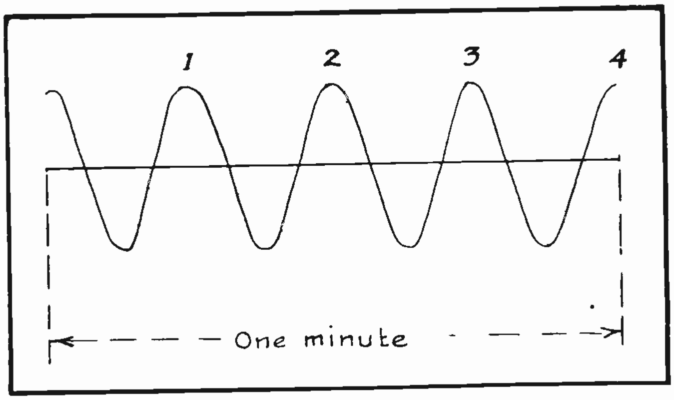

Fig. 8
A Representation Of The Frequency Of A Wave Motion.

IN THE CASE OF SOUND WAVES, WE MUST ALSO DEAL WITH THE EXPRESSION "FREQUENCY". THAT IS, EACH SOUND WAVE IS CONSIDERED AS SET UP BY A CERTAIN NUMBER OF VIBRATIONS PER SECOND -- OR STILL BETTER -- A CERTAIN NUMBER OF CYCLES PER SECOND. THE TERM "CYCLES" IS GENERALLY USED, AND IT SIGNIFIES A COMPLETE VIBRATION. THAT IS, FROM ONE CREST OF THE WAVE FORM TO THE NEXT CREST, FROM ONE TROUGH TO THE NEXT, OR FROM ANY POINT OF THE WAVE FORM TO THE FOLLOWING CORRESPONDING POINT. THE CYCLE IS ALSO PICTURED FOR YOU IN FIG. 9.

TO ILLUSTRATE THIS POINT EVEN MORE CLEARLY, LET US LOOK AT FIGS. 10 AND 11. IN FIG. 10 WE HAVE A SOUND WAVE CONSISTING OF 4 COMPLETE VIBRATIONS, OR 4 CYCLES PER SECOND, WHILE IN FIG. 11 THE SOUND WAVE CONSISTS OF 8 COMPLETE VIBRATIONS, OR 8 CYCLES PER SECOND.

EFFECT OF SOUND WAVES AMPLITUDE AND FREQUENCY

IN THESE TWO ILLUSTRATIONS YOU WILL OBSERVE THAT THE AMPLITUDE OF THE WAVE FORM IS THE SAME IN BOTH DRAWINGS, BUT THE FREQUENCY OF THE SOUND WAVE IN FIG. 11 IS GREATER. THAT IS, THERE ARE MORE CYCLES PER SECOND THAN IN FIG. 10.

SINCE THE AMPLITUDE OF THE WAVE FORMS IN FIGS. 10 AND 11 ARE ALIKE, THE INTENSITY OR LOUDNESS OF THE SOUNDS PRODUCED BY BOTH WILL BE THE same. However, the FREQUENCY OF SOUND WAVES DETERMINES THE PITCH OF THE SOUND PRODUCED, and for this reason, the sound produced by the wave form of Fig. 10 will not be the same as that produced by the wave form of Fig. 11. It will be HIGHER IN PITCH; that is, a higher tone will be produced than that produced by the wave of Fig. 10.

In other words, sound waves of high frequency produce sounds that are high in pitch; another way of saying the same thing is that THE GREATER THE FREQUENCY OF THE SOUND WAVE, THE HIGHER WILL BE THE PITCH OF THE TONE. Conversely, sound waves of low frequency produce sounds of low pitch, and the lower the frequency, the lower will be the pitch of the sound.

This serves to explain why an ordinary violin produces high tones; whereas, a bass violin produces low tones. For example, the strings on the bass violin are comparatively long, and their tension is so adjusted that when plucked they will vibrate naturally at a correspondingly low frequency. This vibration sets the surrounding air into vibration at the same frequency, so that upon striking the ear drum this wave motion of low frequency produces a sensation recognized by the brain as a tone that is low in pitch.

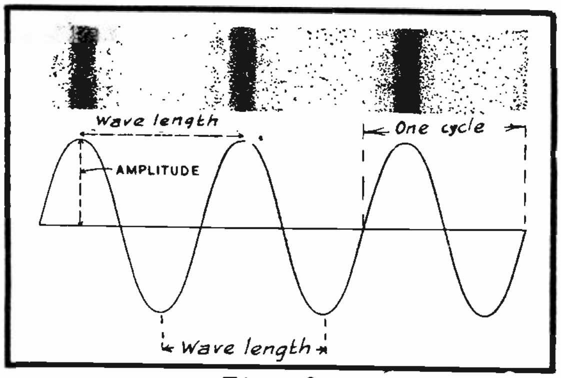

Fig. 9
A Graphic Representation Of Sound Waves.

The violin, on the other hand, employs shorter strings whose tension is rather great; therefore, when plucked, their natural tendency is to vibrate at a more rapid rate and to produce a sound wave of high frequency, so that upon its reception by the ear, the sensation of a high pitched sound is experienced.

The violence with which the string is plucked has nothing to do with the pitch. It simply causes sound waves of greater amplitude to be generated, and this affects only the intensity or loudness of the sound.

THE AUDIBLE FREQUENCY RANGE

There is a limit to the number of vibrations or cycles per second that the human ear can detect as sound; in fact, this limit differs as between individuals. In general, the human ear will recognize as sound only those waves corresponding to frequencies ranging from 20 cycles per second to 20,000 cycles per second. Persons with impaired hearing, however, are limited to a still smaller frequency range and may, therefore, lack the ability to recognize very high or very deep tones.

It may also interest you to know that in the present state of radio broadcasting, sound waves of frequencies up to only 10,000 cycles per second are transmitted, yet the sound reproduction is pleasing to the ear. In fact, in most cases, radio transmitters radiate only those sound whose frequencies range from 30 to 8,000 cycles per second.

THE HUMAN AUDITORY SYSTEM IS ALSO LIMITED AS TO THE INTENSITY OF SOUND WHICH IT CAN ACCEPT WITH COMFORT. THAT IS, IF THE AMPLITUDE OF THE SOUND WAVE IS TOO GREAT, SO THAT THE INTENSITY OF SOUND BECOME EXCESSIVE IT ACTUALLY BECOMES PAINFUL. TO AVOID THIS SENSATION, WE HAVE A NATURAL TENDENCY TO COVER THE EARS WITH OUR HANDS WHEN ANTICIPATING VERY LOUD SOUNDS, TO PREVENT THE SOUND WAVES FROM STRIKING THE EAR DRUMS WITH FULL FORCE.

THEN, OF COURSE, WE MAY ALSO HAVE A CONDITION WHERE A SOUND THAT IS PAINFUL TO ONE PERSON WHO HAS A VERY SENSITIVE HEARING SYSTEM, MAY BE HARDLY PERCEPTIBLE TO ANOTHER WHO IS PARTIALLY DEAF. IN TURN, WE ALSO FIND THAT SOUND WAVES MAY BE OF SUCH SMALL AMPLITUDE THAT EVEN A PERSON WITH AN AUDITORY SYSTEM OF AVERAGE SENSITIVITY CANNOT DETECT THEM.

QUALITY OF SOUND

THIS BRINGS US TO ANOTHER VERY INTERESTING POINT, THE MATTER OF QUALITY PERTAINING TO SOUND. TO ILLUSTRATE, LET US CONSIDER THE TONE OF MIDDLE "C" WHICH IS PRODUCED BY A FREQUENCY OF 256 CYCLES PER SECOND, REGARDLESS OF WHETHER THIS SAME NOTE SHOULD BE PRODUCED BY A PIANO, VIOLIN, CLARINET, CORNET, OR ANY OTHER INSTRUMENT. YET THERE IS SOME PECULIAR CHARACTERISTIC EMBODIED IN THE SOUNDS OF THESE DIFFERENT INSTRUMENTS WHICH ENABLES US TO DETERMINE ONE FROM THE OTHER. WE CALL THIS PECULIAR CHARACTERISTIC TIMBRE OR QUALITY.

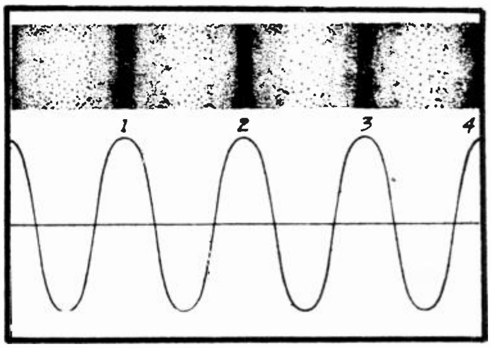

Fig. 10
A Sound Wave Of 4 Cycles Per Second.

THE TIMBRE OF ALL THESE DIFFERENT INSTRUMENTS, OR OF ANY TYPE OF SOUND, FOR THAT MATTER, IS DUE TO OTHER AND LESSER SOUNDS OR OVERTONES WHICH ACCOMPANY THE FUNDAMENTAL NOTE PRODUCED BY THE INSTRUMENT. FOR INSTANCE, WHEN THE NOTE CORRESPONDING TO MIDDLE "C" ON THE PIANO IS PLAYED ON THE CORNET, AS THE AIR PASSES THROUGH THE AIR CHAMBERS OF THE INSTRUMENT AND FINALLY EMERGES, IT SETS THE SURROUNDING AIR INTO A SIMILAR VIBRATION SO AS TO TRANSMIT THIS FUNDAMENTAL SOUND OF MIDDLE "C".

IN ADDITION TO THIS FUNDAMENTAL FREQUENCY, HOWEVER, OTHER TONES ARE AUTOMATICALLY BLENDED WITH IT, AND THESE TONES ARE SPOKEN OF AS "OVERTONES" OR "HARMONICS". THEY ARE LESS PROMINENT THAN THE FUNDAMENTAL FREQUENCY WHICH DETERMINES THE NOTE BEING PRODUCED. ALL INSTRUMENTS PRODUCE OVERTONES AND HARMONICS TO A GREATER OR LESS DEGREE, AND IT IS THESE INTERMINGLING FREQUENCIES THAT SUPPLY THE CHARACTERISTIC RICHNESS OF TONE TO THE VARIOUS INSTRUMENTS. SINCE THE NUMBER AND RELATIVE INTENSITY OF THE OVERTONES PRODUCED BY THE VARIOUS INSTRUMENTS IS NOT THE SAME, WE FIND THAT EACH TYPE OF INSTRUMENT HAS ITS INDIVIDUAL TONE QUALITY OR TIMBRE.

SOUNDS PRODUCED BY VARIOUS INSTRUMENTS

THUS FAR, YOU HAVE LEARNED THAT STRINGED INSTRUMENTS PRODUCE SOUNDS DUE TO THE VIBRATION OF THE STRING, WHICH MAY BE BROUGHT ABOUT BY PLUCK-

ING, DRAWING A BOW OVER THEM, AS IN THE CASE OF THE VIOLIN, OR BY STRIKING THEM, AS WHEN THE KEY OF A PIANO IS DEPRESSED. IN ALL OF THESE CASES, RESONANCE BOXES ARE EMPLOYED TO REINFORCE THE SOUND SO PRODUCED, AS WELL AS TO ENRICH THE TONES.

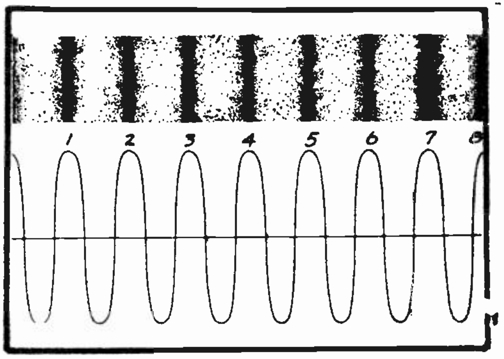

Fig. 11
A Sound Wave Of 8 Cycles Per Second.

IN THE CASE OF DRUMS, ETC., A SKIN, WOOD, OR OTHER SUITABLE MATERIAL IS CAUSED TO VIBRATE BY MEANS OF A BLOW APPLIED BY THE MUSICIAN, THEREBY SETTING THE SURROUNDING AIR INTO THE REQUIRED VIBRATION. HERE THE NATURE OF THE TONE PRODUCED IS DETERMINED BY THE TENSION OR ELASTICITY OF THE MEMBRANE OR BODY TO WHICH THE FORCE IS APPLIED, AIDED BY THE FORM OF THE RESONANCE CHAMBER.

WIND INSTRUMENTS DEPEND UPON THE EFFORTS OF THE MUSICIAN IN BLOWING AIR THROUGH HIS LIPS, OR THROUGH REEDS OR SPECIALLY DESIGNED PASSAGES, SO THAT THE AIR, UPON EMERGING FROM THE INSTRUMENT, WILL AGITATE THE SURROUNDING AIR AT THE REQUIRED FREQUENCY TO PRODUCE THE DESIRED TONE.

THE HUMAN VOICE

NOW WE COME TO THE MOST WONDERFUL SOUND-PRODUCER OF ALL -- THE HUMAN VOICE. TO DESCRIBE THIS DELICATE APPARATUS WE WILL MAKE USE OF FIG. 12, WHICH SHOWS A SECTIONAL VIEW OF THE HUMAN HEAD. THE PARTS THAT CONSTITUTE THE ORGANS OF SPEECH ARE INDICATED THEREON.

THE TRACHEA OR "WINDPIPE" IS THE TUBE THROUGH WHICH AIR CAN BE EXPELLED FROM THE LUNGS INTO THE MOUTH. A MUSCULAR STRUCTURE, COMMONLY SPOKEN OF AS THE "VOCAL CORDS", IS STRETCHED ACROSS THE UPPER END OF THE TRACHEA, AND FORMS A SLIT OR SPACE THROUGH WHICH AIR PASSES AS IT IS EXPELLED FROM THE LUNGS.

BY MUSCULAR ACTION THE OWNER OF THESE CORDS CAN REGULATE THEIR TENSION AND THE SPACE BETWEEN THEM. WHEN WE SPEAK, WE EXPEL AIR FROM THE LUNGS, THROUGH THE TRACHEA AND THENCE THROUGH THE SLIT FORMED BY THE VOCAL CORDS, AND ON INTO THE MOUTH. THIS AIR-FLOW CAUSES THE VOCAL CORDS TO VIBRATE IN MUCH THE SAME MANNER AS DOES A STRING ON A GUITAR OR MANDOLIN.

WHILE SPEAKING, THE OPENING BETWEEN THE VOCAL CORDS IS ALTERNATELY INCREASED AND DECREASED, THEREBY CAUSING THE AIR TO BE PASSED BY THE VOCAL CORDS IN A SERIES

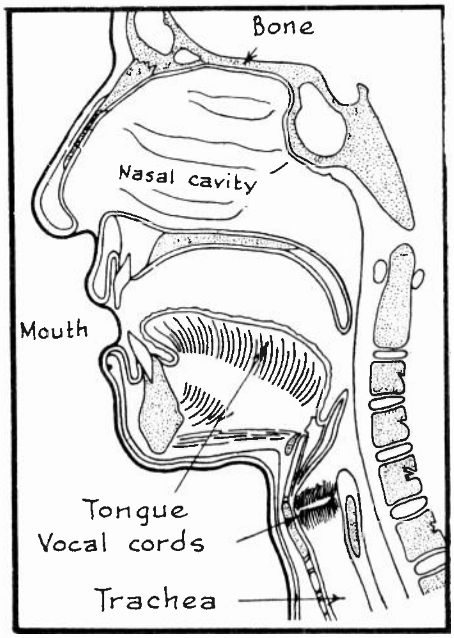

Fig. 12
Sectional View Of The Human Head.

OF WAVES. THESE SOUND WAVES ARE ARRANGED IN A CERTAIN FORMATION, OR "MODULATED", IN THE VOCAL CAVITIES OF THE HEAD. THIS IS BROUGHT ABOUT BY MOVEMENT OF THE TONGUE AND LIPS, WHICH ENABLES THE FORMATION OF THE DIFFERENT SOUNDS CORRESPONDING TO THE VARIOUS LETTERS OF THE ALPHABET. THESE MODULATED SOUND WAVES THEN SPREAD OUTWARD FROM THE MOUTH AND INTO THE AIR, AS ILLUSTRATED IN FIG. 13, AND THENCE TO THE EARS OF ANYONE WITHIN HEARING DISTANCE.

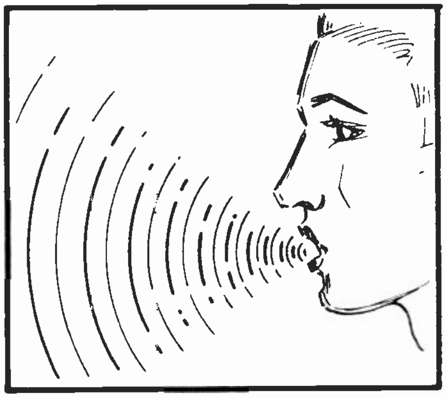

Fig. 13
Emission Of Sound Waves From The Mouth.

THE FUNDAMENTAL FREQUENCY OF THE AVERAGE MALE VOICE IS APPROXIMATELY 120 CYCLES PER SECOND, WHILE THAT OF THE FEMALE VOICE IS IN THE VICINITY OF 240 CYCLES PER SECOND. HOWEVER, WHEN SPEAKING OR SINGING, OVERTONES OR HARMONICS ARE PRODUCED, AND AT TIMES THESE REACH FREQUENCIES AS HIGH AS 9000 CYCLES.

VELOCITY OF SOUND

WE WILL NEXT CONSIDER THE SPEED OF SOUND. NO DOUBT YOU HAVE AT TIMES SEEN A STEAM WHISTLE BLOWING AT A CONSIDERABLE DISTANCE, AND NOTICED THAT YOU COULD SEE THE STEAM EMERGING FROM THE WHISTLE BEFORE HEARING THE SOUND. SEVERAL SECONDS MAY HAVE ELAPSED BEFORE THE SOUND REACHED YOUR EARS. THIS EVERY-DAY EXPERIENCE IS A FINE EXAMPLE TO DEMONSTRATE THE FACT THAT THE TRANSMISSION OF SOUND IS NOT INSTANTANEOUS, BUT THAT SOUND WAVES EXTEND OUTWARD FROM THEIR ORIGIN IN A GRADUAL MANNER. TO BE MORE SPECIFIC, SOUND WAVES TRAVEL THROUGH AIR AT THE SPEED OF 1100 FEET PER SECOND.

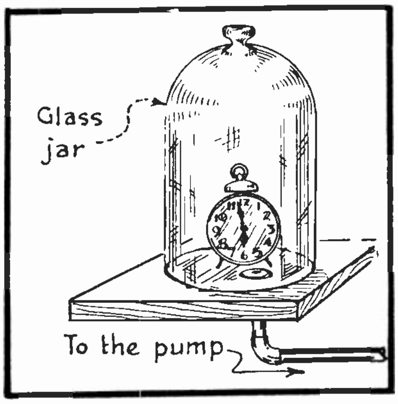

Fig. 14
The Vacuum Experiment.

CONDUCTING MEDIUMS OF SOUND WAVES

ANOTHER INTERESTING AND IMPORTANT FACT TO REMEMBER IS THAT SOUND WAVES TRAVEL THROUGH SOLIDS, LIQUIDS, AIR, OR ANY OTHER CONDUCTING MEDIUM, BUT WILL NOT TRAVEL THROUGH A VACUUM. THIS CAN BEST BE DEMONSTRATED AS SHOWN IN FIG. 14, WHEREIN AN ALARM CLOCK IS ENCLOSED IN A GLASS JAR. SHOULD THE CLOCK BE PERMITTED TO RING UNDER THESE CONDITIONS, WE WILL BE ABLE TO HEAR IT, AND ITS SOUND WILL NOT BE GREATLY DIMINISHED. HOWEVER, IF BY MEANS OF A VACUUM PUMP WE SHOULD DRAW ALL AIR OUT OF THIS JAR, SO THAT THE CLOCK WILL BE ENCLOSED WITHIN A VACUUM, WE WILL THEN BE UNABLE TO HEAR ANY SOUND, EVEN THOUGH THE ALARM BE IN OPERATION. THE REASON IS THAT UNDER THESE CONDITIONS NO SOUND-CONDUCTING MEDIUM EXISTS BETWEEN THE CLOCK, THE GLASS JAR, AND THE SURROUNDING ATMOSPHERE.

RESONANCE

MORE THAN LIKELY, YOU HAVE BY THIS TIME DECIDED THAT THERE ARE A GREAT MANY CHARACTERISTICS ASSOCIATED WITH ACOUSTICS OR THE SCIENCE OF SOUND, AND NOW WE COME TO STILL ANOTHER, RESONANCE. YOU WILL USE THIS

EXPRESSION,"RESONANCE", FREQUENTLY IN YOUR RADIO CAREER, SO YOU MUST BECOME ACQUAINTED WITH IT AS SOON AS POSSIBLE.

THE SIMPLEST METHOD TO REACH AN UNDERSTANDING OF RESONANCE IS BY MEANS OF AN EXPERIMENT WITH WHICH YOU ARE NO DOUBT ALREADY FAMILIAR. FOR INSTANCE, IF YOU MAKE A SOUND WITH YOUR MOUTH, OR SING CLOSE TO THE STRINGS OF A PIANO OR HARP, CERTAIN STRINGS OF THE INSTRUMENT WILL RESPOND, AND WILL PRODUCE THE SAME TONE. THE REASON IS THAT THE STRING RESPONDS OR IS "TUNED" TO THE SAME FREQUENCY AS THAT OF THE SOUND WAVE WHICH STRIKES IT.

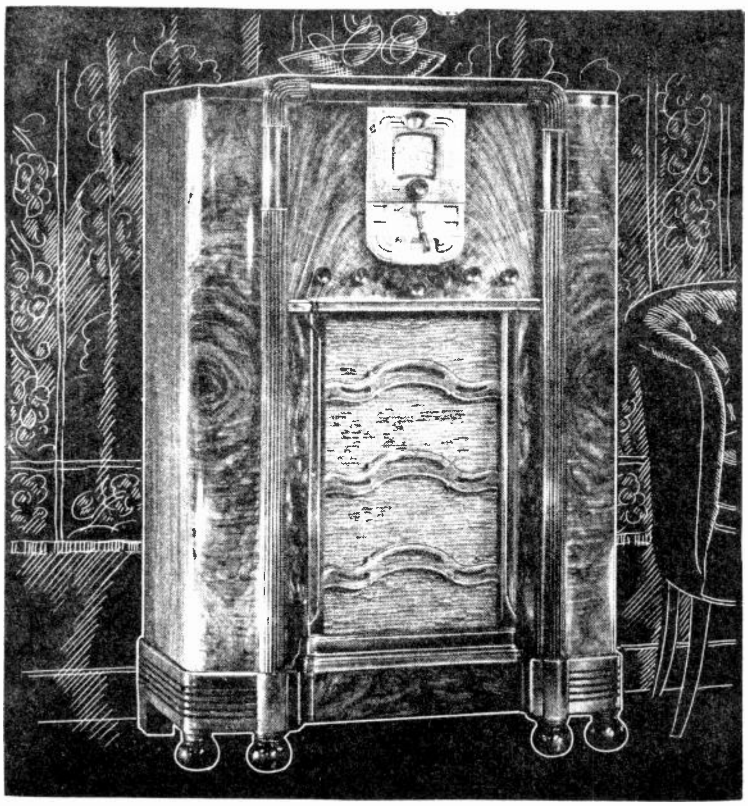

Fig. 15
Tone Quality - A Demand From Modern Receivers.

SINCE THIS IS THE NATURAL FREQUENCY AT WHICH THE STRING VIBRATES, IT WILL BE STIMULATED INTO ACTION BY THE SOUND WAVE, SO THAT IT COMMENCES TO VIBRATE AND TO PRODUCE THE SAME TONE. WE CALL THIS "SYMPATHETIC VIBRATION", AND THE STRING IS SAID TO BE IN RESONANCE, OR OF LIKE FREQUENCY CHARACTERISTIC, AS THE SOURCE OF SOUND WHOSE WAVE STARTS IT INTO ACTION.

THIS SAME CHARACTERISTIC CAN BE WITNESSED WHEN TWO STRINGS OF AN INSTRUMENT ARE TUNED TO THE SAME NOTE OR FREQUENCY. IF THESE TWO STRINGS ARE RATHER CLOSE TO EACH OTHER, AND IF YOU PLUCK ONLY ONE OF THEM, THE OTHER WILL COMMENCE TO VIBRATE AND WILL EMIT THE SAME TONE. THE TWO STRINGS ARE THEN SAID TO BE IN RESONANCE WITH EACH OTHER; OR, AS THE MUSICIAN SAYS, THEY ARE "IN TUNE".

THIS PHENOMENA IS PRESENT IN MOST BODIES, FOR NEARLY ALL BODIES HAVE A NATURAL VIBRATING PERIOD. THAT IS, MASSES OF GLASS, WOOD, ETC, ALL HAVE THE TENDENCY TO VIBRATE AT SOME FREQUENCY, AND THIS VERY THING IS QUITE OFTEN RESPONSIBLE FOR RATTLING AND OTHER ANNOYING SOUNDS IN RADIO RECEIVERS. FOR EXAMPLE, IF A PIECE OF METAL SOMEWHERE IN THE RECEIVER CHASSIS OR CABINET STRUCTURE IS FREE TO VIBRATE, AND ITS NATURAL VIBRATING PERIOD HAPPENS TO BE 300 CYCLES PER SECOND, THEN WHENEVER A NOTE OF 300 CYCLES IS REPRODUCED BY THE LOUDSPEAKER WITH SUFFICIENT VOLUME, THIS PIECE OF VIBRATING METAL WILL CAUSE AN ANNOYING BUZZING SOUND. TO OVERCOME THIS, THE DISTURBING PART WILL HAVE TO BE PREVENTED FROM VIBRATING, OR ITS STRUCTURE CHANGED SO THAT ITS NEW NATURAL FREQUENCY IS ONE THAT WILL NOT RESPOND TO ANY TONES PRODUCED BY THE SPEAKER.

THE MUSICAL SCALE

IN FIG. 16 YOU WILL FIND A VERY USEFUL CHART WHICH SHOWS YOU THE RANGE OF FUNDAMENTAL FREQUENCIES COVERED BY THE VARIOUS TYPES OF MUSICAL INSTRUMENTS, AND BY THE HUMAN VOICE. TO SIMPLIFY MATTERS, THE PIANO KEYBOARD IS LAID OUT FOR YOU AT THE BASE OF THIS CHART, AND DIRECTLY ABOVE EACH KEY THE CORRESPONDING NOTE IS REPRESENTED BY THE LETTERS, A, B, C, ETC., IN ADDITION TO THE PITCH EXPRESSED IN CYCLES PER SECOND. MIDDLE "C" OF THE PIANO, FOR EXAMPLE, IS SHOWN AS HAVING A FREQUENCY OF 256 CYCLES PER SECOND.

THE NOTE CORRESPONDING TO THE KEY MARKED AS C′ AND 512 CYCLES PER SECOND IS ONE OCTAVE, OR THE 8TH FULL NOTE, HIGHER IN PITCH THAN MIDDLE C; THE "OCTAVE" OF ANY FREQUENCY IS A FREQUENCY TWICE AS GREAT. THE NEXT OCTAVE WILL BE "HIGH C", MARKED ABOVE THE PIANO KEY IN FIG. 16 BY C^2, AND ITS FREQUENCY WILL BE TWICE THAT OF C′ OF 1024 CYCLES PER SECOND.

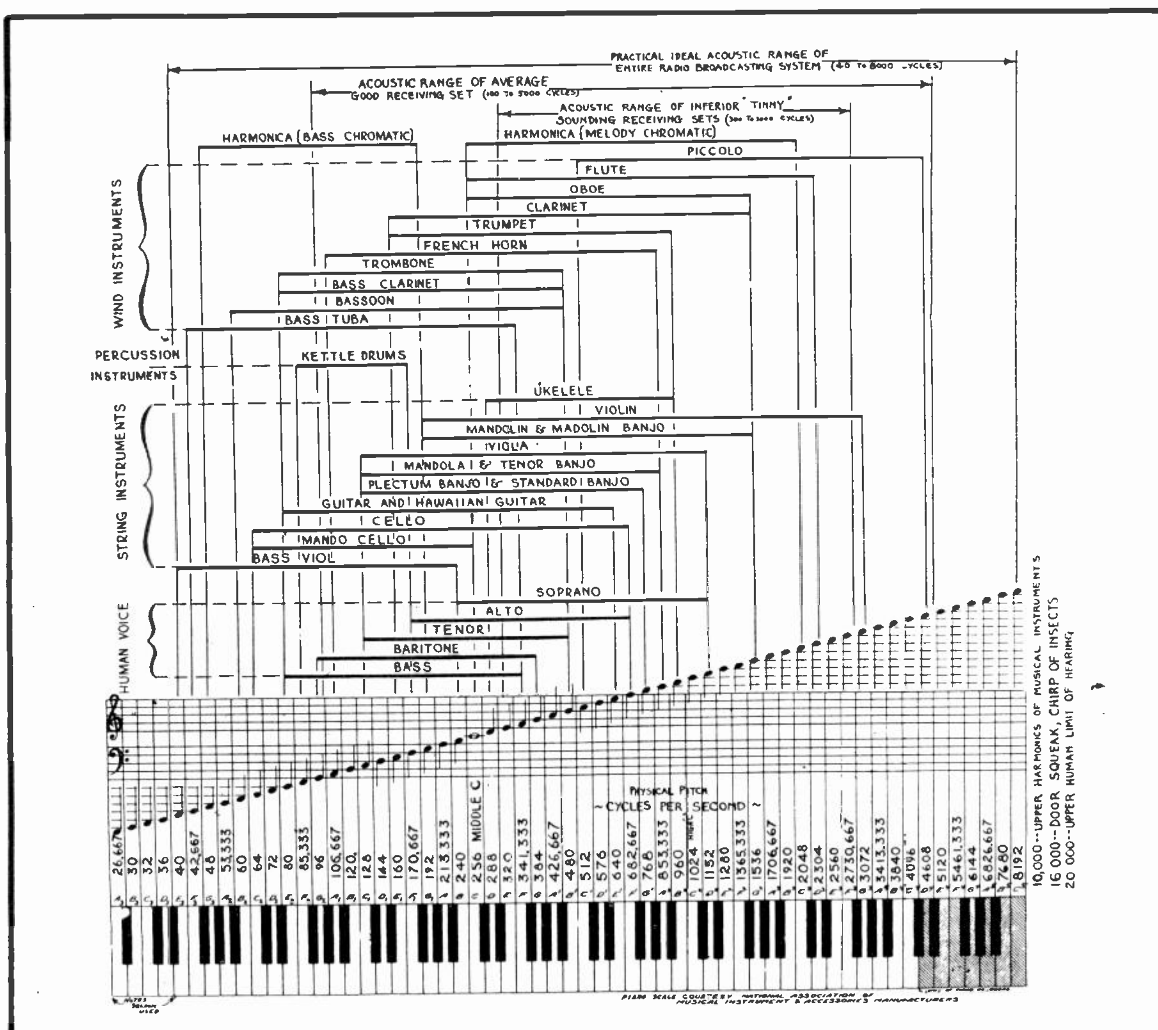

Fig. 16
Chart Showing Frequencies Of The Various Notes On A Piano Keyboard, And The Frequency Ranges Of Some Musical Instruments.

From middle C toward the left of the keyboard the frequencies and pitches become lower. One octave below middle C, for instance, will correspond to C_1, which has a frequency equal to one-half that of middle C, or 128 cycles per second. In this direction, we work into the bass notes or deep tones.

Directly above the musical scale, the frequency-range of each distinct type of human voice or musical instrument is clearly marked, so that you can very easily compare them, and in this way provide yourself with a clear mental picture of conditions just as they are in actual practice.

The piano, organ, and harp will handle about the same frequency range, greater than that of any other common types of instruments. All other instruments have a rather restricted range - some being confined to the lower frequencies, others to the medium frequencies, and a few are restricted to the higher frequency range.

Large symphony orchestras generally include all of the various types of instruments mentioned on the chart of Fig. 16, so that notes will be produced throughout the entire musical scale, from the lowest to the highest audible frequencies. Therefore, in order for transmitters and receivers to reproduce such symphonic selections faithfully, it is evident that the electrical equipment must be designed in such a manner as to handle this great frequency range efficiently. You will no doubt agree that this is a very big job.

Observe in Fig. 16 that the practical, ideal, acoustic range of the entire radio broadcasting system is specified as extending from about 40 to 8000 cycles per second. The acoustic range of the average "good" receiving set, however extends only from about 100 to 5000 cycles per second, while that of the inferior "tinny" receiver extends only from 300 to 3000 cycles per second.

EFFECTS OF FREQUENCY RESTRICTION

If you have had the opportunity to compare the tone quality of a fine radio receiver with that of a receiver of inferior design, you must have noticed that the better receiver reproduced the sounds with greater brilliance. The reason is that the better the design of a receiver, the greater will be the range of audible frequencies reproduced by it.

In other words, if a receiver does not have the ability to reproduce the lower tones produced by the full orchestra which is providing the entertainment, bass notes will be lacking and the music will appear high pitched. That is, the music as received is DISTORTED, and loses its naturalness. In like manner, if the receiver fails to reproduce the higher audible frequencies in their proper proportion, the reproduction appears unpleasantly deep or "boomy".

YOU NEED A KNOWLEDGE OF SOUND

After all of the many things that you have learned from this lesson in connection with sound, you will no doubt agree that this study is

OF GREAT IMPORTANCE IN PROVIDING YOU WITH KNOWLEDGE NECESSARY TO YOUR SUCCESS IN THE RADIO PROFESSION. TO SERVICE RADIO RECEIVERS SO THAT AN IMPROVEMENT CAN BE MADE IN THE TONE QUALITY, THE RADIO TECHNICIAN MUST HAVE A CLEAR UNDERSTANDING OF THE PRINCIPLES OF SOUND, AND THIS IS ALSO TRUE WHEN HE IS CALLED UPON TO DESIGN RADIO SOUND-REPRODUCING EQUIPMENT OF HIGH QUALITY.

DUE TO THE GREAT IMPORTANCE OF THE SUBJECT MATTER PRESENTED IN THIS LESSON, IT IS NECESSARY FOR YOU TO STUDY THIS LESSON VERY CAREFULLY BEFORE CONTINUING WITH THE NEXT ONE. IF NECESSARY, READ THIS LESSON A SECOND OR EVEN A THIRD TIME BUT BY ALL MEANS BE SURE TO MASTER IT.

DURING YOUR WORK BOTH AS A STUDENT AND WHEN ACTIVE IN THE FIELD YOU WILL CONTINUOUSLY USE THESE PRINCIPLES OF SOUND, AND THEY WILL TIME AND AGAIN SERVE AS A VALUABLE TOOL DIRECTLY APPLICABLE TO RADIO.

BEFORE LAYING THIS LESSON ASIDE, BE SURE TO ANSWER THE EXAMINATION QUESTIONS TO THE BEST OF YOUR ABILITY. THEN IN THE FOLLOWING LESSON, WE WILL COMMENCE WITH THE STUDY OF HOW RADIO MESSAGES ARE PRODUCED, TRANSMITTED AND AGAIN REPRODUCED AT THE RECEIVER.

DEAR STUDENT—

A successful life must have Aim and Purpose. When we are without aim, we are without hope of accomplishing anything worth while. On the other hand, if we do have a set purpose and the courage and backbone to achieve it, we are bound to succeed.

On our pathway we may meet discouragement, obstacles, even temporary failure, but we must not lose hope. We must have strength of character, and the determination to follow our aim consistently and courageously.

Let's remember that Aimlessness spells Hopelessness, and that Purpose and Backbone Spell Accomplishment.

JAR

RADIO - TELEVISION

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

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LESSON NO. 2

RADIO COMMUNICATION

UPON COMPLETING THIS LESSON, YOU WILL HAVE A CLEAR UNDERSTANDING OF HOW SOUNDS ARE TRANSMITTED THROUGH SPACE BY RADIO AND AGAIN FAITHFULLY REPRODUCED AT THE RECEIVER. YOU WILL FIND YOUR ADVANCEMENT TO BE RAPID FROM THE VERY BEGINNING OF YOUR TRAINING, THEREBY ENABLING YOU TO REACH YOUR STUDIES OF RECEIVER CONSTRUCTION AND SERVICING AS SOON AS POSSIBLE. THIS IN TURN MEANS THAT YOU WILL BE IN A POSITION TO EARN SPARE-TIME MONEY WITH YOUR RADIO KNOWLEDGE WITHIN A SHORT TIME AFTER COMMENCING YOUR TRAINING.

THE LOGICAL POINT AT WHICH TO COMMENCE OUR INVESTIGATION OF RADIO COMMUNICATION IS WITH THE TRANSMITTER AND IN ORDER TO MAKE THINGS AS EASY AS POSSIBLE FOR YOU, THIS FIRST TRANSMITTER WHICH IS BEING BROUGHT BEFORE YOU IS A VERY SIMPLE ONE, CONSISTING OF NOTHING MORE THAN A VIBRATOR TYPE INDUCTION COIL, A PAIR OF ELECTRODES, A BATTERY, A TELEGRAPH KEY, AN ANTENNA AND A GROUNDED WATER PIPE --ALL CONNECTED TOGETHER AS ILLUSTRATED IN FIG. 2.

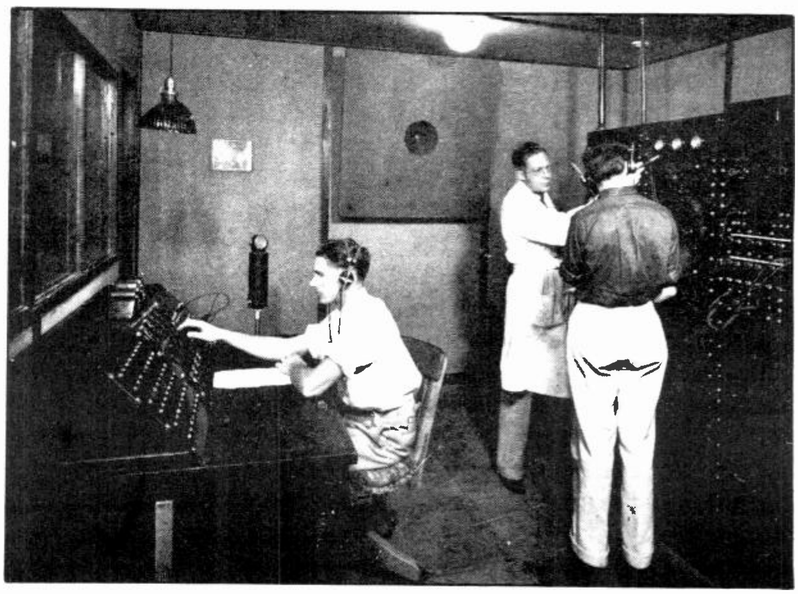

FIG. 1
Students operating control-room equipment of National's broadcast transmitter

IN ORDER THAT YOU MAY GAIN A STILL CLEARER CONCEPTION OF THE "HOOK

UP" OF THIS EQUIPMENT, IT IS BEING ILLUSTRATED AGAIN IN FIG. 3, ONLY IN THIS CASE IT APPEARS IN THE FORM OF A CIRCUIT DIAGRAM.

WE USE SUCH CIRCUIT DIAGRAMS A GREAT DEAL IN RADIO AND THEREFORE, IT IS IMPORTANT THAT YOU ANALYZE FIG. 3 VERY CAREFULLY, NOTING ESPECIALLY THE RADIO SYMBOLS WHICH ARE EMPLOYED TO DESIGNATE THE VARIOUS PARTS SUCH AS THE ANTENNA, GROUND CONNECTION, BATTERY, TELEGRAPH KEY, ETC.,--- WHICH APPEAR IN FIG. 2. AS A GENERAL RULE, CIRCUIT DIAGRAMS CONVEY A MORE COMPLETE PICTURE TO THE EYE AND MIND WHICH IS TRAINED FOR RADIO, THAN DOES AN ELABORATE DRAWING AND IT IS EXTREMELY IMPORTANT THAT YOU ACCUSTOM YOURSELF TO READ THEM AS SOON AS POSSIBLE.

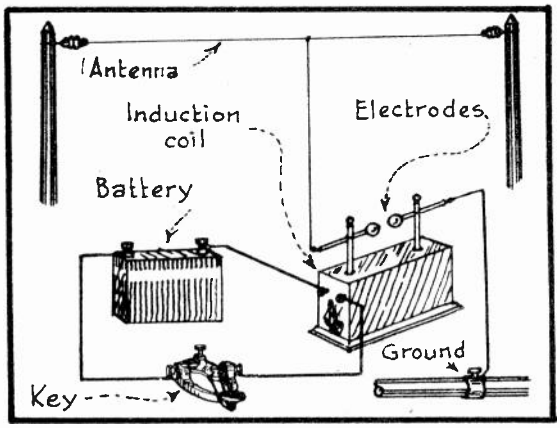

FIG. 2
The simple spark transmitter.

AS YOU WILL OBSERVE IN FIG. 3, THE INDUCTION COIL CONSISTS OF A PRIMARY WINDING AND A SECONDARY WINDING, BOTH WOUND AROUND AN IRON CORE. A SET OF VIBRATOR POINTS IS CONNECTED IN SERIES WITH THE PRIMARY WINDING. (A VIBRATOR-TYPE IGNITION COIL, SUCH AS USED IN THE MODEL "T" FORD AUTOMOBILE, IS A FINE EXAMPLE OF THIS INDUCTION COIL.)

TWO BALL-SHAPED METAL ELECTRODES ARE SLIGHTLY SEPARATED FROM EACH OTHER AND EACH OF THEM, IS CONNECTED TO AN END OF THE INDUCTION COIL'S SECONDARY WINDING. IN ADDITION, ONE OF THE ELECTRODES IS CONNECTED TO THE ANTENNA, WHICH IS IN THE FORM OF AN ELEVATED COPPER WIRE SUSPENDED HORIZONTALLY BETWEEN TWO POLES. THE OTHER ELECTRODE IS CONNECTED TO A COLD-WATER PIPE WHICH PENETRATES INTO THE EARTH ABOUT SIX FEET OR SO.

THE PRIMARY CIRCUIT OF THE INDUCTION COIL IS COMPLETED BY CONNECTING THE BATTERY AND TELEGRAPH KEY IN SERIES WITH THE PRIMARY WINDING AND THE VIBRATOR POINTS.

OPERATION OF THE TRANSMITTER

HAVING FAMILIARIZED YOURSELF WITH THE GENERAL ARRANGEMENT AND CONSTRUCTION OF THIS MINIATURE TRANSMITTER, LET US NOW PROCEED BY SEEING HOW THIS SYSTEM OPERATES.

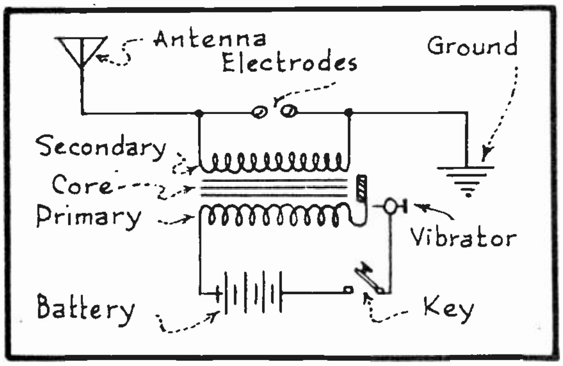

FIG. 3
Diagram of the transmitter.

WE BEGIN BY FIRST DEPRESSING OR CLOSING THE TELEGRAPH KEY. UPON DOING SO, THE VIBRATOR POINTS WILL UNDERGO A VIOLENT VIBRATING ACTION SIMILAR TO THAT EXPERIENCED AT THE VIBRATOR POINTS OF AN ELECTRIC DOORBELL WHEN THE BELL PUSH-BUTTON IS DEPRESSED. AT THE SAME TIME, ELECTRIC SPARKS WILL JUMP OR ARC ACROSS THE AIR GAP SEPARATING THE ELECTRODES, DURING THE ENTIRE TIME THAT THE KEY IS HELD CLOSED.

NOW WHENEVER AN ELECTRIC SPARK DISCHARGE AS THIS OCCURS, ELECTROMAGNETIC WAVES ARE GENERATED AT THE POINT OF SPARKING AND ARE RADIATED

OUTWARD INTO SPACE AS ILLUSTRATED FOR YOU IN FIG. 4. THESE ELECTROMAGNETIC WAVES ARE WHAT WE GENERALLY CALL "RADIO WAVES" AND THEY ARE ALSO KNOWN AS HERTZIAN WAVES. ALTHOUGH THESE WAVES ARE ELECTRICAL IN NATURE AND ARE INVISIBLE, YET THEY SPREAD OUTWARD THROUGH SPACE SOMEWHAT SIMILAR AS DO THE SOUND WAVES ABOUT WHICH YOU WERE TOLD IN THE PREVIOUS LESSON.

ALL ELECTRIC SPARKS TO A CERTAIN EXTENT PRODUCE RADIO WAVES AND IT IS FOR THIS REASON THAT THE OPERATION OF A LIGHTING SWITCH IN THE HOME, OR THE SPARKING AT THE TROLLEY WIRE OF A PASSING STREET CAR WILL CAUSE A SNAPPY OR CRACKLING NOISE TO BE PRODUCED BY THE SPEAKER OF A NEARBY RADIO RECEIVER WHICH HAPPENS TO BE OPERATING AT THE TIME.

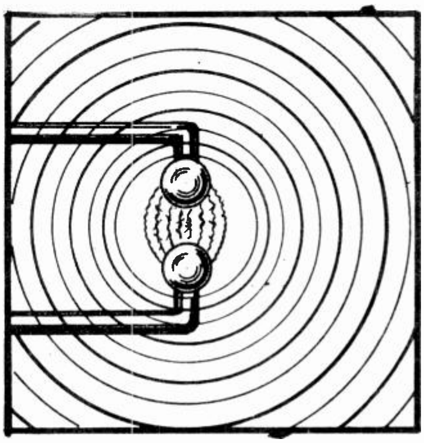

FIG. 4
Electromagnetic wave radiation from a spark discharge.

ALTHOUGH RADIO WAVES WOULD BE RADIATED DIRECTLY FROM THE SPARK GAP OF OUR ELEMENTARY TRANSMITTER IN THE EVENT THAT NO ANTENNA WERE EMPLOYED, YET THE USE OF THE ANTENNA AND GROUNDING SYSTEM INCREASES THE EFFICIENCY OF RADIATION A GREAT DEAL. THE ANTENNA SYSTEM LITERALLY ASSISTS IN FLINGING THESE WAVES OUT INTO SPACE SO THAT THEY WILL TRAVEL MUCH FARTHER THAN IF THE ANTENNA SYSTEM WERE NOT USED.

EACH TIME THAT THE KEY OF THIS TRANSMITTER IS CLOSED, SPARKING WILL OCCUR AT THE GAP BETWEEN THE ELECTRODES AND A SERIES OF ELECTROMAGNETIC WAVES WILL BE RADIATED BY THE ANTENNA SYSTEM BUT THE INSTANT THAT THE KEY IS RELEASED OR OPENED, ALL SPARKING AND WAVE RADIATION WILL STOP. THUS IT CAN BE SEEN THAT BY OPERATING THE KEY AT SUCCESSIVE INTERVALS, INDIVIDUAL SPARK DISCHARGES AND ELECTROMAGNETIC WAVE RADIATIONS WILL BE PRODUCED AND AS EACH WAVE RADIATION OCCURS, A SNAPPING NOISE WILL BE HEARD IN THE HEADPHONES OR SPEAKER OF ANY RADIO RECEIVER WITHIN RECEIVING DISTANCE.

NATURALLY, THESE "RADIO SIGNALS" WILL BE SOMEWHAT WEAK DUE TO THE SIMPLICITY OF THE TRANSMITTER AND CONSEQUENTLY, THE SNAPPING NOISES PRODUCED AT THE RECEIVER WILL ONLY BE EFFECTIVE WITHIN A RATHER SMALL AREA. NEVERTHELESS, THIS SIMPLE SPARK TRANSMITTER IS A FUNDAMENTAL RADIO-TELEGRAPH TRANSMITTER, FOR IN THIS TYPE OF RADIO COMMUNICATION, THE KEY IS CLOSED AT DEFINITE INTERVALS SO AS TO PRODUCE SPARKING AND WAVE RADIATIONS OF VARIOUS DURATIONS.

THAT IS, BY HOLDING THE KEY CLOSED FOR ONLY AN INSTANT, ELECTROMAGNETIC WAVES WILL BE RADIATED FOR BUT A SHORT PERIOD OF TIME, THUS PRODUCING AN ABRUPT SNAPPING SOUND AT THE RECEIVER. IN RADIO TELEGRAPHY WORK, SUCH AN ABRUPT SNAPPING SOUND IS CONSIDERED AS A "DOT." BY HOLDING THE TRANSMITTER KEY CLOSED LONGER, THE NOISE PRODUCED AT THE RECEIVER BY THE SPARK DISCHARGE WILL BE OF LONGER DURATION AND THIS IS CONSIDERED IN RADIO-TELEGRAPHY WORK AS A "DASH." VARIOUS COMBINATIONS OF SUCH "DOTS" AND "DASHES" FORM LETTERS OF THE TELEGRAPHIC CODE AND THUS CONTROLLED RADIATIONS OF ELECTROMAGNETIC WAVES ARE USED TO SPELL WORDS.

IN A LATER LESSON, YOU ARE GOING TO LEARN JUST EXACTLY HOW TO SEND AND RECEIVE MESSAGES BY MEANS OF THIS CODE.

THE CONDUCTING MEDIUM OF RADIO WAVES

SOUND WAVES, YOU WILL REMEMBER, DEPEND UPON SOME SUCH CONDUCTING MEDIUM AS AIR, LIQUIDS, SOLIDS OR A GASEOUS BODY IN ORDER TO BE PROPAGATED OUTWARD FROM THE POINT AT WHICH THE WAVE MOTION ORIGINATES. RADIO WAVES, HOWEVER, ARE ENTIRELY DIFFERENT FROM SOUND WAVES IN THIS RESPECT, FOR THEY WILL EVEN PENETRATE A VACUUM WITH EASE. THIS BEING THE CASE, THE QUESTION NOW ARISES THAT IF RADIO WAVES DEPEND UPON NONE OF THE CUSTOMARY FORMS OF CONDUCTION, THEN WHAT IS IT WHICH SERVES AS THEIR CONDUCTING MEDIUM?

THIS VERY QUESTION HAS LONG BEEN A PUZZLE TO LEADING SCIENTISTS, BUT FINALLY AFTER MUCH STUDY AND REPEATED EXPERIMENTS, THEY HAVE DECIDED THAT THE ETHER IS THE CONDUCTING MEDIUM FOR RADIO WAVES. THE FOLLOWING EXPLANATION WILL GIVE YOU A PRACTICAL UNDERSTANDING OF WHAT ETHER IS.

LET US SUPPOSE THAT WE CONNECT A VACUUM PUMP TO A GLASS JAR IN THE SAME MANNER AS WAS ALREADY ILLUSTRATED FOR YOU IN THE PREVIOUS LESSON. NOW YOU ALREADY KNOW THAT AS THE AIR IS GRADUALLY PUMPED OUT OF THIS JAR, A PARTIAL VACUUM WILL BE ESTABLISHED WITHIN THE JAR. EVENTUALLY, IF EVERY BIT OF AIR IS PUMPED OUT OF THE JAR, WE WOULD ORDINARILY SAY THAT A PERFECT VACUUM EXISTS WITHIN IT.

THE AVERAGE PERSON WOULD NOW CONSIDER THE JAR AS BEING PERFECTLY EMPTY AND THAT THERE IS AT THIS TIME ABSOLUTELY NOTHING IN IT. SCIENTISTS, HOWEVER, FOLLOW A DIFFERENT TREND OF THOUGHT AND CLAIM THATTHERE IS STILL "SOMETHING" LEFT IN THE EVACUATED JAR AND THEY CALL THIS "SOMETHING" ETHER. THIS ETHER IS CONSIDERED BY THEM AS OCCUPYING ALL SPACE OF THE UNIVERSE, EVEN IN SUCH REMOTE REGIONS AS THE VAST SPACES ABOVE THE ATMOSPHERIC BLANKET WHICH SURROUNDS OUR EARTH.

BY REASONING IN THIS MANNER, THIS THEORY IN A WAY EXPLAINS WHY IT IS THAT RADIO WAVES ARE ABLE TO LITERALLY EXTEND OUTWARD TO ALL PARTS-OVERCOMING ALL OBSTACLES WITH COMPARATIVE EASE. THERE ARE, NEVERTHE--LESS, CERTAIN THINGS AND CONDITIONS WHICH IMPEDE OR HINDER THE PROPAGATION OF RADIO WAVES - THE MOST COMMON OFFENDER BEING LARGE MINERAL DEPOSITS, ESPECIALLY IRON, WHICH HAS A VERY MARKED TENDENCY TO "ABSORB" RADIO ENERGY. IN FACT, MANY INSTANCES OF DIFFICULT RECEPTION INCERTAIN REGIONS HAVE BEEN FOUND TO BE DUE TO SOME LARGE MINERAL DEPOSIT IN THE EARTH AT SOME POINT BETWEEN THE TRANSMITTER AND RECEIVER ABSORBING SOME OF THE RADIATED ENERGY AND THEREBY PREVENTING A SUFFICIENT QUANTITY OF IT FROM REACHING THE RECEIVER.

THE SPEED OF RADIO WAVES

RADIO WAVES ALSO DIFFER GREATLY FROM SOUND WAVES IN RESPECT TO SPEED. FOR INSTANCE, FROM YOUR PREVIOUS LESSON, YOU WILL RECALL THAT SOUND WAVES TRAVEL THROUGH AIR AT AN APPROXIMATE SPEED OF 1100 FT. OR 335 METERS PER SECOND. RADIO WAVES, ON THE OTHER HAND, TRAVEL THROUGH THE ETHER AT A SPEED EQUIVALENT TO THAT OF LIGHT OR AT A RATE OF APPROXIMATELY 186,000 MILES PER SECOND OR 300,000,000 METERS PER SECOND. THUS IT FOLLOWS THAT FOR TRANSMITTING RADIO MESSAGES OVER WHAT WE GENERALLY CONSIDER AS RELATIVELY SHORT DISTANCES, WE CAN THINK OF THE RADIO WAVES AS ARRIVING AT THE RECEIVER PRACTICALLY INSTANTLY AFTER BEING TRANSMITTED.

FREQUENCY OF RADIO WAVES

THE FREQUENCY OF RADIO WAVES IS MUCH GREATER THAN THAT OF SOUND WAVES. FOR EXAMPLE, SOUND WAVES INCLUDE THE BAND OF FREQUENCIES FROM ABOUT 20 CYCLES PER SECOND UP TO 20,000 CYCLES PER SECOND. THE FREQUENCY RANGE FOR RADIO WAVES, HOWEVER, EXTENDS FROM 20,000 CYCLES PER SECOND TO 300,000,000 CYCLES PER SECOND, WHILE SOME OF THE ULTRA-HIGH FREQUENCIES, WITH WHICH A NUMBER OF SHORT-WAVE ENTHUSIASTS ARE EXPERIMENTING, RANGE UP TO AS HIGH AS 300,000,000,000 CYCLES PER SECOND.

IT IS ALSO OF INTEREST TO NOTE THAT SCIENTISTS HAVE DISCOVERED THAT HEAT AND LIGHT ARE ALSO CONDUCTED IN THE FORM OF WAVES AND ONLY DIFFER FROM RADIO WAVES IN RESPECT TO FREQUENCY.

IN FIG. 5 A FREQUENCY SCALE HAS BEEN PREPARED FOR YOU, WHICH WILL ENABLE YOU TO MORE EASILY COMPARE THE FREQUENCY RANGES OF THE VARIOUS TYPES OF WAVE FORMS. AS YOU WILL OBSERVE, MOST OF THE FREQUENCIES ON THIS SCALE ARE SPECIFIED IN KILOCYCLES.

ONE KILOCYCLE IS EQUAL TO 1000 CYCLES AND IT IS ABREVIATED AS "KC". HENCE A FREQUENCY OF 20,000 CYCLES PER SECOND IS THE SAME AS 20 KC PER SECOND, ETC. YOU WILL NO DOUBT REALIZE THAT THROUGH THE USE OF THE UNIT "KILOCYCLE," WE CAN AVOID THE USE OF TOO MANY CIPHERS WHERE THE HIGHER FREQUENCIES ARE INVOLVED.

WHERE THE AUDIBLE OR SOUND FREQUENCIES ARE CONCERNED, IT IS GENERALLY THE PRACTICE TO SPEAK OF THESE FREQUENCIES IN TERMS OF CYCLES PER SECONDS BUT FOR FREQUENCIES ABOVE THE AUDIBLE RANGE, THE UNIT "KC" IS ALMOST EXCLUSIVELY USED.

FOR THE VERY HIGH FREQUENCIES, THE UNIT "MEGACYCLES" IS OFTEN EMPLOYED AND ONE MEGACYCLES IS EQUIVALENT TO ONE MILLION CYCLES.

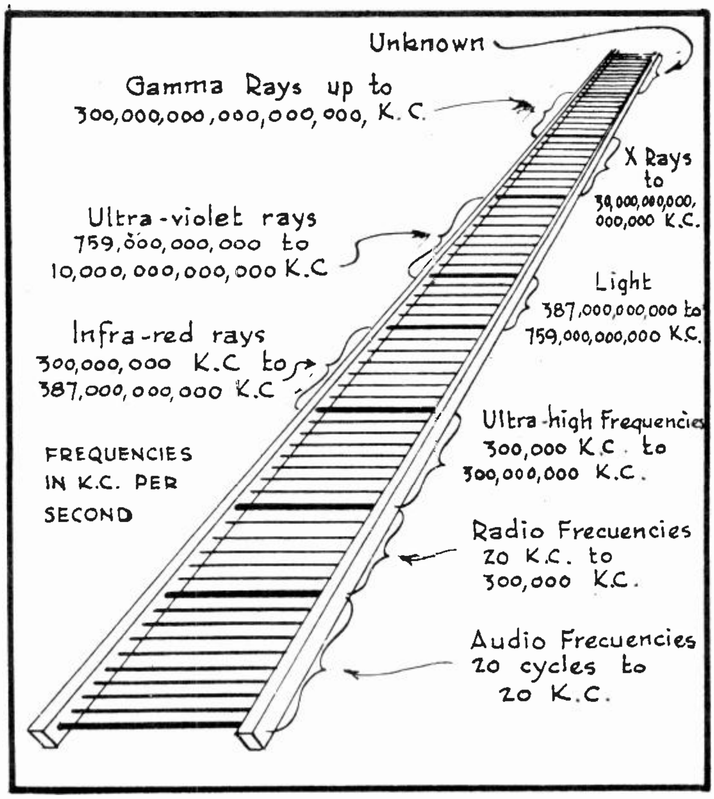

FIG. 5
Frequency scale of various types of waves.

RELATION BETWEEN SPEED, WAVELENGTH AND FREQUENCY

WE REPRESENT RADIO WAVES ON PAPER IN MUCH THE SAME MANNER AS WE DO SOUND WAVES, AS YOU WILL OBSERVE UPON LOOKING AT FIG. 6, WHERE YOU ARE SHOWN A GRAPHIC REPRESENTATION OF A RADIO WAVE. HERE A DISTANCE OF 300,000,000 METERS IS BEING REPRESENTED ALONG A HORIZONTAL LINE AND WHICH ALSO REPRESENTS THE DISTANCE TRAVELED BY THE WAVE FORM DURING A TIME INTERVAL OF ONE SECOND.

NOW THEN, IF THERE ARE 300,000,000 INDIVIDUAL CYCLES WITHIN THIS TIME INTERVAL OF ONE SECOND, THEN IT IS OBVIOUS THAT THE WAVELENGTH, OR THE DISTANCE BETWEEN TWO SUCCESSIVE CRESTS OR BETWEEN TWO SUCCESSIVE TROUGHS OF THE WAVE FORM IS EQUAL TO ONE METER.

NO DOUBT, YOU HAVE ALREADY LEARNED FROM PAST EXPERIENCES DURING YOUR ASSOCIATION WITH RADIO THAT THE WAVELENGTH OF ALL BROADCAST STATIONS IS SPECIFIED IN METERS. IN OTHER WORDS, WAVELENGTH AS APPLIED TO RADIO IS BASED UPON THE METRIC SYSTEM OF MEASUREMENT RATHER THAN UPON THE ENGLISH SYSTEM OF MEASUREMENT. BY CONSIDERING THE FACT THAT 1 METER IS EQUAL TO 3.28 FT., YOU WILL HAVE A BETTER IDEA AS TO THEIR COMPARATIVE LENGTHS.

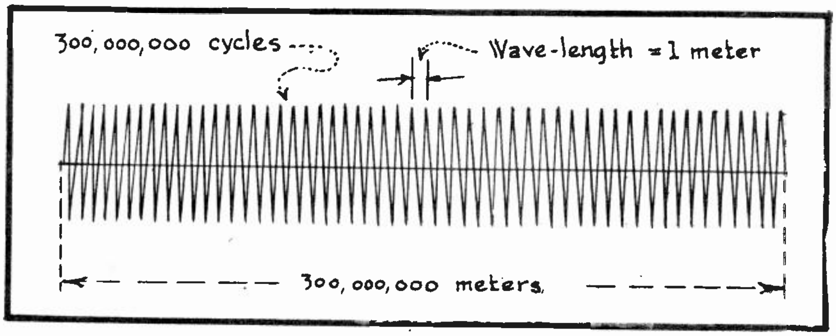

FIG. 6

Wavelength as used in Radio.

SINCE THE VELOCITY OR SPEED WITH WHICH RADIO WAVES ARE PROPOGATED THRU THE ETHER IS ALWAYS THE SAME, THEN ONE NEED ONLY TO DIVIDE THE SPEED OR 300,000,000 METERS PER SECOND BY THE FREQUENCY OF THE WAVE FORM EXPRESSED IN CYCLES PER SECOND IN ORDER TO DETERMINE THE WAVELENGTH. FOR EXAMPLE, IF A CERTAIN BROADCAST STATION IS TRANSMITTING AT A FREQUENCY OF 600 KC PER SECOND (600,000 CYCLES) THEN ITS WAVELENGTH WILL BE EQUAL TO 300,000,000 DIVIDED BY 600,000 OR 500 METERS.

IN CASE THAT WE KNOW THE WAVELENGTH BUT NOT THE FREQUENCY, THEN WE CAN VERY EASILY DETERMINE THE FREQUENCY BY SIMPLY DIVIDING THE SPEED OF 300,000,000 METERS PER SECOND BY THE WAVELENGTH EXPRESSED IN METERS. IN OTHER WORDS, IF THE WAVELENGTH IS KNOWN TO BE 500 METERS, THEN THE CORRESPONDING FREQUENCY WILL BE EQUAL TO 300,000,000 DIVIDED 500 OR 600,000 CYCLES PER SECOND, WHICH YOU WILL READILY NOTE IS ALSO THE SAME AS 600 KC PER SECOND.

THIS RELATION BETWEEN THE SPEED, FREQUENCY AND WAVELENGTH CAN BE ARRANGED INTO CONVENIENT AND PRACTICAL FORMULAS IN THE FOLLOWING MANNER:

$$\lambda = \frac{300,000,000}{F} \quad \text{OR} \quad F \quad \frac{300,000,000}{\lambda}$$

HERE YOU WILL OBSERVE THAT THE GREEK LETTER "λ" IS USED TO DESIGNATE WAVELENGTH AND THE LETTER "F" TO DESIGNATE FREQUENCY. THESE ABBREVIATIONS FOR WAVELENGTH AND FREQUENCY HAVE BECOME STANDARDIZED IN RADIO PRACTICE AND WHEN USED IN THESE FORMULAS AS GIVEN HERE, THE WAVELENGTH MUST ALWAYS BE EXPRESSED IN METERS AND THE FREQUENCY IN CYCLES PER SECOND.

TUNING THE TRANSMITTER

MANY TRANSMITTERS ARE RADIATING RADIO WAVES AT THE SAME TIME AND IF THESE WAVES SHOULD ALL HAVE THE SAME FREQUENCY AND WAVELENGTH, WE WOULD HAVE A SAD STATE OF CONFUSION WHEN TRYING TO LISTEN TO A PROGRAM OR MESSAGE BECAUSE ALL OF THE SIGNALS WOULD BE IMPRESSED UPON OUR EARS AT THE

SAME TIME.

TO AVOID THIS CONDITION, EACH TRANSMITTER WITHIN A CERTAIN DISTRICT HAS ITS EQUIPMENT ADJUSTED SO AS TO RADIATE WAVES OF A DIFFERENT FREQUENCY FROM THAT OF THE OTHERS.

THE LENGTH OF THE ANTENNA WHICH IS USED WITH A TRANSMITTER HAS A GREAT DEAL TO DO WITH THE FREQUENCY OF THE ELECTROMAGNETIC WAVE WHICH IS RADIATED BY IT. THAT IS, THE LONGER THE ANTENNA, THE LONGER WILL BE THE WAVELENGTH AND THE LOWER THE FREQUENCY OF THE RADIATED WAVE. SHORT ANTENNAS, ON THE OTHER HAND, HAVE A NATURAL TENDENCY TO RADIATE WAVES OF SHORTER WAVELENGTH AND HIGHER FREQUENCY. (NOTICE ESPECIALLY THAT THE SHORTER THE WAVELENGTH OF ANY GIVEN WAVE-FORM, THE HIGHER WILL BE ITS FREQUENCY.)

NOW ACCORDING TO THE FACTS WHICH WERE OUTLINED FOR YOU IN THE PRECEDING PARAGRAPH, YOU CAN READILY SEE THAT IN ORDER TO RADIATE WAVES OF A CONSIDERABLY LONG WAVELENGTH, IT WOULD SEEM APPARENT THAT IT WOULD BE NECESSARY TO EMPLOY AN ANTENNA OF GREAT LENGTH, BUT TOO LONG AN ANTENNA IS IMPRACTICAL FROM A CONSTRUCTIONAL STANDPOINT. IT SO HAPPENS, HOWEVER, THAT THE EFFECTIVE LENGTH OF AN ANTENNA CAN BE EITHER INCREASED OR DECREASED BY USING THE ANTENNA COIL ARRANGEMENT WHICH IS ILLUSTRATED IN FIG. 7.

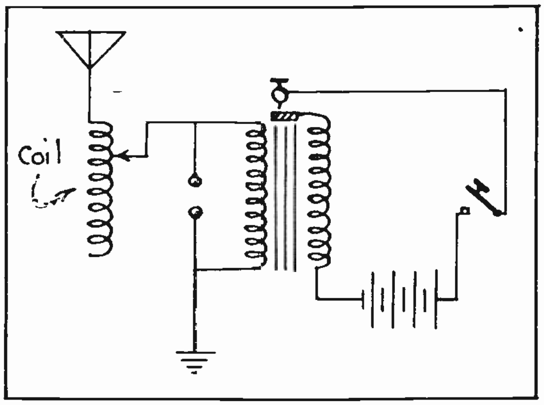

FIG. 7
The tuned transmitter.

IN THE CASE OF FIG. 7, WE AGAIN HAVE OUR SIMPLE SPARK TRANSMITTER, ONLY THAT NOW A SPECIAL COIL OF BARE COPPER WIRE IS CONNECTED TO THE ANTENNA. SOME MEANS SUCH AS A CLIP IS THEN PROVIDED SO THAT THE ANTENNA ELECTRODE CAN BE FASTENED TO DIFFERENT POINTS ON THIS ANTENNA COIL. IN THIS WAY, THE EFFECTIVE LENGTH OF THE ANTENNA CAN BE VARIED.

TO A CERTAIN EXTENT, SUCH AN ADJUSTABLE ANTENNA COIL OFFERS "TUNING FACILITIES." THAT IS, BY INCREASING THE EFFECTIVE LENGTH OF THE ANTENNA, THE TRANSMITTER NATURALLY RADIATES ELECTROMAGNETIC WAVES OF LONGER WAVELENGTH AND LOWER FREQUENCY. BY DECREASING THE EFFECTIVE LENGTH OF THE ANTENNA, THE SYSTEM HAS A NATURAL TENDENCY TO RADIATE ELECTROMAGNETIC WAVES OF SHORTER WAVELENGTH AND HIGHER FREQUENCY.

THE ACT OF ADJUSTING THE FREQUENCY, TO WHICH SUCH A RADIO DEVICE HAS A NATURAL TENDENCY TO RESPOND, IS SPOKEN OF AS TUNING. THIS PROCESS CAN CONVENIENTLY BE COMPARED TO THE TUNING OF SOME SUCH STRING INSTRUMENT AS A HARP OR PIANO, IN WHICH CASE WE ALSO SPEAK OF TUNING WHEN ADJUSTING THE TENSION AND EFFECTIVE LENGTH OF THE WIRE OR STRING SO THAT IT WILL VIBRATE AT A DEFINITE FREQUENCY.

IN ACTUAL COMMERCIAL PRACTICE, MORE COMPLEX AND ACCURATE ARRANGEMENTS ARE EMPLOYED FOR TUNING TRANSMITTERS THAN THE SYSTEM SHOWN YOU IN FIG. 7 AND YOU WILL HAVE AMPLE OPPORTUNITY OF BECOMING THOROUGHLY FAMILIAR WITH THESE MORE ELABORATE SYSTEMS IN LATER LESSONS. FOR THE PRESENT HOWEVER, FIG. 7 WILL SERVE TO FAMILIARIZE YOU WITH THE FUNDAMENTAL PRIN-

CIPLES CONCERNING THE CONTROL OF RADIO WAVES IN RESPECT TO FREQUENCY.

AMPLITUDE AS USED WITH RADIO WAVES

IN THE CASE OF RADIO WAVES, WE ALSO DEAL WITH THE EXPRESSION "AMPLITUDE" THE SAME AS WE DO WHEN WORKING WITH SOUND WAVES. THIS IS ILLUSTRATED FOR YOU IN FIG. 8, WHERE YOU WILL OBSERVE THAT THE WAVE-FORM OR CURVE IS CONSIDERED AS EXTENDING ABOVE AND BELOW A HORIZONTAL REFERENCE LINE, WHICH IS DESIGNATED AS THE "ZERO LINE."

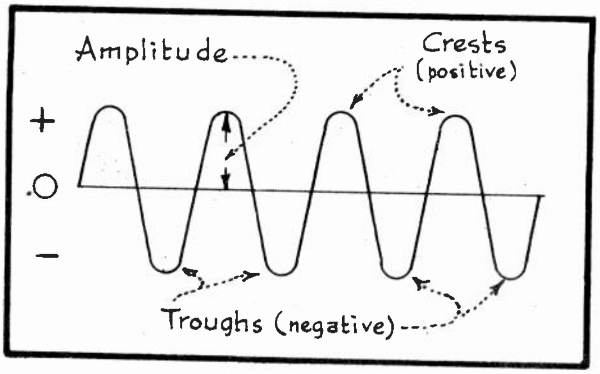

FIG. 8
Amplitude and polarity of the waves.

ELECTRICALLY SPEAKING, THIS HORIZONTAL REFERENCE LINE INDICATES ZERO VOLTAGE. THE PORTION OF THE CURVE ABOVE THIS REFERENCE OR ZERO LINE DENOTES A POSITIVE VOLTAGE AND THE PORTION BELOW THE ZERO LINE DENOTES A NEGATIVE VOLTAGE. THIS IS SHOWN IN FIG. 8 BY THE FACT THAT THE UPPER PORTION OF THE CURVE IS MARKED WITH THE SYMBOL (+) WHICH SIGNIFIES POSITIVE AND THE PORTION BELOW THE CURVE WHICH IS MARKED WITH THE SYMBOL (–) WHICH SIGNIFIES NEGATIVE.

DON'T WORRY ABOUT THIS POLARITY PROPOSITION AT THE PRESENT TIME BECAUSE YOU WILL RECEIVE MORE DETAILED INFORMATION CONCERNING THIS LATER ON. SIMPLY REMEMBER THAT THE POSITIVE PORTION OF THE WAVE FORM GOES ABOVE THE ZERO LINE AND THE NEGATIVE PORTION BELOW THE LINE.

CONTINUOUS AND DAMPED WAVES

IN FIG. 9 YOU WILL SEE TWO DISTINCT TYPES OF WAVE-FORMS AS EMPLOYED IN RADIO. IN THE UPPER ILLUSTRATION, A WAVE-FORM IS SHOWN IN WHICH THE AMPLITUDE IS CONSTANT. THIS IS KNOWN AS A CONTINUOUS TYPE OF WAVE AND IT IS THE TYPE WHICH IS AT THE PRESENT TIME BEING EMPLOYED WITH ALL MODERN TRANSMITTER DESIGNS, BOTH FOR RADIO-TELEGRAPH AND RADIO- TELEPHONE PURPOSES.

THE LOWER ILLUSTRATION OF FIG. 9 PICTURES A WAVE-FORM IN WHICH THE AMPLITUDE OF THE WAVE RAPIDLY DIMINISHES. THIS WAVE TYPE IS KNOWN AS A DAMPED-WAVE.

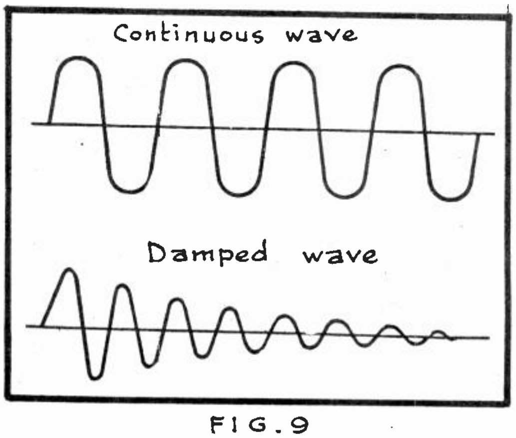

FIG. 9
Continuous and damped waves.

THE NATURE OF THE DAMPED WAVE CAN NO DOUBT BE STILL MORE CLEARLY ILLUSTRATED BY MEANS OF FIG. 10. HERE WE HAVE A FREELY SUSPENDED PENDULUM SWINGING ACROSS A CALIBRATED SCALE.

BY STRIKING THE PENDULUM A SHARP BLOW, IT WILL COMMENCE TO SWING ACROSS THE SCALE FROM ONE SIDE TO THE OTHER. THE AMPLITUDE WILL BE MAXI imum during the first oscillation or swing and will then gradually decrease as time goes on until the oscillatory motion finally dies out altogether.

Should this motion of the pendulum be drawn on paper in the form of a curve, it will appear as the wave motion which is illustrated directly below the scale in Fig. 10. As you will observe, this oscillatory motion can be very nicely compared with that of a damped radio wave.

The elemental spark transmitter, which was illustrated for you in this lesson, radiates damped radio waves in a very extreme form. This is one of the reasons why simple transmitters of this type are very unsatisfactory for practical radio purposes.

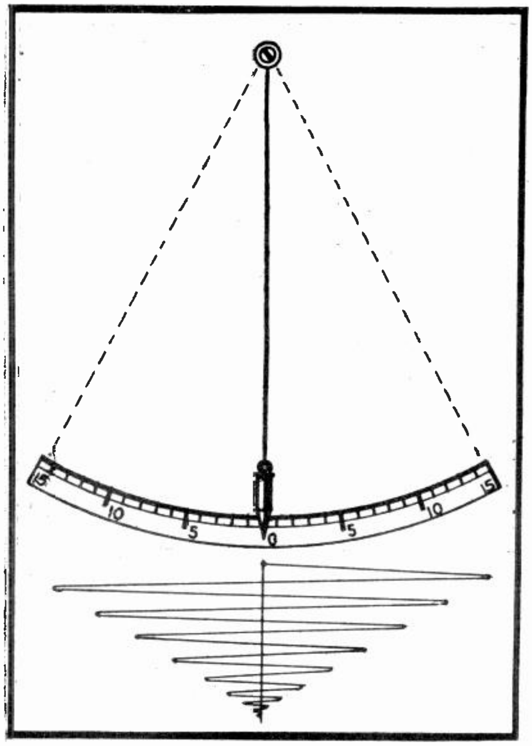

FIG. 10
Damped oscillation

You see, highly damped waves are produced by any sparking electrical discharge and thus if any such miscellaneously generated electromagnetic waves reach a receiver at the same time as the damped waves radiated by the crude transmitter, it would be very difficult for the receiving operator to distinguish the intended signal waves from ordinary noises or "static."

To overcome this deficiency, spark transmitters of later design were constructed differently as you shall learn in a more advanced lesson dealing with radio transmitters. These more modern spark transmitters were equipped with a special form of spark gap which causes a series of sparks to be produced in rapid succession as the operator's key is depressed. This results in a better tone of the signal when it is received - quite different from static noises so that the signal becomes more intelligible.

In the still more modern transmitters, such as used at the present time, no spark discharge is any longer being used at all. Instead, electrical currents are generated in special oscillator circuits employing radio tubes. These electrical currents reverse their direction of flow through the circuit at a very rapid rate - thousands of times per second. We call currents of this type HIGH FREQUENCY CURRENTS, ELECTRICAL OSCILLATIONS or RADIO FREQUENCY CURRENTS.

These high frequency currents are then passed into the antenna, where in the radioman's language, they "excite" the antenna and cause electromagnetic waves to be radiated from it. The waves in this case, however, are undamped. That is, they are of the CONTINUOUS TYPE.

Bear in mind that at this time, we are only dealing with radio transmitters in a general way, so as to simply give you a general idea

AS TO HOW RADIO WAVES ARE PRODUCED AND SENT OUT INTO SPACE. IN YOUR MORE ADVANCED LESSONS, OF COURSE, WE WILL GO INTO THE DETAILED DISCUSSIONS CONCERNING THE CONSTRUCTION AND OPERATION OF ALL TYPES OF TRANSMITTER EQUIPMENT.

RADIO TELEPHONY

SO FAR IN THIS LESSON, WE HAVE ONLY CONSIDERED THE TRANSMISSION OF RADIO MESSAGES BY "CODE" OR THE "DOT AND DASH SYSTEM." THIS FORM OF RADIO COMMUNICATION IS KNOWN AS "RADIO-TELEGRAPHY" AND IS QUITE OFTEN CALLED "WIRELESS-TELEGRAPHY." BESIDES THIS FORM, HOWEVER, WE ALSO HAVE THE TYPE OF RADIO COMMUNICATION IN WHICH YOU ARE NO DOUBT EVEN MORE INTERESTED - NAMELY THAT OF THE TRANSMISSION OF VOICE, MUSIC, ETC. THIS FORM OF RADIO TRANSMISSION COMES UNDER THE GENERAL CLASSIFICATION OF RADIO-TELEPHONY.

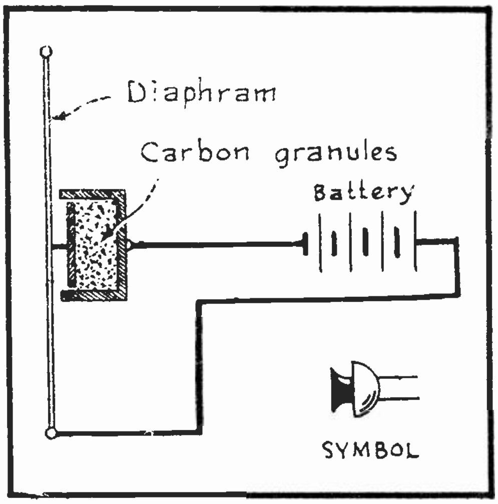

FIG. 11
The microphone circuit.

IT IS OF INTEREST TO NOTE THAT MANY OF THE PRINCIPLES, WHICH ARE USED IN RADIO-TELEPHONY, WERE TAKEN FROM THAT OTHER POPULAR FORM OF COMMUNICATION THE TELEPHONE. FOR INSTANCE IN FIG. 11, WE HAVE A SIMPLIFIED DRAWING OF THE MICROPHONE CIRCUIT WHICH IS USED IN VOICE TRANSMISSION IN BOTH TELEPHONE AND RADIO SYSTEMS. THE PURPOSE OF THIS VALUABLE ARRANGEMENT IS TO CONVERT SOUNDS INTO ELECTRICAL CURRENTS AND THE FOLLOWING EXPLANATIONS WILL SHOW YOU HOW THIS IS DONE.

IN FIG. 11 YOU ARE LOOKING AT THE MICROPHONE FROM THE SIDE, SO THAT YOUR EYE IS IN LINE WITH THE EDGE OF THE DIAPHRAM. THIS DIAPHRAM, HOWEVER, IS IN REALITY DISK-SHAPED, MADE FROM A THIN METALLIC SHEET HAVING A CERTAIN AMOUNT OF FLEXIBILITY AND IT IS PIVOTED AROUND ITS RIM.

A SMALL PISTON-LIKE UNIT IS FASTENED TO THE CENTER OF THIS DIAPHRAM AND WILL MOVE IN AND OUT OF A SMALL CUP CONTAINING FINELY GROUND CARBON GRANULES WHENEVER THE CENTER POINT OF THE DIAPHRAM IS FORCED TO BEND INWARDS AND OUTWARDS.

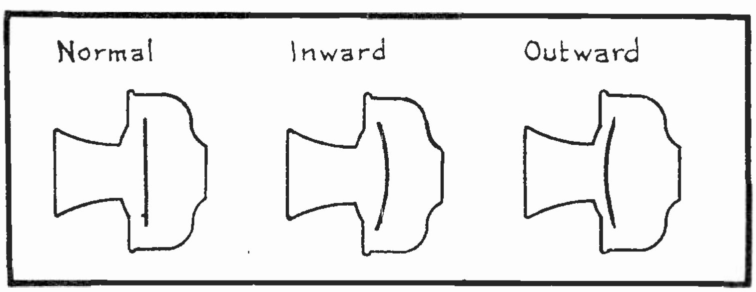

FIG.12
The diaphram vibrations.

NOW THEN, IN FIG. 12 YOU WILL SEE THE POSITION OF THE DIAPHRAM IN THE "MOUTH PIECE" OR "MICROPHONE" OF AN ORDINARY TELEPHONE. NORMALLY THE DIAPHRAM MAINTAINS THE RELATIVELY STRAIGHT POSITION AS SHOWN AT THE LEFT OF FIG. 12. HOWEVER, IF WE SPEAK IN FRONT OF THIS MICROPHONE OR "TRANSMITTER," AS IT IS GENERALLY CALLED AMONG TELEPHONE MEN, THE SOUND WAVES WHICH ARE PRODUCED BY THE SPEECH WILL BE IMPRESSED UPON THE DIAPHRAM WITH VARYING PRESSURE, THEREBY CAUSING THE

DIAPHRAM TO BEND INWARDS AND OUTWARDS CORRESPONDINGLY AS SHOWN YOU IN THE CENTER AND RIGHT ILLUSTRATIONS OF FIG. 12.

BY REFERRING BACK TO FIG. 11 AGAIN, YOU WILL NOTICE THAT A BATTERY IS CONNECTED TO THE MICROPHONE BY MEANS OF A PAIR OF WIRES. WITH THE DIAPHRAM AT REST, A CERTAIN AMOUNT OF BATTERY CURRENT WILL FLOW FROM THE BATTERY, THROUGH THE DIAPHRAM, CARBON GRANULES AND BACK TO THE BATTERY AGAIN.

HOWEVER, IF A SOUND WAVE CAUSES THE DIAPHRAM TO BEND INWARDS, THEN THE DIAPHRAM PISTON WILL MOVE FARTHER INTO THE CUP OF CARBON GRANULES AND THEREBY PRESS THESE CARBON GRANULES TIGHTER TOGETHER. THIS CONDITION REDUCES THE ELECTRICAL RESISTANCE OF THE CIRCUIT SO THAT MORE BATTERY CURRENT WILL FLOW THROUGH THE SYSTEM THAN WHEN THE DIAPHRAM IS IN ITS NORMAL POSITION.

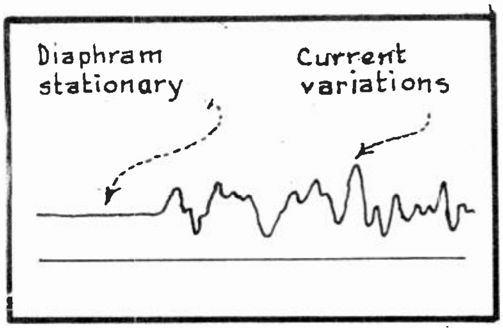

FIG. 13
A pulsating current.

ON THE OTHER HAND, IF THE SOUND WAVE IMPRESSION UPON THE DIAPHRAM AT A CERTAIN INSTANT IS SUCH THAT THE DIAPHRAM IS CAUSED TO MOVE OUTWARDS, THEN THE PRESSURE UPON THE CARBON GRANULES WILL BE LESS THAN NORMAL. IN THIS WAY THE CARBON GRANULES WILL BE FREE TO MOVE FARTHER APART AND THUS INCREASE THE ELECTRICAL RESISTANCE OF THE CIRCUIT, WITH THE RESULT THAT THE FLOW OF BATTERY CURRENT THROUGH THE SYSTEM WILL ALSO AT THIS TIME BE LESS THAN NORMAL.

IN OTHER WORDS, AS THE SOUND WAVES CAUSE THE DIAPHRAM TO UNDERGO A VIBRATORY MOTION, THE CURRENT FLOW THROUGH IT WILL VARY ITS INTENSITY CORRESPONDINGLY BUT IT NEVER REVERSES ITS DIRECTION OF FLOW. WE CALL A CURRENT OF THIS NATURE A PULSATING DIRECT CURRENT AND WE CAN ILLUSTRATE IT ON PAPER IN THE FORM OF A CURVE AS SHOWN IN FIG. 13.

THUS YOU CAN NOW SEE HOW THE MICROPHONE ENABLES US TO CONVERT SOUND WAVES INTO ELECTRICAL CURRENTS OF CORRESPONDING VARIATION.

THE RECEIVER OR HEADPHONE

THE RECEIVER OR HEADPHONE IN BOTH A TELEPHONE AND RADIO SYSTEM PERFORMS A TASK WHICH IS JUST THE OPPOSITE TO THAT OF THE MICROPHONE. THAT IS, IT CONVERTS PULSATING ELECTRIC CURRENTS BACK INTO SOUND.

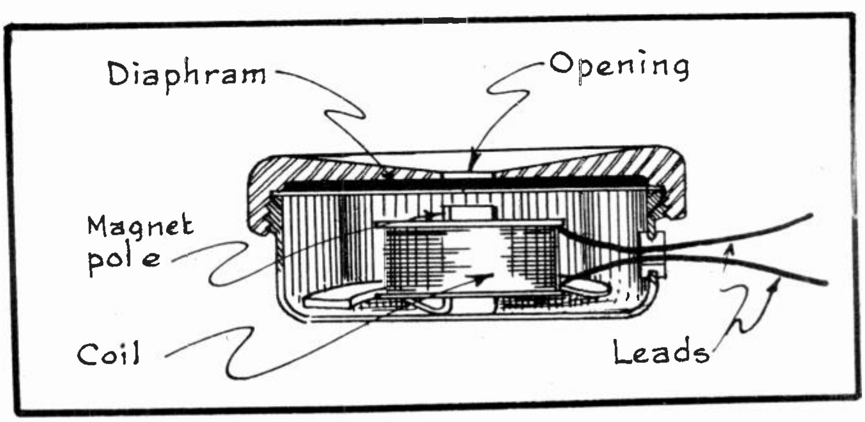

FIG. 14
Construction of the headphone

IN FIG. 14

YOU ARE LOOKING AT THE FUNDAMENTAL PRINCIPLES OF CONSTRUCTION AS FOUND IN THE ORDINARY HEADPHONE. THIS UNIT CONSISTS OF A SMALL PERMANENT MAGNET, THE POLES OF WHICH ARE SPACED ONLY A SLIGHT DISTANCE FROM THE CENTRAL PORTION OF THE DIAPHRAM. THE DIAPHRAM IN THIS CASE ALSO IS A DISK-SHAPED UNIT MADE FROM THIN METAL POSSESSING A CERTAIN AMOUNT OF FLEXIBILITY AND IT IS PIVOTED AROUND ITS RIM TO THE SHELL OR HOUSING OF THE ASSEMBLY.

IN ADDITION, COILS OF VERY THIN INSULATED WIRE ARE WOUND AROUND THE POLES OF THE PERMANENT MAGNET AND UNDER NORMAL CONDITIONS, THE CENTRAL PORTION OF THE DIAPHRAM IS ATTRACTED OR PULLED DOWNWARDS BY THE PERMANENT MAGNET.

IN THE ELEMENTARY FORM OF TELEPHONE SYSTEM, THE HEADPHONE COIL OR COILS WOULD BE CONNECTED INTO THE CIRCUIT AS SHOWN YOU IN FIG. 15. HERE YOU WILL NOTICE THAT THE BATTERY CURRENT WILL NOW FLOW THROUGH THE WINDINGS OF THE HEADPHONE AS WELL, IN ORDER TO COMPLETE ITS TRIP THROUGH THE MICROPHONE.

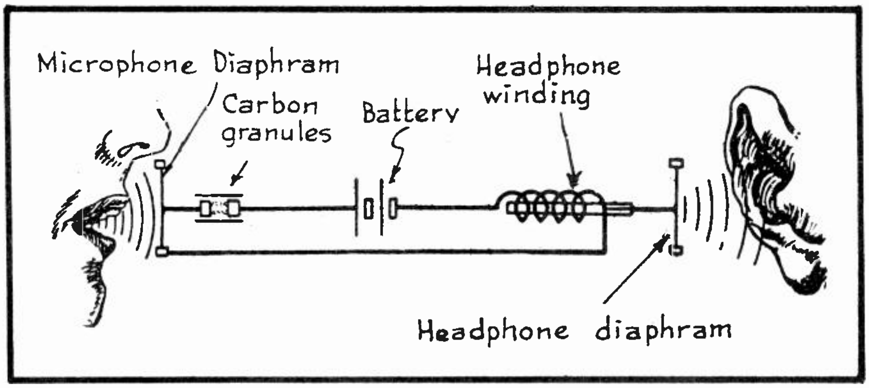

FIG. 15

Fundamental principles of the telephone.

IN OTHER WORDS, THE SAME PULSATING CURRENT AS BROUGHT ABOUT BY THE ACTION OF THE MICROPHONE, WILL ALSO NOW FLOW THROUGH THE HEADPHONE WINDINGS AND THIS VARIATION OF CURRENT INTENSITY THROUGH THE HEADPHONE WINDINGS CAUSES A MAGNETIC REACTION WITH THE PERMANENT MAGNETS OF THE HEADPHONE WHICH IN TURN CAUSES THE HEADPHONE DIAPHRAM TO BE BENT OUTWARDS AND INWARDS IN DIRECT STEP WITH THE CURRENT VARIATION IN ITS WINDINGS.

SINCE THE HEADPHONE DIAPHRAM IS IN DIRECT CONTACT WITH THE AIR THROUGH THE OPENING PROVIDED IN ITS COVER, AS SHOWN IN FIG. 14, IT WILL AGITATE THE AIR INTO A WAVE MOTION, THE FREQUENCY OF WHICH IS IN DIRECT STEP WITH THE VARIATION OF CURRENT INTENSITY IN THE CIRCUIT. THEN SINCE THIS CURRENT INTENSITY IS DIRECTLY DEPENDENT UPON THE NATURE OF THE SOUND WAVES IMPRESSED UPON THE MICROPHONE, IT IS CLEAR THAT THE WAVE MOTION PRODUCED IN THE AIR BY THE HEADPHONE DIAPHRAM WILL BE AN EXACT REPRODUCTION OF THAT ACTUATING THE MICROPHONE DIAPHRAM. THE RESULT IS THAT THE EXACT SAME SOUNDS ARE HEARD AT THE HEADPHONE AS THOSE ORIGINALLY PRODUCED IN FRONT OF THE MICROPHONE.

APPLICATION OF SOUND TO RADIO

OUR NEXT STEP WILL BE TO SEE HOW SOUNDS CAN BE TRANSMITTED BY RADIO AND FOR THIS WE WILL REFER TO FIG. 16, WHERE THE ESSENTIAL PARTS OR DIVISIONS WHICH GO TO MAKE UP A MODERN BROADCAST TRANSMITTER ARE SHOWN.

HERE YOU WILL OBSERVE THAT WE AGAIN HAVE OUR MICROPHONE CIRCUIT but instead of being connected to a headphone, it feeds into a section of the transmitting equipment which we call the A. F. AMPLIFIER. This unit serves to intensify the sound current variations so that they will be adaptable to transmission purposes.

After these variations have been intensified or amplified, as we generally say, then they are passed on to the MODULATOR. However, the OSCILLATOR is generating high frequency currents at the same time which are also fed into the modulator and this oscillator energy is to be used to produce the continuous radio wave at the antenna.

It is the modulator's duty to combine the sound current variations with the high frequency currents generated by the oscillator and we call this process MODULATION. The result of this process is that instead of the wave which is radiated by the antenna having a constant amplitude, its amplitude continually changes with the variations of the sound currents. In this way, the wave, which is produced by the oscillator circuit, can be considered to serve solely to carry the sound variations with it through space and for this reason is generally spoken of as being the CARRIER WAVE and its frequency the CARRIER FREQUENCY.

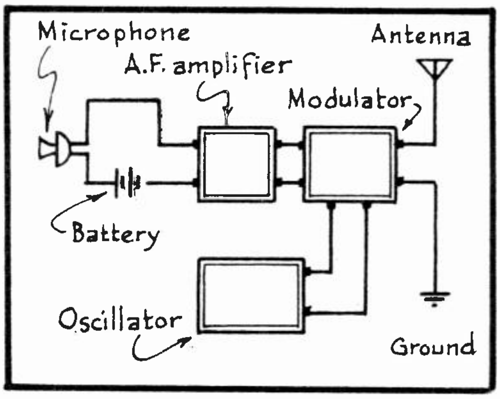

FIG. 16

Essential parts of the modern transmitter.

The left half of Fig. 17 in itself tells a brief but complete story of sound transmission by radio. The units of the transmitter are illustrated in the upper portion of of this drawing and the corresponding electrical occurrences are shown directly below. Notice here how the microphone circuit and A.F. amplifier convert the sound waves to an intensified pulsating electrical current, how the oscillator generates the high frequency currents of constant amplitude or intensity and how the modulator adds the electrical sound changes onto the carrier frequency, thereby changing its amplitude accordingly or modulating it and a corresponding radio wave is then radiated by the antenna.

RECEPTION OF RADIO PROGRAMS

Now that the modulated radio wave is being propagated through space, the next point in which you will be interested is the manner in which we RECEIVE radio programs. This process is pictorially described for you in the right hand portion of Fig. 17.

The antenna of the receiver serves as a "catcher" of radio waves, as it were, in that the radio waves strike it as they pass on through space and in doing so, generate electrical currents of corresponding frequency in the antenna. These currents are similar to those in the antenna of the transmitter, in that they consist of the modulated or mixed sound and radio-frequency currents.

Due to the feebleness of the energy which reaches the receiver's antenna, it must be built up or amplified and this is accomplished with

THE R. F. AMPLIFIER, WHICH BESIDES THIS DUTY ALSO SERVES TO TUNE-IN THE STATIONS WHICH RADIATES WAVES OF A GIVEN FREQUENCY.

FROM HERE, THE MODULATED CURRENTS ARE PASSED ON TO THE DETECTOR WHICH SERVES TO SEPARATE THE SOUND FREQUENCIES FROM THE CARRIER FREQUENCY. THE SOUND FREQUENCIES ARE THEN IMPRESSED UPON THE A. F. AMPLIFIER WHICH INTENSIFIES THEM SUFFICIENTLY TO ACTUATE THE DIAPHRAM OF THE LOUD SPEAKER, WHICH THEN SETS UP THE SOUND WAVES IN THE AIR IN THE SAME MANNER AS DOES THE HEADPHONE IN OUR SIMPLE TELEPHONE CIRCUIT OF FIG. 15.

DIRECTLY BELOW THE DIVISIONS OF THE RECEIVER IN FIG. 17 WE HAVE THE CURVES CORRESPONDING TO THE CHANGES WHICH OCCUR AS THE SIGNAL IS PASSED ON FROM THE ANTENNA TO THE LOUD SPEAKER.

YOU SHOULD NOW HAVE A GOOD FUNDAMENTAL UNDERSTANDING OF WHAT OCCURS DURING THE TRANSMISSION AND RECEPTION OF RADIO PROGRAMS AND YOU MAY REST ASSURED THAT AS YOU PROGRESS WITH YOUR STUDIES, YOU WILL GRADUALLY

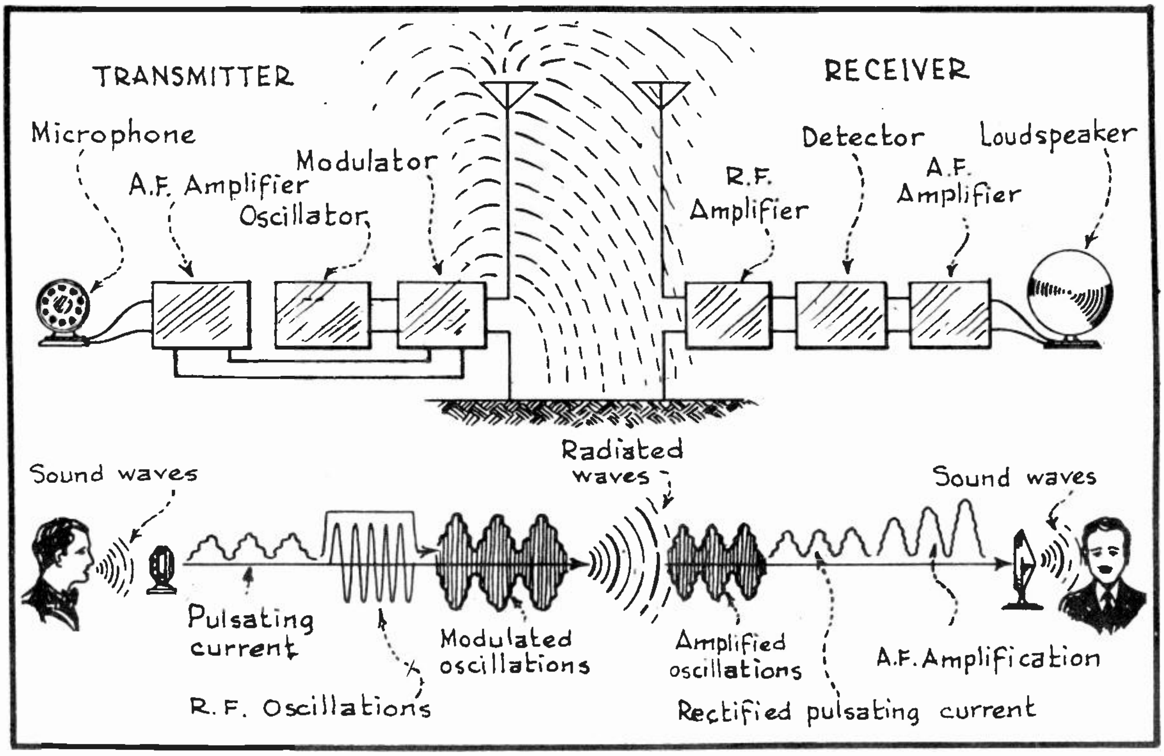

FIG. 17

Transmission and reception of Radio programs.

FIND YOUR KNOWLEDGE TO BECOME MORE COMPLETE. AS WE CONTINUE, WE ARE GOING TO STUDY EACH PART OF ALL TYPES TRANSMITTERS AND RECEIVERS IN GREAT DETAIL, CONSIDERING THEM FROM THE STANDPOINTS OF DESIGN, CONSTRUCTION AND OPERATION.

Education

"We ought to be ashamed to remain in ignorance in a land where the blind, the deaf and dumb, and even cripples and invalids, manage to obtain a good education."

"Make a resolution that you are going to be an educated man or woman."

"The best educated people are those who are always learning, always absorbing knowledge from every possible source and at every opportunity."

"Some people are always at school, always storing up precious bits of knowledge."

"The man who has learned the art of seeing things looks with his brain."

"It cannot be done," cries the man without imagination. "It çan be done, it shall be done," cries the dreamer.

Examination Questions

LESSON NO. 2

> Great minds have purposes, others have wishes. Little minds are tamed and subdued by misfortune; but great minds rise above them.

1. - WHAT TYPE OF RADIO WAVES DOES AN ELEMENTARY TYPE SPARK TRANSMITTER RADIATE?

2. - WHAT IS THE CONDUCTING MEDIUM FOR RADIO WAVES?

3. - WHAT IS THE RELATION BETWEEN THE SPEED, WAVELENGTH, AND FREQUENCY OF RADIO WAVES?

4. - WHAT IS MEANT BY TUNING AS APPLIED TO RADIO?

5. - ARE CONTINUOUS OR DAMPED WAVES USED IN THE TRANSMISSION OF RADIO PROGRAMS?

6. - WHAT IS THE MAIN PURPOSE OF THE MICROPHONE?

7. - WHAT IS THE MAIN PURPOSE OF THE HEADPHONE?

8. - WHAT IS MEANT BY A PULSATING DIRECT CURRENT?

9. - WHAT IS THE DETECTOR IN A RADIO RECEIVER USED FOR?

10. - BRIEFLY DESCRIBE WHAT OCCURS FROM THE TIME THAT THE SOUNDS ARE PICKED UP BY THE MICROPHONE AT THE TRANSMITTER UNTIL THEY ARE AGAIN REPRODUCED AT THE LOUD SPEAKER.

RADIO - TELEVISION

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

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LESSON NO. 3

ELECTRICITY AS APPLIED TO RADIO

RADIO IS IN REALITY A HIGHLY SPECIALIZED FIELD OF THE ELECTRICAL INDUSTRY AND IS THEREFORE BASED UPON THE SAME ELECTRICAL PRINCIPLES. FOR THIS REASON, IT IS OF GREAT IMPORTANCE THAT BEFORE ENTERING YOUR DETAILED STUDY OF THE CONSTRUCTION AND OPERATION OF RADIO EQUIPMENT, YOU MUST FIRST ACQUIRE SOMEWHAT OF AN UNDERSTANDING OF THE ELECTRICAL TERMS AND PRINCIPLES WHICH WE ARE GOING TO APPLY IN OUR RADIO STUDIES IMMEDIATELY TO FOLLOW.

WE FULLY REALIZE THAT YOU ARE EXCEEDINGLY ANXIOUS TO GET RIGHT INTO THE HEART OF YOUR RADIO STUDIES AS SOON AS POSSIBLE, SO THAT YOU MAY APPLY YOUR KNOWLEDGE TO ACTUAL PRACTICAL USE. WITH THIS POINT IN MIND, WE HAVE MADE A SPECIAL EFFORT IN PREPARING THIS PRELIMINARY ELECTRICAL INSTRUCTION SO THAT YOU CAN COVER THIS WORK QUICKLY AND YET AT THE SAME TIME, ENABLING YOU TO FORTIFY YOURSELF WITH A SUFFICIENT KNOWLEDGE OF THESE IMPORTANT SUBJECTS FOR IMMEDIATE RADIO APPLICATION.

Fig. 1
Conducting Television Test
At National

SINCE THE FIRST KNOWLEDGE OF ELECTRICITY WAS OBTAINED BY MAN, MANY THEORIES HAVE BEEN ADVANCED TO EXPLAIN JUST EXACTLY WHAT ELECTRICITY IS AND IT HAS NOT BEEN UNTIL QUITE RECENTLY THAT A SATISFACTORY EXPLANATION HAS BEEN OFFERED IN TERMS OF THE NOW POPULAR "ELECTRON THEORY" WHICH IS GOING TO BE EXPLAINED TO YOU IN DETAIL A LITTLE LATER ON.

FOR THE PRESENT, IT IS ONLY NECESSARY FOR YOU TO REMEMBER THAT ELECTRICITY IS A FORM OF ENERGY EXISTING IN EVERYTHING: IN OTHER WORDS, IT EXISTS IN YOUR BODY, IN THE PAPER OF THIS LESSON, IN YOUR TABLE, CHAIRS, ETC., AND THE ONLY REASON WHY YOU ARE ORDINARILY UNAWARE OF ITS PRESENCE IS THAT IT IS NOT IN MOTION.

EVEN THOUGH YOU DO NOT YET KNOW EXACTLY WHAT ELECTRICITY IS, YET THIS DOES NOT PREVENT YOU FROM USING IT INTELLIGENTLY. THE MAIN THING WHICH YOU MUST BE FAMILIAR WITH REGARDING THIS WONDERFUL FORM OF ENERGY IS TO KNOW ITS CHARACTERISTICS, THAT IS, HOW IT ACTS UNDER CERTAIN CONDITIONS. WITH THIS KNOWLEDGE ALONE, YOU WILL BE ABLE TO HANDLE IT SUCCESSFULLY.

ELECTRICITY, WHEN MOVING UNDER CERTAIN CONDITIONS, PRODUCES CERTAIN SYMPTOMS AND IT IS DUE TO THESE SYMPTOMS THAT WE ACTUALLY RECOGNIZE THE PRESENCE OF ELECTRICAL ENERGY.

FROM THE FACTS SO FAR MENTIONED, YOU CAN READILY SEE, THAT WE HUMANS CANNOT CREATE NOR DESTROY THIS ENERGY CALLED ELECTRICITY. WHEN WE BOASTFULLY SAY THAT WE ARE PRODUCING ELECTRICITY BY OPERATING A GENERATOR, WE ARE NOT ACTUALLY SPEAKING THE TRUTH. ALL THAT WE ARE DOING IN THIS CASE IS TO PRODUCE A DISTURBANCE, WHICH WILL BRING ABOUT THE NECESSARY CONDITIONS SO THAT THE ELECTRICITY WILL BE FORCED TO MOVE.

ELECTRICITY SIMPLIFIED

QUITE A NUMBER OF THE CHARACTERISTICS OF ELECTRICITY CAN BE COMPARED TO THE ACTIONS OF WATER AND SINCE YOU ARE ALREADY SOMEWHAT FAMILIAR WITH THE "MECHANICS" ASSOCIATED WITH WATER, YOU WILL FIND THIS COMPARISON TO ASSIST YOU GREATLY IN VISUALIZING MORE CLEARLY WHAT OCCURS WHEN WE PUT ELECTRICITY TO WORK.

IN FIG. 2 WE HAVE TWO TANKS FILLED WITH WATER TO THE SAME LEVEL. THE TANKS ARE CONNECTED TOGETHER WITH A PIPE SYSTEM IN WHICH ARE INCLUDED A VALVE AND A WATER TURBINE. NOW THEN, IF THE VALVE SHOULD BE OPENED, IT IS OBVIOUS THAT THE BLADES OF THE TURBINE WOULD NOT BE CAUSED TO ROTATE BY ANY FLOW OF WATER, FOR THE SIMPLE REASON THAT THERE IS NO DIFFERENCE IN PRESSURE BETWEEN THE TWO TANKS TO PRODUCE ANY CURRENT OF WATER. IN ORDER TO HAVE A SUITABLE PRESSURE TO CAUSE A CURRENT FLOW THROUGH THIS SYSTEM, THE WATER LEVEL IN ONE OF THE TANKS WOULD HAVE TO BE HIGHER THAN THAT IN THE OTHER TANK.

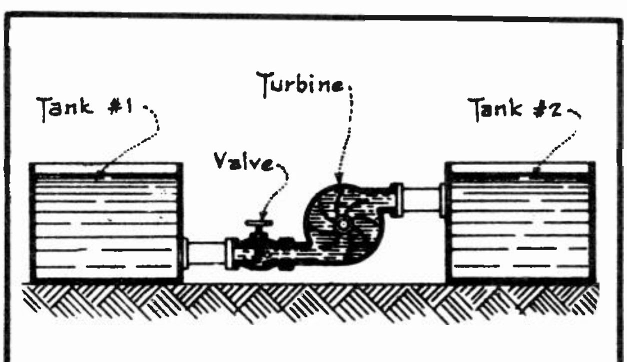

FIG. 2
The hydraulic system at rest.

NOW LET US CHANGE THIS HYDRAULIC SYSTEM TO THAT ILLUSTRATED IN FIG. 3. HERE WE HAVE ADDED A PUMP WHICH IS DRIVEN BY A MOTOR THROUGH A BELT. THE INLET OPENING OF THIS PUMP IS CONNECTED TO TANK #1 BY MEANS OF A PIPE, WHILE THE OUTLET OPENING OF THE PUMP IS FITTED WITH A LENGTH OF PIPE WHICH PROJECTS PART WAY OVER THE TOP OF TANK #2.

WITH THIS PUMP IN OPERATION, IT WILL SERVE TO DRAW WATER FROM TANK #1 AND FORCE IT OVER INTO TANK #2. THEN IF THE SYSTEM IS SO ADJUSTED THAT THE WATER IN TANK #2 IS MAINTAINED AT A HIGHER LEVEL THAN THAT IN TANK #1, A SUFFICIENT DIFFERENCE IN PRESSURE WILL EXIST BETWEEN THE WATER IN THE TWO TANKS, SO AS TO CAUSE WATER TO FLOW FROM TANK #2 TO TANK #1, AND IN THIS MANNER CAUSE THE BLADES OF THE TURBINE TO ROTATE.

THE MAIN THING WHICH YOU SHOULD NOTICE IN REGARDS TO FIGS. 2 AND 3 IS THAT WATER EXISTS IN BOTH CASES BUT THAT A CURRENT OF WATER FOR PRODUCING USEFUL WORK DOES NOT EXIST UNLESS A DIFFERENCE IN PRESSURE IS AVAILABLE.

GENERATING ELECTRICAL PRESSURE

WHEN DEALING WITH ELECTRICITY, WE HAVE A SIMILAR CONDITION TO CONTEND WITH AS THAT WHICH WE JUST CONSIDERED RELATIVE TO THE WATER SYSTEM. FOR EXAMPLE IN FIG. 4 YOU WILL SEE A GENERATOR CONNECTED TO A SWITCH AND A LAMP BY MEANS OF A PAIR OF WIRES, THEREBY COMPLETING AN ELECTRICAL CIRCUIT. THE GENERATOR IS BEING DRIVEN BY A GASOLINE ENGINE WHICH IS CONNECTED TO IT THROUGH A BELT.

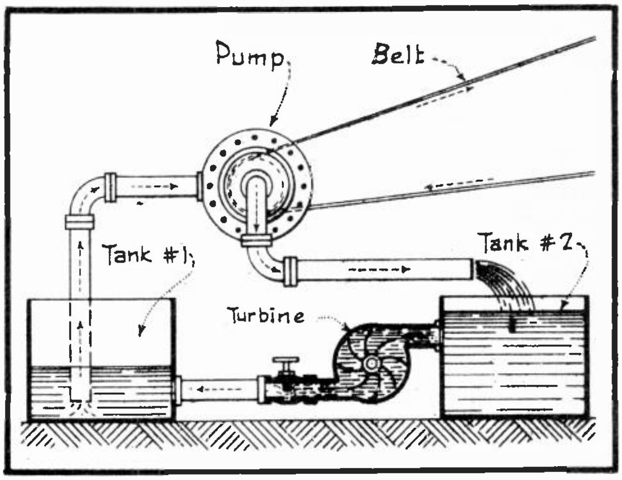

FIG. 3

Producing a difference in waterlevel.

WITH THE SWITCH CLOSED AND THE GENERATOR AT REST, THE LAMP DOES NOT BURN AND YET THERE IS JUST AS MUCH ELECTRICITY IN THE SYSTEM AS IF THE GENERATOR WERE OPERATING. THIS CONDITION CAN VERY NICELY BE COMPARED TO FIG. 2, WHERE THERE IS PLENTY OF WATER BUT NO CURRENT TO ACCOMPLISH ANY USEFUL WORK.

NOW IF WE SHOULD START UP THE GASOLINE ENGINE IN FIG. 4 SO THAT IT WILL DRIVE THE GENERATOR, AN ELECTRIC CURRENT WILL FLOW THROUGH THE CIRCUIT AND THEREBY CAUSE THE LAMP TO BURN. WHAT REALLY HAPPENS HERE IS THAT THE GENERATOR, WHEN IN OPERATION, CAUSES A CERTAIN DISTURBANCE WHICH ESTABLISHES A DIFFERENCE OF POTENTIAL ACROSS THE CIRCUIT.

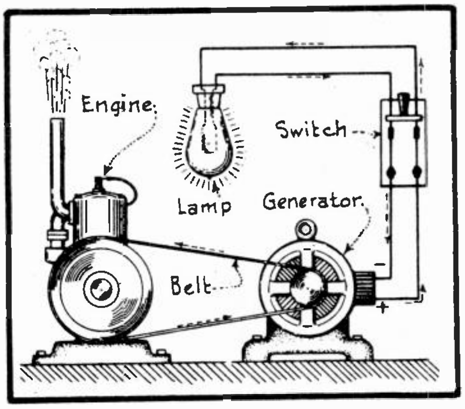

FIG. 4

The generator at work.

THIS DIFFERENCE IN POTENTIAL CAN BE COMPARED WITH THE DIFFERENCE IN THE WATER LEVEL OF THE TWO TANKS IN FIG. 3. THAT IS, A PRESSURE NOW EXISTS WHICH WILL CAUSE AN ELECTRIC CURRENT TO FLOW THROUGH THE CIRCUIT, SO THAT USEFUL WORK MAY BE ACCOMPLISHED.

CONDUCTORS AND INSULATORS

ONE OF THE PECULIARITIES OF AN ELECTRIC CURRENT IS THAT WHEN IT FLOWS THROUGH A CIRCUIT, IT HAS A NATURAL TENDENCY TO RETURN TO ITS STARTING POINT AND FOR THIS REASON, WE MUST ALWAYS PROVIDE A COMPLETE CIRCUIT IN ORDER FOR THE CURRENT TO COMPLETE ITS "ROUND-TRIP."

ANOTHER IMPORTANT POINT WHICH WE HAVE TO KEEP IN MIND IS THAT WE

MUST ALWAYS LAY-OUT OUR CIRCUITS OR PATHS FOR THE ELECTRIC CURRENT, SO THAT THE CURRENT WILL ONLY FLOW WHERE WE WANT IT TO AND NOT JUST ANYWHERE. FORTUNATELY, WE HAVE TWO DISTINCT TYPES OF MATERIALS AVAILABLE WHICH HELP US TO CARRY OUT THIS PLAN.

FIRST WE HAVE THOSE SUBSTANCES WHICH WILL PERMIT AN ELECTRIC CURRENT TO FLOW THROUGH THEM WITH COMPARATIVE EASE AND WE CLASSIFY MATERIALS OF THIS TYPE AS CONDUCTORS. METALS MAKE UP THE LARGER PART OF THE COMMERCIALLY ADAPTED ELECTRICAL CONDUCTORS; AMONG THEM BEING SILVER, COPPER, ALUMINUM, NICKLE, IRON, ETC. OF THESE, COPPER IS THE MOST EXTENSIVELY USED, NOT BECAUSE IT IS THE BEST CONDUCTOR AVAILABLE BUT BECAUSE IT IS THE BEST CONDUCTOR AVAILABLE AT A REASONABLE COST.

WE ALSO HAVE THOSE MATERIALS WHICH OFFER A GREAT DEAL OF OPPOSITION TOWARDS A FLOW OF CURRENT, AND WE CLASSIFY MATERIALS OF THIS TYPE AS INSULATORS. THERE IS NO KNOWN PERFECT INSULATOR BUT THERE ARE SOME VERY GOOD ONES, SUCH AS DRY AIR, MICA, PORCELAIN, BAKELITE, GLASS, PAPER, RUBBER, ETC.

THE VOLT - UNIT OF ELECTRICAL PRESSURE

IN PRACTICE, WE DO NOT GENERALLY USE THE TERM "ELECTRICAL PRESSURE", AS WE HAVE USED IT SO FAR IN THIS LESSON. INSTEAD OF THIS, WE USE THE CORRECT TECHNICAL TERM, ELECTROMOTIVE FORCE AND WHICH IS USUALLY ABBREVIATED AS E. M. F.

THE VOLT IS THE UNIT FOR MEASURING ELECTROMOTIVE FORCE AND IN RADIO WORK WHERE VERY SMALL VOLTAGE VALUES ARE FREQUENTLY USED, YOU WILL FREQUENTLY EMPLOY THE TERMS MILLIVOLT AND MICROVOLT. ONE MILLIVOLT IS EQUAL TO THE ONE-THOUSANDTH PART OF A VOLT, THAT IS, ONE MILLIVOLT IS EQUIVALENT TO .001 VOLT. ONE MICROVOLT, ON THE OTHER HAND, IS EQUAL TO THE ONE-MILLIONTH PART OF A VOLT OR ONE MICROVOLT IS EQUIVALENT TO .000001 VOLT.

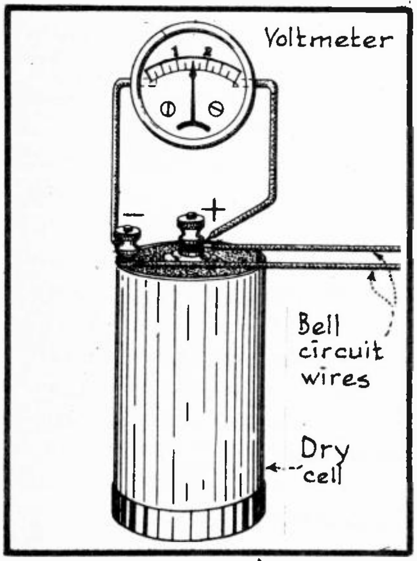

FIG. 5
Measuring voltage.

YOU WILL ALSO COME ACROSS SUCH TERMS AS VOLTAGE AND DIFFERENCE OF POTENTIAL WHEN REFERRING TO THE NUMBER OF VOLTS WHICH ARE DEVELOPED ACROSS ANY GIVEN CIRCUIT.

TO MEASURE THE VOLTAGE OF A CIRCUIT, WE USE AN INSTRUMENT KNOWN AS A VOLTMETER AND IN FIG. 5, YOU WILL SEE THE MANNER IN WHICH IT IS EMPLOYED. HERE THE VOLTAGE ACROSS A DRY CELL IS BEING MEASURED. THE SCALE OF THE VOLTMETER IS CALIBRATED IN VOLTS AND THE NEEDLE OF THE INSTRUMENT WILL THUS INDICATE THE ELECTROMOTIVE FORCE DIRECTLY IN VOLTS.

WHEN MEASURING VOLTAGE, IT IS ALWAYS IMPORTANT TO REMEMBER THAT THE VOLTMETER MUST BE CONNECTED ACROSS THE CIRCUIT AND FOR THIS REASON IT IS NOT NECESSARY TO OPEN OR INTERRUPT THE CIRCUIT WHEN TAKING SUCH A MEASUREMENT.

YOU WILL RECEIVE DETAILED INFORMATION REGARDING VOLTMETER CONNECTIONS FOR TAKING MEASUREMENTS IN VARIOUS TYPES OF RADIO CIRCUITS AS YOU

CONTINUE WITH YOUR STUDIES.

THE AMPERE - UNIT OF ELECTRICAL CURRENT

THE AMPERE IS THE UNIT OF ELECTRICAL CURRENT AND TO MEASURE THIS QUANTITY, WE USE AN INSTRUMENT WHICH IS KNOWN AS AN AMMETER. FIG. 6 SHOWS YOU HOW THE CURRENT FLOW THROUGH A CIRCUIT IS MEASURED WITH AN AMMETER AND AS YOU WILL OBSERVE, THE INSTRUMENT IS CONNECTED DIRECTLY INTO THE CIRCUIT. IN OTHER WORDS, TO MEASURE THE CURRENT FLOW, IT IS NECESSARY TO OPEN OR INTERRUPT THE CIRCUIT IN ORDER TO CONNECT THE AMMETER INTO THE SYSTEM. THEN SINCE THE SCALE OF THIS INSTRUMENT IS CALIBRATED IN "AMPERES," THE NEEDLE WILL INDICATE THE CURRENT FLOW DIRECTLY IN AMPERES.

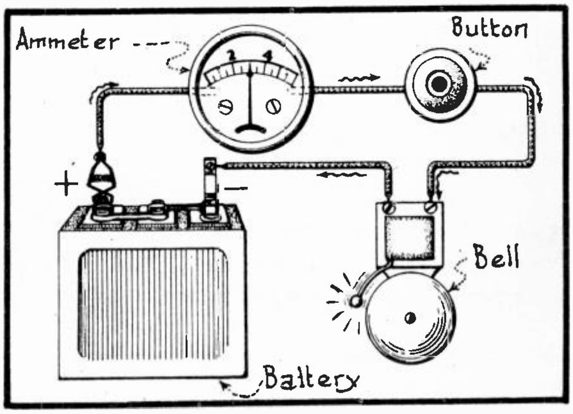

FIG. 6
Measuring current.

A STORAGE BATTERY IS THE SOURCE OF E.M.F. IN FIG. 6 AND THE CURRENT WILL FLOW THROUGH THE CIRCUIT AS INDICATED BY THE ARROWS THE INSTANT THAT THE PUSH BUTTON IS CLOSED SO AS TO COMPLETE THE CIRCUIT. ANOTHER IMPORTANT POINT TO BEAR IN MIND REGARDING FIG. 6 IS THAT THE NATURE OF THE E.M.F. AS FURNISHED BY ALL CELLS AND BATTERIES IS SUCH AS TO PRODUCE A DIRECT CURRENT, THAT IS, A CURRENT WHICH FLOWS IN ONE DIRECTION ONLY.

THE TERMINAL OR POINT FROM WHICH A DIRECT CURRENT LEAVES THE SOURCE OF E.M.F. ON ITS TRIP AROUND THE WIRED CIRCUIT IS CALLED THE POSITIVE TERMINAL AND WE IDENTIFY IT WITH THE SYMBOL (+) AS SHOWN YOU IN FIG. 6.

THE TERMINAL OR POINT AT WHICH THE CURRENT RETURNS FROM THE WIRED CIRCUIT TO THE SOURCE OF E.M.F. IS CALLED THE NEGATIVE TERMINAL AND WE IDENTIFY IT WITH THE SYMBOL (-) AS ALSO SHOWN IN FIG. 6. THUS YOU SEE, THAT WE CONSIDER THE DIRECT CURRENT AS FLOWING THROUGH THE WIRED CIRCUIT FROM POSITIVE TO NEGATIVE OR FROM (+) TO (-).

IN RADIO, WE FREQUENTLY WORK WITH VERY SMALL QUANTITIES OF CURRENT SO THAT THE AMPERE IS A RATHER LARGE UNIT TO EMPLOY. IN SUCH CASES, WE USE A SMALLER UNIT THE MILLIAMPERE, WHICH IS EQUAL TO THE ONE-THOUSANDTH PART OF AN AMPERE. THE MICRO-AMPERE IS ALSO OFTEN USED AND IT IS EQUAL TO THE ONE-MILLIONTH PART OF AN AMPERE.

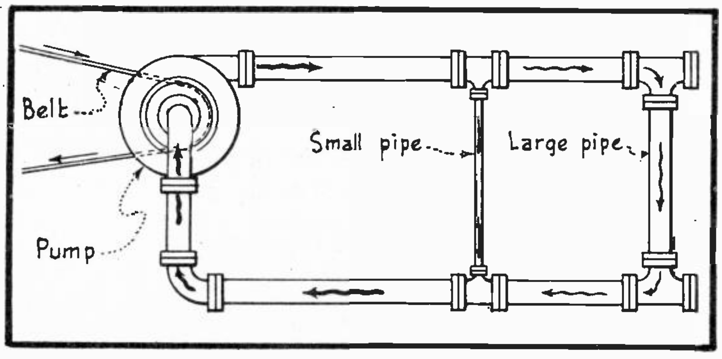

FIG. 7
Resistance in a hydraulic system.

THE OHM - UNIT OF ELECTRICAL RESISTANCE

HAVING CONSIDERED ELECTROMOTIVE FORCE AND CURRENT, WE WILL NOW INVESTIGATE THE OPPOSITION WHICH ALL CONDUCTORS OFFER TOWARDS A FLOW OF

ELECTRIC CURRENT. THE NATURE OF THIS OPPOSITION OR RESISTANCE, AS WE CALL IT, CAN NO DOUBT BE MADE CLEARER TO YOU IF YOU WILL FIRST ANALYZE THE HYDRAULIC SYSTEM WHICH IS ILLUSTRATED FOR YOU IN FIG. 7.

HERE YOU WILL SEE A WATER PUMP WHOSE INLET AND OUTLET OPENINGS ARE FITTED WITH PIPES OF RATHER LARGE SIZE. THESE TWO MAIN PIPES ARE THEN IN TURN CONNECTED TOGETHER BY MEANS OF TWO MORE PIPES, ONE OF WHICH IS SMALLER THAN THE OTHER.

NOW THEN, IF THE PUMP IS SET INTO OPERATION SO THAT A CURRENT OF WATER IS FORCED TO CIRCULATE THROUGH THE SYSTEM, IT IS CLEAR THAT THE ROUGH INNER WALLS OF THE PIPES, THE ELBOWS AND DIAMETER OF THE PIPE WILL ALL HAVE A PRONOUNCED EFFECT UPON THE EASE WITH WHICH THE WATER CAN FLOW THROUGH THE SYSTEM. IN OTHER WORDS, ALL OF THESE FACTORS TEND TO RETARD THE FLOW OF WATER.

ANOTHER IMPORTANT POINT WHICH YOU SHOULD NOTICE IN FIG. 7 IS THAT A GREATER CURRENT OF WATER FLOWS THROUGH THE LARGER PIPES THAN THROUGH THE SMALLER ONE, FOR THE SIMPLE REASON THAT THE SMALLER ONE OFFERS MORE OPPOSITION OR RESISTANCE THAN THE LARGER ONE.

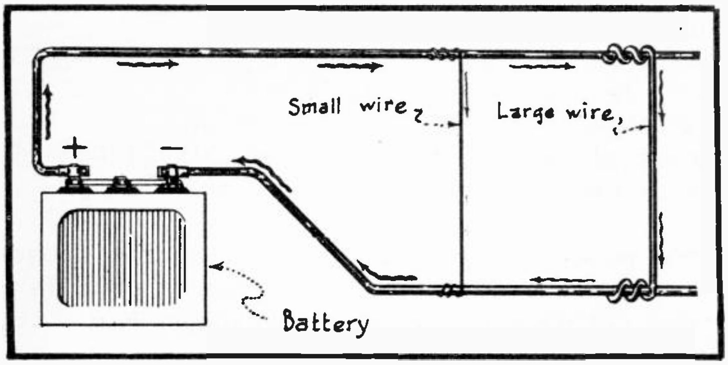

FIG. 8
The effect of resistance in an electrical circuit.

WE HAVE A SIMILAR CONDITION IN RESPECT TO ELECTRICAL CIRCUITS, FOR AS YET THERE IS NO PERFECT CONDUCTOR. ALL OF THEM OFFER A CERTAIN AMOUNT OF RESISTANCE.

IN FIG. 8 YOU WILL SEE AN ELECTRICAL CIRCUIT WHICH CAN BE COMPARED QUITE NICELY TO THEWATER CIRCUIT OF FIG. 7. AS YOU WILL NOTE IN FIG. 8, TWO LARGE CONDUCTORS (WIRES) ARE CONNECTED TO THE TERMINALS OF A STORAGE BATTERY AND THESE TWO MAIN WIRES ARE IN TURN CONNECTED TOGETHER BY ANOTHER PAIR OF WIRES, ONE OF WHICH HAS A SMALLER DIAMETER THAN THE OTHER.

THE CURRENT WILL FLOW THROUGH THE CIRCUIT OF FIG. 8 AS INDICATED BY THE ARROWS. IT WILL FLOW THROUGH THE LARGER WIRES WITH COMPARATIVE EASE, WHEREAS THE WIRE OF SMALLER DIAMETER OFFERS THE GREATEST AMOUNT OF OPPOSITION OR RESISTANCE AND THUS PREVENTS VERY MUCH CURRENT FROM FLOWING THROUGH IT.

NOT ONLY DOES THE ELECTRICAL RESISTANCE OF A CONDUCTOR DEPEND UPON ITS DIAMETER BUT IT ALSO DEPENDS UPON THE MATERIAL FROM WHICH THE CONDUCTOR IS MADE, UPON THE LENGTH OF THE CONDUCTOR, AND UPON ITS TEMPERATURE.

SINCE ALL CONDUCTORS OFFER RESISTANCE, IT IS OBVIOUS THAT WE MUST HAVE A UNIT FOR THE MEASUREMENT OF THIS VALUE. HENCE THE "OHM" WAS ADOPTED AS THE UNIT FOR ELECTRICAL RESISTANCE. THE UNIT MEGOHM IS ALSO FREQUENTLY EMPLOYED WHERE LARGE RESISTANCE VALUES ARE BEING HANDLED AND IT IS EQUAL TO ONE MILLION OHMS.

MAGNETISM

We use magnets and magnetic effects a great deal in RADIO and so it is advisable that you become familiar with them now so that you will be thoroughly prepared to apply these magnetic principles to the radio circuits which are going to be explained to you in the next lesson.

As a child, you were no doubt impressed with the manner in which a magnet attracted pieces of iron and steel but at that time you no doubt gave little thought to the phenomenae which made this possible. Now, however, we shall investigate the nature of magnetism in a more technical manner.

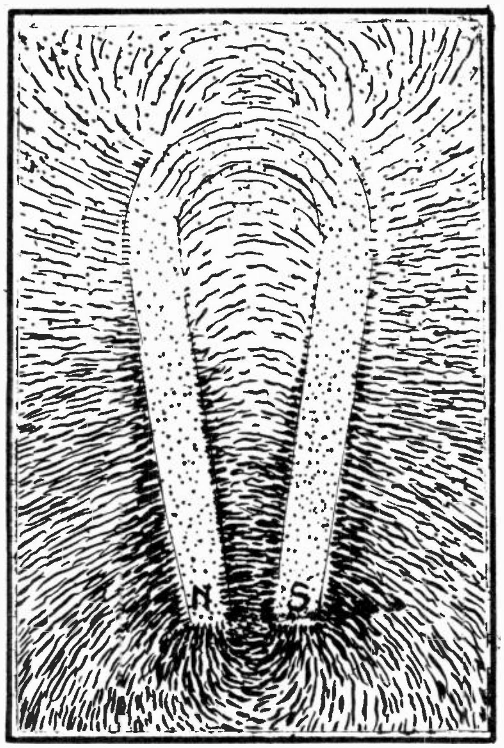

FIG. 9
The magnetic field.

Let us suppose, for example, that we should place a sheet of paper over an ordinary horseshoe magnet, sprinkle finely divided particle of iron on the paper and then gently tap the edge of the paper. Upon doing so, we will find the particles of iron to arrange themselves into a definite pattern similar to that shown you in Fig. 9. This simple experiment serves to show you that the magnet must possess a force of some kind so as to effect the particles of iron in this way.

If the same experiment should be repeated, the pattern formed by the iron particles would be a duplicate of that obtained with the previous experiment, thereby proving that the magnetic force surrounding a magnet always exerts itself along DEFINITE LINES and we call these lines LINES OF FORCE. The entire space in which these lines of force exist around a magnet is called the MAGNETIC FIELD.

THE POLES OF A MAGNET

If a bar magnet of the type shown in Fig. 10 is suspended freely at its center by a cord, then one of its ends will always point towards the NORTH and the other end towards the SOUTH pole of the earth. We call the north-seeking end of the magnet the NORTH POLE and the other end the SOUTH POLE. Steel and iron are the best known metals which will respond to magnetism.

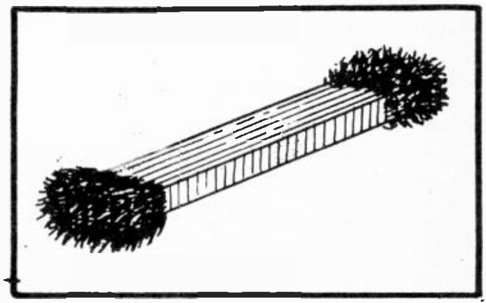

FIG. 10
The magnetic poles.

The power of attraction of a magnet is always concentrated at certain points and not throughout its entire

LENGTH. YOU CAN PROVE THIS FOR YOURSELF BY DIPPING A BAR MAGNET IN SOME IRON FILINGS. WHEN YOU WITHDRAW THE MAGNET YOU WILL FIND THAT THE IRON FILINGS ARE ALL BUNCHED AT THE TWO ENDS OF THE MAGNET AS SHOWN IN FIG. 10. IT IS AT THESE TWO ENDS THAT THE MAGNETIC STRENGTH IS CONCENTRATED.

REACTION BETWEEN MAGNETIC POLES

LET US PROCEED AND SEE HOW THE POLES OF TWO SEPARATE MAGNETS AFFECT EACH OTHER. AN INTERESTING EXPERIMENT SHOWING THIS ACTION IS ILLUSTRATED FOR YOU IN FIG 11, WHERE THE NORTH AND SOUTH POLES ARE RESPECTIVELY MARKED AS "N" AND "S".

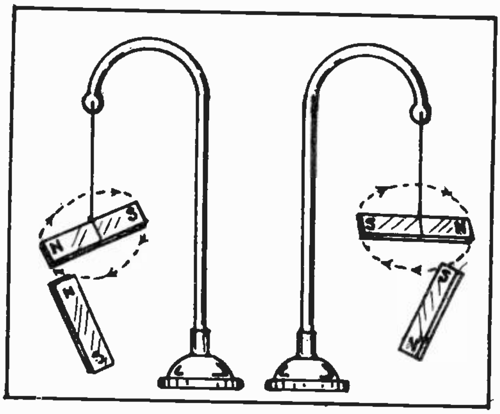

FIG. 11
Like poles repel
Unlike poles attract.

NOTE THAT WHEN TWO LIKE POLES ARE BROUGHT NEAR EACHOTHER AS SHOWN AT THE LEFT OF FIG. 11, THE SUSPENDED MAGNET WILL BE REPELLED. THAT IS, IT WILL SWING AWAY FROM THE OTHER MAGNET. HOWEVER, IF TWO UNLIKE POLES ARE BROUGHT TOGETHER, AS SHOWN AT THE RIGHT OF FIG. 11, THEN YOU WILL FIND THAT THE SWINGING MAGNET WILL BE ATTRACTED TOWARDS THE OTHER MAGNET.

FROM THESE TWO SIMPLE EXPERIMENTS, YOU CAN READILY SEE THAT LIKE MAGNETIC POLES REPEL EACHOTHER, WHEREAS UNLIKE MAGNET POLES ATTRACT EACH OTHER.

CHARACTERISTICS OF THE LINES OF FORCE

ANOTHER INTERESTING AND IMPORTANT FEATURE IS THAT THE LINES OF FORCE ARE UNBROKEN LINES, LEAVING THE MAGNET BY WAY OF THE NORTH POLE, PASSING THROUGH THE SPACE SURROUNDING THE MAGNET AND RETURNING TO THE MAGNET THROUGH THE SOUTH POLE.

TO DETERMINE THE DIRECTION OF THE LINES OF FORCE AROUND A MAGNET, YOU CAN PLACE A SMALL COMPASS (AS USED FOR DETERMINING DIRECTIONS) IN THE MAGNETIC FIELD. THE NORTH END OF THE COMPASS NEEDLE WILL THEN POINT IN THE DIRECTION OF THE MAGNETIC LINES OF FORCE. THIS IS ILLUSTRATED FOR YOU IN FIG. 12.

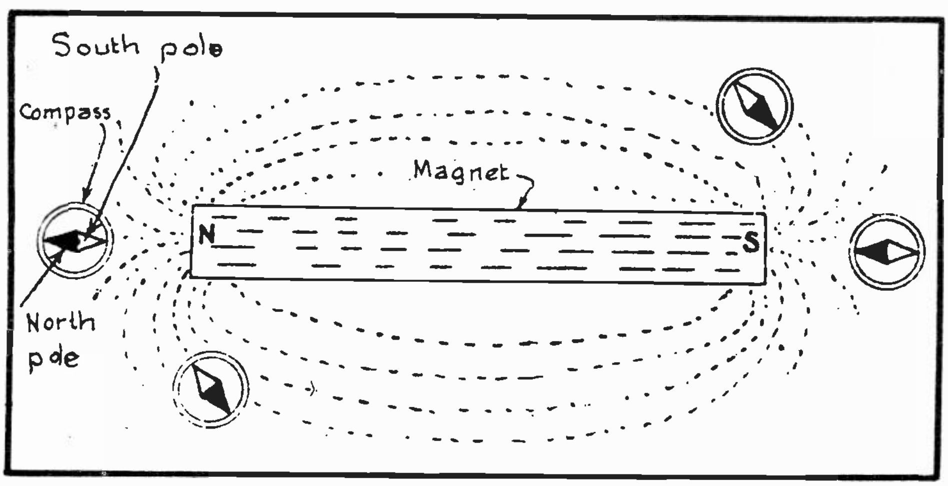

FIG. 12
Determining polarity of a magnet with a compass.

NO MATTER WHETHER THE MAGNET IS OF THE HORSE-SHOE TYPE OR THE BAR TYPE, THE LINES OF FORCE WILL ALWAYS PASS OUT OF THE MAGNET AT THE NORTH POLE AND RETURN TO THE MAGNET THROUGH THE SOUTH POLE. THOUSANDS OF LINES OF FORCE MAKE UP THE MAGNETIC FIELD AND SOMETIMES THESE LINES OF FORCE ARE CALLED THE MAGNETIC FLUX.

ALSO NOTICE IN FIG. 12 THAT THE SOUTH POLE OF THE COMPASS NEEDLE POINTS TOWARDS THE NORTH POLE OF THE MAGNET, WHILE THE NORTH END OF THE COMPASS NEEDLE POINTS TOWARDS THE SOUTH POLE OF THE MAGNET. IN THIS WAY, THE POLES OF A MAGNET CAN BE IDENTIFIED QUICKLY.

THE MOLECULAR THEORY OF MAGNETISM

SCIENTISTS CLAIM THAT THE DIFFERENCE BETWEEN A PIECE OF METAL WHICH IS MAGNETIZED, AND ONE WHICH IS NOT, IS THE ARRANGEMENT OF THE MOLECULES WITHIN THE METAL. (MOLECULES ARE THE SMALLEST PARTS INTO WHICH A SUBSTANCE CAN BE DIVIDED BUT YET RETAINING THE PROPERTIES OF THE SUBSTANCE. THESE PARTICLES ARE TOO SMALL FOR YOU TO SEE WITH YOUR NAKED EYE, HOWEVER THEIR EXISTENCE IS AN ESTABLISHED FACT.)

THE MOLECULES WITHIN A BAR OF IRON OR STEEL, WHICH IS NOT MAGNETIZED, ARE ARRANGED IN A DISORDERLY MANNER AS SHOWN IN THE UPPER ILLUSTRATION OF FIG. 13. WHEN THIS SAME BAR IS MAGNETIZED, THEN THESE MOLECULES RE-ARRANGE THEMSELVES AND STRAIGHTEN THEMSELVES OUT IN AN ORDERLY MANNER AS SHOWN IN THE LOWER ILLUSTRATION OF FIG. 13.

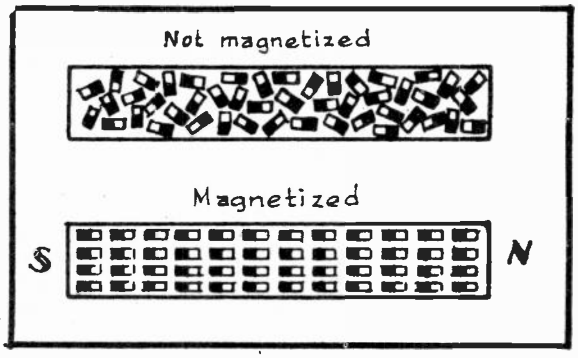

FIG. 13
Molecular arrangement of a magnetized and unmagnetized bar.

THIS THEORY OFFERS AN EXPLANATION AS TO WHY A PIECE OF SOFT IRON WILL BE MORE READILY MAGNETIZED THAN A PIECE OF STEEL BUT YET IS NOT CAPABLE OF RETAINING ITS MAGNETISM FOR SO GREAT A LENGTH OF TIME AS STEEL. THAT IS, THE MOLECULES IN A PIECE OF SOFT IRON STRAIGHTEN THEMSELVES OUT MUCH QUICKER THAN THOSE OF STEEL BUT THE MOLECULES IN THE STEEL WILL REMAIN IN AN ORDERLY MANNER MORE SO THAN THOSE IN THE SOFT IRON.

THIS SAME THEORY ALSO SHOWS US WHY A MAGNET WILL HAVE ITS MAGNETIC STRENGTH REDUCED WHEN JARRED VIOLENTLY. THE REASON FOR THIS BEING THAT THE JARRING CAUSES THE MOLECULES TO BE JARRED OR SHIFTED FROM THEIR ORDERLY POSITION.

ELECTROMAGNETISM

SO FAR IN THIS LESSON, WE HAVE ONLY BEEN DEALING WITH MAGNETS IN WHICH THE MAGNETISM WAS THE PROPERTY OF THE METAL ITSELF. WE CLASSIFY MAGNETS OF THIS TYPE AS PERMANENT MAGNETS.

BESIDES MAGNETISM OF THIS TYPE, HOWEVER, IT IS ALSO POSSIBLE TO PRODUCE A MAGNETIC FIELD BY PASSING AN ELECTRIC CURRENT THROUGH A CONDUCTOR. IN "A" OF FIG. 14, FOR EXAMPLE, WE HAVE A COMPASS NEEDLE PLACED NEXT TO A WIRE THROUGH WHICH NO ELECTRIC CURRENT IS FLOWING. UNDER

THESE CONDITIONS NO EFFECT WHATEVER WILL BE NOTICED UPON THE COMPASS NEEDLE.

NOW IF WE SHOULD PERMIT A DIRECT CURRENT TO FLOW THROUGH THIS WIRE THEN THE COMPASS NEEDLE WILL BE DEFLECTED, OR SWING ON ITS PIVOT AS ILLUSTRATED IN ILLUSTRATION "B" OF FIG. 14. THE REASON FOR THIS BEHAVIOR OF THE COMPASS NEEDLE IS THAT WHENEVER A CURRENT FLOWS THROUGH A CONDUCTOR, MAGNETIC LINES OF FORCE WILL BE PRODUCED AND THEY WILL ENCIRCLE THE CONDUCTOR IN THE MANNER AS SHOWN BY THE ARROWS IN "B" OF FIG. 14.

THERE IS A DEFINITE RELATION BETWEEN THE DIRECTION IN WHICH THE CURRENT FLOWS THROUGH THE CONDUCTOR AND THE DIRECTION IN WHICH THE RESULTING MAGNETIC FIELD ENCIRCLES THE CONDUCTOR. THIS IS CLEARLY ILLUSTRATED IN FIG. 15, WHERE THE CURRENT FLOW THROUGH THE WIRE IS INDICATED BY THE LARGER ARROWS AS FLOWING FROM THE RIGHT TOWARDS THE LEFT.

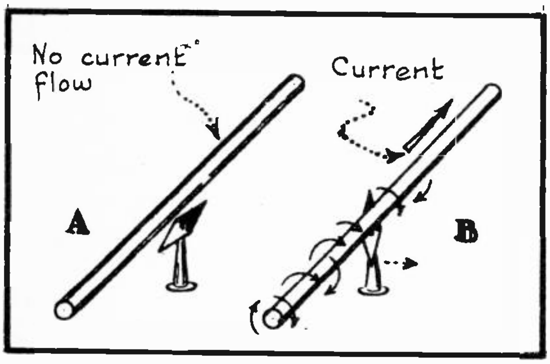

FIG. 14
Magnetic field surrounding a conductor.

SHOULD WE LOOK AT THIS SAME CONDUCTOR FROM ITS END, SO THAT THE CURRENT IS FLOWING AWAY FROM US AS INDICATED BY THE (+) INSIDE OF THE CONDUCTORS' CROSS-SECTION AT THE RIGHT OF FIG. 15, THEN THE MAGNETIC LINES OF FORCE WILL ENCIRCLE THE CONDUCTOR IN A CLOCKWISE DIRECTION. HOWEVER, IF WE SHOULD LOOK AT THE OTHER END OF THIS SAME CONDUCTOR, SO THAT THE CURRENT WILL BE FLOWING TOWARDS US, AS INDICATED BY THE "DOT" INSIDE OF THE CONDUCTORS' CROSS-SECTION AT THE LEFT OF FIG. 15, THEN THE LINES OF FORCE WILL ENCIRCLE THE CONDUCTOR IN A COUNTER-CLOCKWISE DIRECTION.

INSTEAD OF LEAVING THE CONDUCTOR OF FIG. 15 IN THE FORM OF A STRAIGHT WIRE, LET US WIND IT INTO THE SHAPE OF A COIL AS SHOWN IN FIG. 16. NOW IF WE SHOULD CONNECT THIS COIL TO A BATTERY SO THAT CURRENT WILL FLOW THROUGH IT, THE MAGNETIC LINES PRODUCED AROUND EACH TURN OF OF WIRE IN THE COIL WOULD ALL UNITE AND THEREBY ESTABLISH A MAGNETIC FIELD WHICH SURROUNDS THE COIL AS A WHOLE.

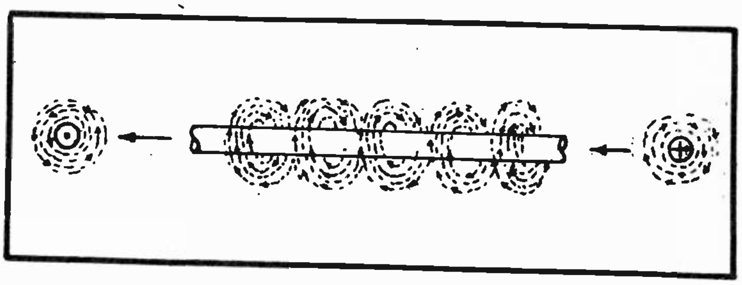

FIG. 15
Direction of the magnetic field.

WITH THE CURRENT FLOWING THROUGH THE COIL AS INDICATED BY THE ARROWS, THE LINES OF FORCE WOULD ENCIRCLE THE COIL IN THE DIRECTION AS ALSO SHOWN IN THIS ILLUSTRATION. NOTICE THAT IN THE CASE OF A COIL OF THIS TYPE, THE LINES OF FORCE ALSO FLOW FROM THE NORTH POLE TO THE SOUTH POLE, THE SAME AS WITH A PERMANENT MAGNET. WE CLASSIFY A WINDING OF THIS TYPE AS A SOLENOID.

SOMETIMES, WE ALSO CALL A WINDING SUCH AS THIS AN "AIR-CORE COIL".

EFFECT OF AN IRON CORE

IF A SOFT BAR OF IRON IS INSERTED INTO THE COIL OF WIRE, THEN WE WOULD CLASSIFY THE UNIT AS AN ELECTROMAGNET AND IT WOULD APPEAR AS ILLUSTRATED IN FIG. 17. IT SO HAPPENS THAT SOFT IRON WILL CONDUCT LINES OF FORCE MUCH MORE READILY THAN WILL AIR AND FOR THIS REASON, A GREATER NUMBER OF LINES OF FORCE WILL BE CONCENTRATED ABOUT THE WINDING------IN THIS WAY, NATURALLY INCREASING THE MAGNETIC STRENGTH OF THE UNIT. WHENEVER IRON IS USED IN THE CONSTRUCTION OF A WINDING IN THIS MANNER, WE SPEAK OF IT AS BEING AN IRON CORE.

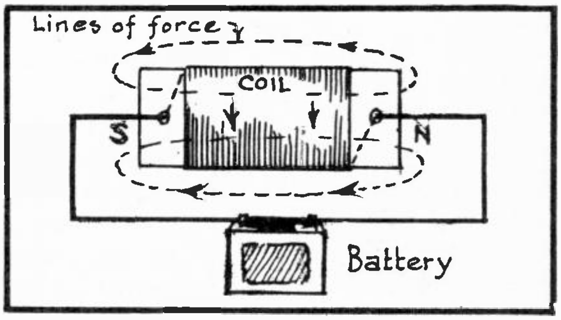

FIG. 16
Magnetic field surrounding a coil.

NOTICE ESPECIALLY IN FIG.17, THE DIRECTION OF CURRENT FLOW THROUGH THE WINDING, THE LOCATION OF THE NORTH AND SOUTH POLES AND THE DIRECTION IN WHICH THE LINES OF FORCE ENCIRCLE THE ELECTROMAGNET.

ALTHOUGH THE IRON CORE OF AN ELECTROMAGNET HAS A PRONOUNCED EFFECT UPON THE INTENSITY OF THE RESULTING MAGNETIC FIELD, YET IT IS ALSO TRUE THAT THE AMOUNT OF CURRENT PASSING THROUGH THE WINDING AND THE NUMBER OF TURNES USED IN THE WINDING WILL ALSO HAVE A MARKED EFFECT UPON THE MAGNETIC STRENGTH OF THE UNIT. IN OTHER WORDS, THE GREATER THE NUMBER OF TURNS USED IN THE WINDING FOR A GIVEN CURRENT FLOW, THE GREATER WILL BE THE NUMBER OF LINES OF FORCE WHICH ARE ESTABLISHED. THEN TOO, THE GREATER THE FLOW OF CURRENT THROUGH A WINDING OF A GIVEN NUMBER OF TURNS, THE GREATER WILL BE THE NUMBER OF LINES OF FORCE WHICH ARE ESTABLISHED.

THE RIGHT - HAND RULE

ALTHOUGH THE POLARITY OF AN ELECTROMAGNET CAN BE DETERMINED BY HOLDING A COMPASS NEAR ITS EXTREMITIES AS ALREADY EXPLAINED RELATIVE TO PERMANENT MAGNETS, YET WE ALSO HAVE A VERY HANDY RULE WHICH IS VERY SIMPLE TO APPLY. WE CALL THIS THE RIGHT-HAND RULE AND IT IS ILLUSTRATED FOR YOU IN FIG. 18.

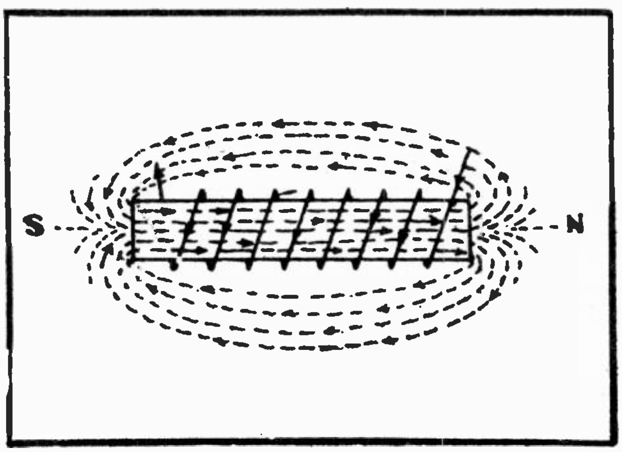

FIG. 17
An electromagnet.

TO DETERMINE THE POLARITY OF AN ELECTROMAGNET IN THIS MANNER, GRASP THE WINDING WITH THE RIGHT HAND AS SHOWN IN FIG. 18, SO THAT ALL OF YOUR FINGERS, WITH THE EXCEPTION OF THE THUMB, POINT IN THE DIRECTION IN WHICH THE CURRENT IS FLOWING THROUGH THE WINDING. THE THUMB SHOULD BE EXTENDED AS IN FIG. 18 AND IT WILL THEN BE POINTING TOWARDS THE NORTH POLE OF THE ELECTROMAGNET. THE OTHER EXTREMETY OF THE UNIT WILL OF COURSE THEN BE THE SOUTH POLE.

ELECTROMAGNETIC INDUCTION

SINCE IT IS TRUE THAT THE FLOW OF AN ELECTRIC CURRENT THROUGH A CONDUCTOR WILL CAUSE LINES OF FORCE TO ENCIRCLE THE CONDUCTOR, THEN IT IS ALSO LOGICAL TO BELIEVE THAT IF LINES OF FORCE CAN BE MADE TO ENCIRCLE

A CONDUCTOR, THEY IN TURN SHOULD BE ABLE TO CAUSE A CURRENT FLOW THROUGH THE CONDUCTOR. SUCH IS THE CASE IN ACTUAL PRACTICE.

IN FIG. 19, FOR EXAMPLE, YOU WILL SEE THE NORTH AND SOUTH POLES OF A MAGNET, WITH THE RESULTING MAGNETIC LINES OF FORCE EXTENDED BETWEEN THEM. THE ENDS OF A LARGE WIRE ARE CONNECTED TO A GALVANOMETER BY MEANS OF A PAIR OF SMALLER WIRES. (A GALVANOMETER IS A SENSITIVE INSTRUMENT WHICH IS USED TO INDICATE THE PRESENCE OF VERY WEAK ELECTRICAL CURRENTS.)

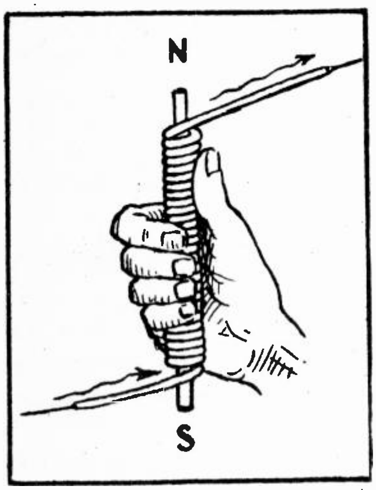

FIG. 18
Polarity.

NOW IF THE LARGE WIRE IS PASSED RAPIDLY FROM THE LEFT TOWARDS THE RIGHT AS INDICATED BY THE LARGE ARROW, THEN A VOLTAGE WILL BE GENERATED IN THE CONDUCTOR, CAUSING A CURRENTTO FLOW THROUGH THE GALVANOMETER CIRCUIT AS SHOWN AND ITS PRESENCE WILL BE INDICATED BY A DEFLECTION OF THE GALVANOMETER NEEDLE. WHENEVER A VOLTAGE IS GENERATED IN THIS WAY, WE SPEAK OF THIS PHENOMENA AS ELECTROMAGNETIC INDUCTION.

THE VOLTAGE, WHICH IS GENERATED BY MEANS OF ELECTROMAGNETIC INDUCTION, WILL BE DEPENDENT UPON THE NUMBER OF LINES CUT BY THE CONDUCTOR PER SECOND. THIS MEANS THAT THE GENERATED VOLTAGE CAN BE INCREASED BY PASSING THE CONDUCTOR THROUGH THE MAGNETIC FIELD AT A GREATER SPEED, BY PROVIDING A MAGNETIC FIELD OF GREATER INTENSITY OR BY USING A CONDUCTOR IN THE FORM OF A COIL--CONSISTING OF SEVERAL TURNS OF WIRE. WE GENERALLY REFER TO A CONDUCTOR OR COIL WHICH IS USED FOR THIS PURPOSE AS BEING AN "INDUCTOR."

ANOTHER WAY OF GENERATING A VOLTAGE BY MEANS OF INDUCTION IS TO LEAVE THE CONDUCTOR IN A STATIONARY POSITION AND CAUSE THE MAGNETIC LINES OF FORCE TO PASS ACROSS IT. THIS CAN BE BETTER ILLUSTRATED WITH THE AID OF FIG. 20, WHERE WE HAVE A WINDING WITH A SOFT IRON CORE AND THE ENDS OF THE WINDING CONNECTED ACROSS A BATTERY CIRCUIT CONSISTING OF FOUR DRY CELLS.

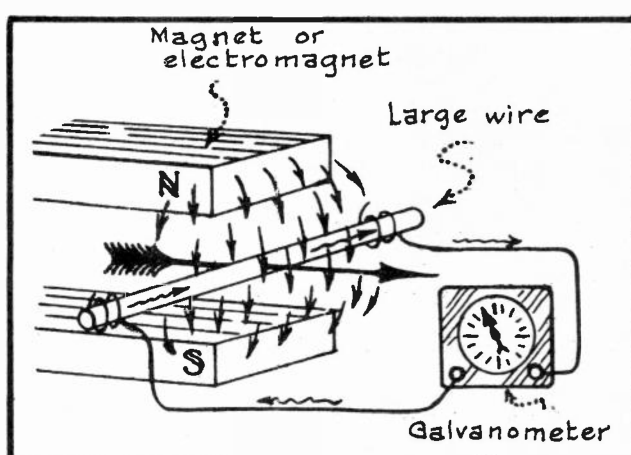

FIG. 19
Electromagnetic induction.

IF THE TWO ENDS OF THIS CIRCUIT ARE TOUCHED TOGETHER SO AS TO COMPLETE THE CIRCUIT, THEN THE CURRENT FLOW THROUGH THE WINDING WILL CAUSE A MAGNETIC FIELD TO BE ESTABLISHED AROUND IT.

NOW IF THE TWO ENDS OF THIS CIRCUIT ARE DRAWN APART AFTER THE MAGNETIC FIELD HAS ONCE BEEN COMPLETELY BUILT UP, A HEAVY FLASH OR SPARK WILL BE PRODUCED AT THE POINT WHERE THE CIRCUIT IS INTERRUPTED. THIS SPARK WILL BE MUCH MORE INTENSE THAN THE SPARK OBTAINED UPON INTER-

RUTING THE BATTERY CIRCUIT ALONE, WITH NO ELECTROMAGNET CONNECTED IN THE SYSTEM, THUS SHOWING THAT A VOLTAGE IS BEING FURNISHED BY SOME SOURCE OTHER THAN THE BATTERY.

WHAT REALLY OCCURS IN THE SYSTEM OF FIG. 20 IS THAT UPON INTERRUPTING THE CIRCUIT, THE MAGNETIC FIELD WILL COLLAPSE ABRUPTLY AND THE LINES OF FORCE WILL RECEDE OR DISAPPEAR INTO THE IRON CORE. IN DOING SO, THEY WILL CUT THROUGH THE TURNS OF WIRE USED IN THE COIL VERY RAPIDLY AND THUS GENERATES A VOLTAGE BY INDUCTION ACROSS THIS COIL. THIS INDUCED VOLTAGE IS MUCH GREATER THAN THE VOLTAGE AS FURNISHED BY THE BATTERY AND FOR THIS REASON THE SPARK AT THE POINT WHERE THE CIRCUIT IS INTERRUPTED IS MUCH MORE INTENSE THAN A BATTERY SPARK.

IF THE VOLTAGE IS INDUCED INTO THE SAME WINDING WHICH ESTABLISHES THE MAGNETIC FIELD IN THE FIRST PLACE, THEN WE SPEAK OF THIS TYPE OF INDUCTION AS BEING AUTO-INDUCTION.

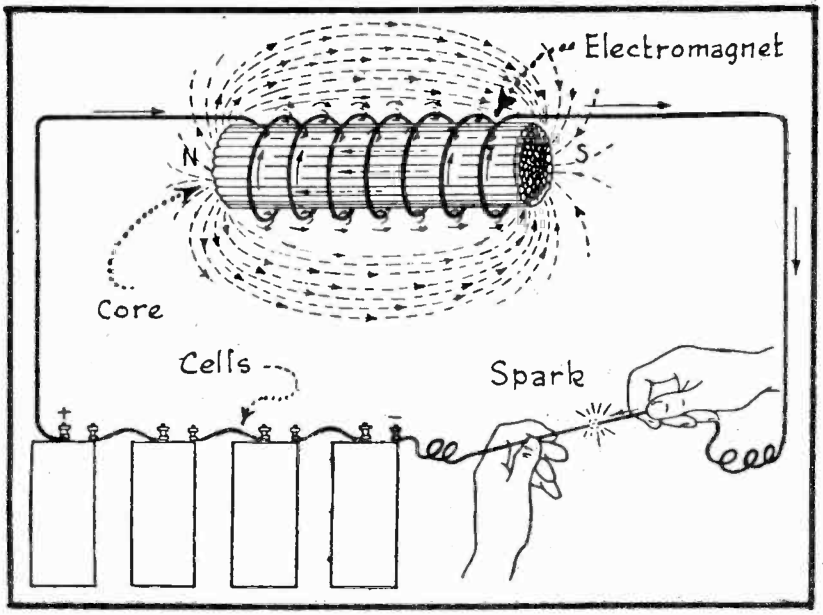

FIG. 20
A demonstration of auto induction.

MUTUAL INDUCTION

IN FIG. 21 YOU WILL FIND AN ARRANGEMENT WHICH IS STILL DIFFERENT. HERE TWO SEPARATE WINDINGS ARE THOROUGHLY INSULATED FROM EACHOTHER.

THE EXTREMETIES OF ONE OF THE WINDINGS IS CONNECTED TO A STORAGE BATTERY THROUGH A SWITCH, WHILE THE EXTREMETIES OF THE OTHER WINDING ARE CONNECTED TO THE TERMINALS OF A GALVANOMETER. THE WINDING WHICH IS CONNECTED TO THE SOURCE OF E.M.F., OR THE BATTERY IN THIS CASE, IS CALLED THE PRIMARY WINDING, WHILE THE OTHER WINDING IS REFERRED TO AS THE SECONDARY WINDING. THE ENTIRE UNIT, CONSISTING OF THE TWO WINDINGS AND THE IRON CORE IS CALLED AN INDUCTION COIL.

IF THE SWITCH OF THE CIRCUIT IN FIG. 21 IS CLOSED, BATTERY CURRENT WILL FLOW THROUGH THE PRIMARY WINDING IN THE DIRECTION INDICATED BY THE ARROWS. THIS CURRENT FLOW THROUGH THE PRIMARY WINDING WILL CAUSE A MAGNETIC FIELD TO BE ESTABLISHED AROUND THE ENTIRE COIL. THEN IF THE SWITCH IS SUDDENLY OPENED, BATTERY CURRENT WILL STOP FLOWING AND THE MAGNETIC FIELD WILL COLLAPSE INTO THE IRON CORE. AS IT DOES SO, THE LINES OF FORCE WILL ALSO PASS RAPIDLY ACROSS THE WIRE OF THE SECONDARY WINDING AND INDUCE A VOLTAGE IN THE SECONDARY WINDING, AS WELL AS IN THE PRIMARY WINDING. THE VOLTAGE THUS GENERATED IN THE PRIMARY WINDING, WHEN THE CIRCUIT IS OPENED, IS PRODUCED BY AUTO-INDUCTION, WHILE THAT GENERATED IN THE SECONDARY WINDING IS PRODUCED BY WHAT WE TERM MUTUAL INDUCTION

THE GALVANOMETER IN FIG. 21 WILL INDICATE THE PRESENCE OF AN ELECTRIC CURRENT AT THE TIME THE MAGNETIC FIELD COLLAPSES AND INDUCES THE VOLTAGE IN THE SECONDARY WINDING.

IT IS OF COURSE TRUE THAT MAGNETIC LINES OF FORCE WILL ALSO PASS OVER BOTH WINDINGS OF THE INDUCTION COIL AS THE MAGNETIC FIELD COMMENCES TO BUILD UP WHEN THE SWITCH IN THE PRIMARY CIRCUIT IS FIRST CLOSED. HOWEVER, THE FIELD BUILDS UP AT A MUCH SLOWER RATE THAN IT COLLAPSES BECAUSE WHEN BUILDING UP, THE LINES OF FORCE CUT THROUGH THE TURNS OF THE PRIMARY WINDING IN SUCH A DIRECTION THAT THE VOLTAGE INDUCED IN THIS WINDING DURING THIS PERIOD OPPOSES THE BATTERY VOLTAGE. THIS SERVES TO RETARD THE FLOW OF BATTERY CURRENT SOMEWHAT AND RESULTS IN A COMPARATIVELY SLOW MAGNETIC FIELD FORMATION. THIS OPPOSING VOLTAGE WHICH IS GENERATED IN THIS WAY IS SPOKEN OF AS THE COUNTER-ELECTROMOTIVE FORCE.

BY PROVIDING THE INDUCTION COIL WITH A SECONDARY WINDING OF MANY MORE TURNS OF WIRE THAN THE PRIMARY WINDING, THE VOLTAGE INDUCED INTO THE SECONDARY WINDING WILL BE MUCH GREATER THAN THE PRIMARY VOLTAGE. ON THE OTHER HAND, IF THERE ARE MORE TURNS OF WIRE IN THE PRIMARY WINDING THAN IN THE SECONDARY WINDING THEN THE VOLTAGE INDUCED INTO THE SECONDARY WINDING WILL BE LESS THAN THE PRIMARY VOLTAGE.

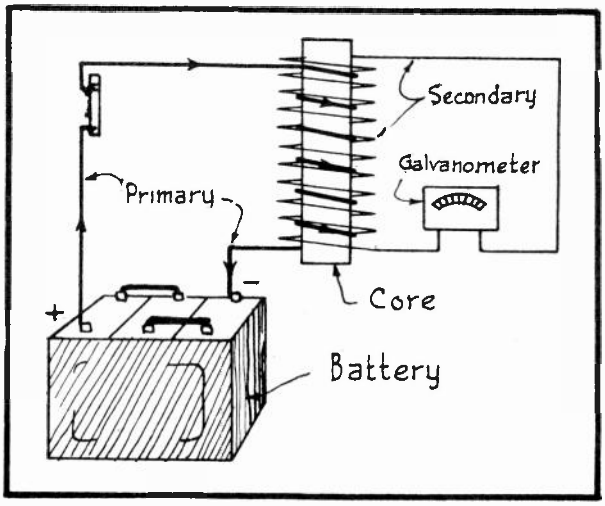

FIG. 21
Mutual induction.

IN THIS LESSON, YOU HAVE HAD THE OPPORTUNITY OF LEARNING MANY THINGS ABOUT ELECTRICITY. EVERY BIT OF THIS INFORMATION IS GOING TO BE OF PRACTICAL VALUE TO YOU IN THE LESSONS TO COME, AS WELL AS IN YOUR WORK IN THE INDUSTRY, THEREFORE IT IS OF GREAT IMPORTANCE THAT YOU MASTER IT.

IN YOUR NEXT LESSON, YOU WILL COMMENCE YOUR INTENSIVE STUDY OF RADIO RECEIVERS. THIS MEANS THAT IN A VERY SHORT TIME, YOU WILL HAVE SUFFICIENT KNOWLEDGE TO ENGAGE IN THE ORDINARY TYPE OF SERVICE WORK AND WHERE YOU CAN START "EARNING WHILE LEARNING.

DEAR STUDENT—

EVERY YOUTH WOULD LIKE TO ATTAIN SUCCESS, HONOR AND INFLUENCE. BUT NEARLY EVERYONE FAILS. WHY? BECAUSE THERE ARE DIFFICULTIES IN THE WAY. WHAT ARE THESE DIFFICULTIES? THE THINGS THAT PREVENT ACHIEVEMENT -- THE HARD THINGS. WHAT IS THE CUSTOMARY WAY OF TREATING THEM? TO DODGE THEM OR SLUR THEM. WHY SHOULD THAT BE THE COMMON WAY? BECAUSE IT IS THE EASIEST WAY, OF COURSE.

TO YIELD IS EASY; TO RESIST HARD.

GRAPPLE THE FIRST DIFFICULTY THAT COMES UP. WRESTLE TILL YOU DOWN IT, IF IT TAKES TILL THE BREAK OF DAY. GET ON TOP OF IT WITH BOTH FEET.

JAK

RADIO - TELEVISION

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LESSON NO. 4

Operation of Radio Receivers

You have thus far learned how the transmitter radiates electromagnetic waves. These waves gradually become weaker the farther they travel from their point of origin, but it requires very little of this radiated energy to make satisfactory reception possible, provided that the receiver is sufficiently sensitive.

THE ANTENNA

The ANTENNA is the first part of the receiving station which is required to handle the transmitted signal and in Fig. 2 you will see a typical antenna installation, such as most frequently used for receiving purposes.

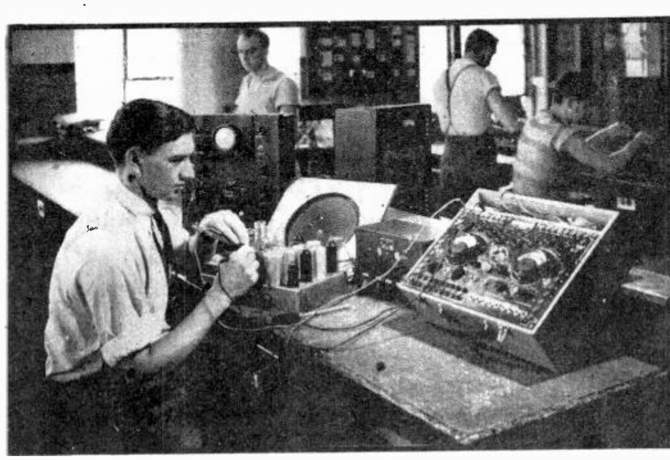

Fig. 1
Student Testing Receiver
With Modern Analyzer.

The particular antenna here illustrated consists of a single copper wire which is suspended horizontally between two insulators at a height of about 25 to 30 ft. From one end of the elevated antenna, a wire is run to the antenna terminal of the receiver, which is located inside of the building. We call this wire between the antenna and the receiver the LEAD-IN wire. In Fig. 2, you will also see the symbol which we use in order to represent an antenna in radio diagrams.

For best performance, an antenna of the type illustrated in Fig. 2 should not be less than 30 ft long and the most popular type of wire now used for this purpose consists of seven strands of #25 to #22 B & S size enameled copper wire all twisted together so as to form a single conductor. In some cases, however, a single #12 B & S copper wire is used for

THIS PURPOSE.

THE ANTENNA WIRE SHOULD BE THOROUGHLY INSULATED FROM ITS SUPPORTS BY SPECIAL ANTENNA-TYPE INSULATORS OF GOOD QUALITY. THE LEAD-IN WIRE MAY CONSIST OF A #18 TO A #14 B & S SIZE STRANDED COPPER WIRE EQUIPPED WITH WEATHERPROOF RUBBER INSULATION AND IT SHOULD BE KEPT WELL INSULATED FROM THE BUILDING.

BESIDES THE ANTENNA, THE RECEIVER SHOULD ALSO BE PROVIDED WITH A SATISFACTORY GROUNDING SYSTEM. IN FIG. 3 YOU WILL SEE AN EXAMPLE OF THE SIMPLEST TYPE OF GROUND CONNECTION AND AS YOU WILL OBSERVE, IT CONSISTS OF NOTHING MORE THAN A COPPER STRAP WHICH IS FASTENED IN THE FORM OF A CLAMP AROUND A COLD WATER PIPE. WHEN MAKING A CONNECTION AS THIS, IT IS IMPORTANT THAT YOU FIRST ASSURE YOURSELF THAT THE PIPE TO WHICH YOU ARE MAKING THE CONNECTION, ACTUALLY IS A COLD WATER PIPE WHICH PENETRATES THE SURFACE OF THE EARTH AT SOME POINT IN THE PIPING SYSTEM.

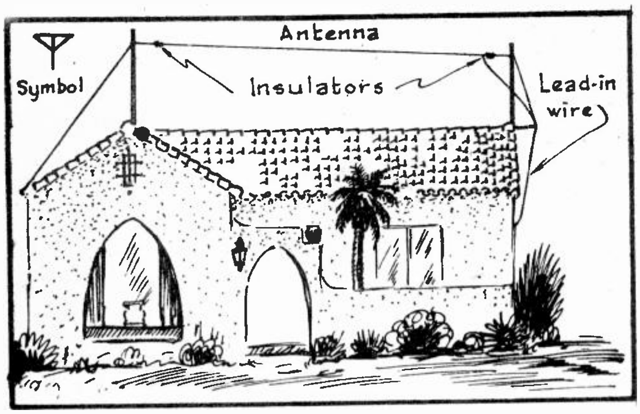

FIG. 2
A typical antenna instalation.

BESIDES THIS PRECAUTION, IT IS ALSO ESSENTIAL THAT YOU SCRAPE THE PIPE WELL BEFORE CLAMPING THE GROUNDING STRAP TO IT. THE REASON FOR THIS IS THAT ANY DIRT, PAINT, RUST OR OTHER FOREIGN SUBSTANCE ON THE OUTER SURFACE OF THE PIPE WILL PREVENT THE GROUNDING STRAP FROM ESTABLISHING A GOOD ELECTRICAL CONTACT WITH THE CLEAN METAL OF THE PIPE. A GOOD ELECTRICAL CONTACT IS NECESSARY AT THIS POINT IF THE BEST RESULTS ARE TO BE EXPECTED.

A WIRE IS THEN RUN FROM THE GROUNDING CLAMP TO THE GROUND TERMINAL OF THE RECEIVER AND WE CALL THIS WIRE THE GROUND WIRE. FOR THIS PURPOSE, A #14 TO A #18 B&S SIZE STRANDED COPPER WIRE WITH RUBBER INSULATION AND A BRAID COVERING IS FREQUENTLY USED.

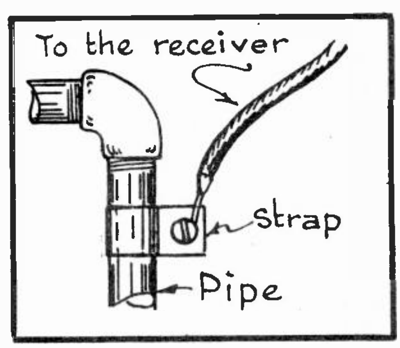

FIG. 3
A water-pipe ground connection.

ANOTHER POPULAR FORM OF GROUND CONNECTION IS ILLUSTRATED FOR YOU IN FIG. 4. THIS TYPE IS ESPECIALLY ADAPTABLE IN SUCH CASES WHERE A GROUNDED COLD WATER PIPE IS NOT AVAILABLE. AS YOU WILL OBSERVE IN FIG. 4, THE GROUND CONNECTION IN THIS INSTANCE IS MADE BY DRIVING A 6 FT. LENGTH OF IRON PIPE OR AN IRON ROD INTO THE GROUND FAR ENOUGH SO THAT ONLY 3 TO 4 INCHES OF IT REMAIN TO PROJECT ABOVE THE SURFACE OF THE EARTH. A COPPER STRAP IS THEN CLAMPED TO THE EXPOSED END OF THE PIPE AS HERE SHOWN AND THE GROUND WIRE IS FASTENED TO IT.

WHEN PREPARING A GROUND CONNECTION OF THE TYPE SHOWN IN FIG.4, IT IS IMPORTANT TO NOTE THAT THE NATURE OF THE SOIL AT THE LOCATION CHOSEN FOR IT IS SUCH THAT THE LOWER PORTION OF THE IRON PIPE OR ROD WILL BE IM

BEDDED IN MOIST EARTH. IN ADDITION, THE PIPE OR ROD WILL HAVE TO BE SCRAPED AT THE POINT WHERE THE COPPER STRAP IS TO BE APPLIED.

IN FIG. 4 YOU WILL ALSO FIND THE SYMBOL WHICH WE USE IN ORDER TO REPRESENT A GROUND CONNECTION IN RADIO DIAGRAMS.

FROM THE DESCRIPTION SO FAR GIVEN YOU IN THIS LESSON, YOU HAVE A SUFFICIENT KNOWLEDGE CONCERNING ANTENNA AND GROUND CORRECTIONS, SO THAT WE CAN APPLY THEM TO OUR FOLLOWING RADIO CIRCUITS. IN A LATER LESSON, YOU WILL RECEIVE STILL MORE COMPLETE INSTRUCTION REGARDING THE FINER POINTS FOR THE CONSTRUCTION OF ANTENNA AND GROUNDING SYSTEMS OF ALL TYPES.

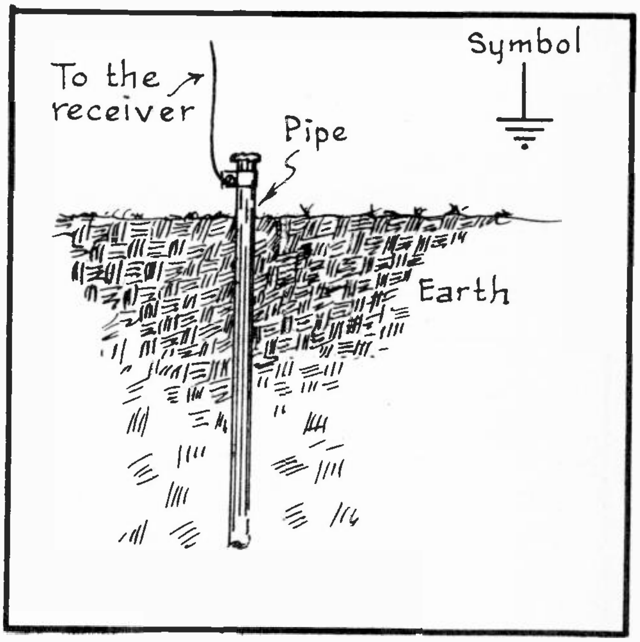

FIG. 4

Another form of ground connection.

THE ANTENNA CIRCUIT

NOW LET US INVESTIGATE HOW THE ANTENNA AND GROUND ARE CONNECTED TO THE CIRCUITS OF THE RECEIVER. THIS IS SHOWN YOU IN FIG. 5, WHERE YOU WILL OBSERVE THAT THE ANTENNA LEAD-IN WIRE IS CONNECTED TO ONE END OF A COIL WHILE THE GROUND WIRE IS CONNECTED TO THE OTHER END OF THE COIL. THIS CONSTITUTES THE ANTENNA CIRUIT.

WE GENERALLY REFER TO THIS COIL AS THE ANTENNA COIL AND IT IS CONSTRUCTED BY WINDING A SMALL SIZE INSULATED WIRE ON A TUBULAR-SHAPED FORM WHICH IS MADE OF SOME SUCH INSULATING MATERIAL AS BAKELITE, HARD RUBBER OR CARDBOARD. THE SYMBOL FOR THIS ANTENNA CIRCUIT IS ALSO ILLUSTRATED FOR YOU IN FIG. 5.

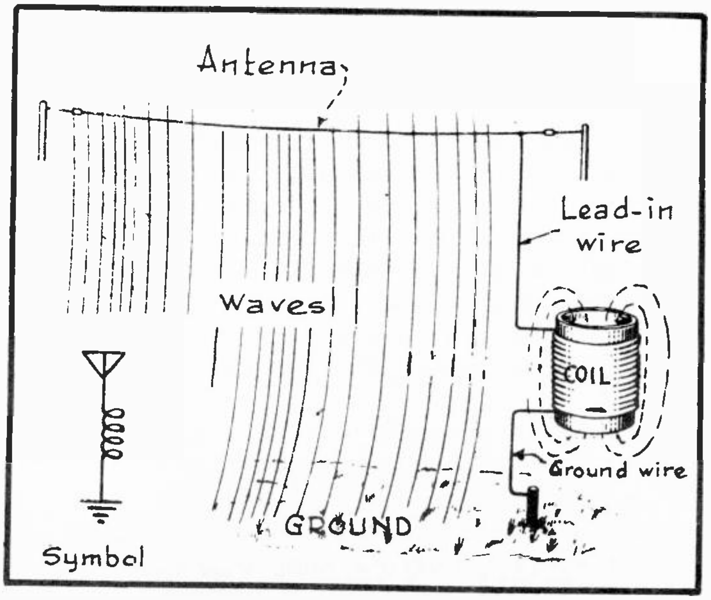

FIG. 5

The antenna circuit.

NOW THEN, AS THE ELECTROMAGNETIC WAVES WHICH ARE RADIATED BY THE TRANSMITTER, STRIKE THE ANTENNA OF THE RECEIVER, THEY WILL INDUCE A VOLTAGE IN IT AND CAUSE ALTERNATING CURRENTS OF CORRESPONDING FREQUENCY TO FLOW BACK AND FORTH BETWEEN THE ANTENNA AND GROUND AT A TREMENDOUS RATE. SINCE THE ANTENNA COIL IS INSTALLED BETWEEN THE ANTENNA AND

GROUND, THESE SAME CURRENTS WILL OF COURSE HAVE TO FLOW THROUGH ITS WINDING.

IT IS TRUE THAT THE VOLTAGE AND CURRENT INDUCED IN THE ANTENNA CIRCUIT BY THE PASSING RADIO WAVES ARE VERY FEEBLE BUT NEVERTHELESS SUFFICIENT ELECTRICAL ENERGY IN AN ACTIVE STATE IS NOW AVAILABLE IN THIS CIRCUIT SO THAT IT CAN BE USED TO OPERATE THE RECEIVER.

IN VIEW OF THE FACT THAT WE ARE NOW DEALING WITH ALTERNATING CURRENTS, IT WILL BE WELL THAT WE TAKE A LITTLE TIME NOW AND STUDY THE NATURE OF THESE CURRENTS IN GREATER DETAIL.

ALTERNATING CURRENT

TO EXPLAIN THE ACTIONS OF AN ALTERNATING CURRENT IN A CIRCUIT, WE WILL AGAIN MAKE USE OF A WATER SYSTEM. THIS TIME IN THE FORM ILLUSTRATED IN FIG. 6.

BY EXAMINING FIG. 6 VERY CAREFULLY, YOU WILL OBSERVE THAT WE HAVE HERE A PISTON WHICH IS CAUSED TO MOVE BACK AND FORTH IN THE CYLINDER OF A PUMP. TWO OUTLETS ARE PROVIDED IN THE CYLINDER OF THE PUMP AND THEY ARE INTERCONNECTED BY A CONTINUOUS SECTION OF PIPE. THE SYSTEM IS FILLED WITH WATER.

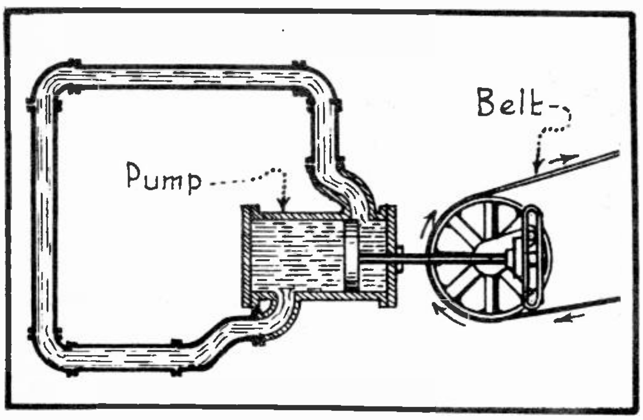

FIG. 6
Hydraulic equivalent of an alternating current.

WHEN THE MOTION OF THE FLYWHEEL AT ANY ONE INSTANT IS SUCH AS TO CAUSE THE PISTON TO TRAVEL FROM THE RIGHT TOWARDS THE LEFT, THEN IT WILL FORCE THE WATER THROUGH THE PIPE IN ONE DIRECTION UNTIL THE PISTON REACHES THE END OF ITS STROKE. THE FLOW OF WATER WILL THEN STOP FOR AN INSTANT.

THEN AS THE FLYWHEEL CAUSES THE PISTON TO MOVE THROUGH THE CYLINDER FROM THE LEFT TOWARDS THE RIGHT, THE WATER WILL FLOW THROUGH THE THE SYSTEM OF PIPES IN THE OPPOSITE DIRECTION UNTIL THE PISTON REACHES THE END OF ITS STROKE. THE WATER CIRCULATION WILL THEN STOP AND AGAIN REVERSE ITS DIRECTION OF TRAVEL AS THE PISTON COMMENCES ITS STROKE TOWARDS THE LEFT. THUS THE WATER WILL CONTINUALLY REVERSE ITS DIRECTION OF FLOW THROUGH THE PIPE AS LONG AS THE PISTON MOVES BACK AND FORTH IN THE CYLINDER. THEREBY PROVIDING US WITH AN ALTERNATING CURRENT OF WATER.

AN ALTERNATING ELECTRICAL CURRENT BEHAVES IN A SIMILAR MANNER, FOR IN THIS CASE, THE "PUMP" OR ALTERNATING CURRENT GENERATOR PRODUCES A VOLTAGE WHICH COMMENCES WITH A ZERO VALUE AND THEN GRADUALLY INCREASES. AS IT DOES SO, IT CAUSES A CURRENT OF INCREASING INTENSITY TO FLOW THROUGH THE CIRCUIT IN ONE DIRECTION UNTIL A MAXINUM VALUE IS REACHED. THE VOLTAGE AND CURRENT IN THIS DIRECTION THEN GRADUALLY DECREASE TO A VALUE OF ZERO AGAIN. NOW THE ACTION OF THE ALTERNATING CURRENT GENERATOR WILL REVERSE SO AS TO COMMENCE BUILDING UP A VOLTAGE

OF OPPOSITE POLARITY AND THEREBY CAUSE THE CURRENT TO FLOW THROUGH THE CIRCUIT IN THE OPPOSITE DIRECTION. AFTER A MAXIMUM VALUE IN THIS DIRECTION HAS BEEN REACHED, THE VOLTAGE AND CURRENT GRADUALLY COMMENCE TO ONCE MORE APPROACH A ZERO VALUE, ONLY TO BUILD UP A VOLTAGE AND CURRENT IN THE OTHER DIRECTION AGAIN. THUS THE VOLTAGE IS CONTINUALLY CHANGING ITS POLARITY AND THE CURRENT ITS DIRECTION OF FLOW.

WE REPRESENT AN ALTERNATING CURRENT IN THE FORM OF A CURVE AS SHOWN IN FIG. 7. HERE THE HORIZONTAL LINE REPRESENTS A VOLTAGE OF ZERO AND THE PORTION OF THE CURVE ABOVE THIS LINE IS POSITIVE WHILE THE PORTION BELOW THE ZERO LINE IS NEGATIVE. NOTICE HOW THE VOLTAGE CONTINUALLY CHANGES FROM POSITIVE TO NEGATIVE AND THUS REVERSES ITS POLARITY PERIODICALLY -- THE CURRENT WILL OF COURSE REVERSE ITS DIRECTION OF FLOW ACCORDINGLY.

WHEN THE VOLTAGE AND CURRENT BUILD UP FROM ZERO TO A MAXIMUM POSITIVE VALUE AND RETURN TO ZERO AGAIN, WE SPEAK OF THIS AS ONE ALTERNATION. IN LIKE MANNER, IF THE VOLTAGE AND CURRENT BUILD UP FROM A ZERO TO A MAXIMUM NEGATIVE VALUE AND THEN BACK TO ZERO, WE SPEAK OF THIS AS ONE ALTERNATION ALSO. THUS WE HAVE AN ENTIRE SERIES OF POSITIVE AND NEGATIVE ALTERNATIONS FOLLOWING EACHOTHER IN CONSECUTIVE ORDER AS ILLUSTRATED IN FIG. 7. TWO SUCCESSIVE ALTERNATIONS CONSTITUTE A CYCLE AND THIS IS ALSO POINTED OUT TO YOU IN FIG. 7.

THE NUMBER OF CYCLES THAT ARE COMPLETED PER SECOND FOR ANY GIVEN ALTERNATING CURRENT IS SPOKEN OF AS ITS FREQUENCY. COMMERCIAL ALTERNATING CURRENT OF POWER AND LIGHT CIRCUITS, FOR EXAMPLE, GENERALLY HAVE A FREQUENCY OF 25, 50 OR 60 CYCLES PER SECOND. IT IS CUSTOMARY TO ABREVIATE ALTERNATING CURRENT AS "A.C".

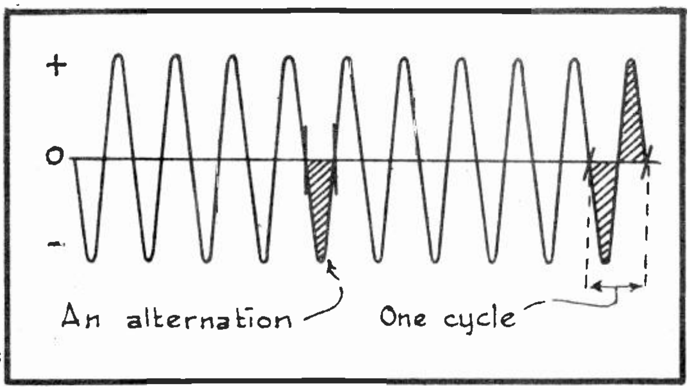

FIG. 7

Representing an alternating current.

SINCE THE ELECTROMAGNETIC WAVES WHICH ARE RADIATED BY THE TRANSMITTER ARE OF A VERY HIGH FREQUENCY VALUE, THE CURRENTS WHICH ARE INDUCED THEREBY IN THE ANTENNA CIRCUIT OF THE RECEIVER WILL BE OF A CORRESPONDING FREQUENCY, THAT IS, THOUSANDS OF CYCLES PER SECOND. CURRENTS OF SUCH A HIGH FREQUENCY VALUE AS THIS ARE USUALLY REFERRED TO AS RADIO FREQUENCY CURRENTS (R.F. CURRENTS) OR OSCILLATING CURRENTS.

THE TUNED CIRCUIT

NOW LETS' ADD ANOTHER SECTION OF THE RECEIVER TO OUR ANTENNA CIRCUIT OF FIG. 5. THE SECTION WHICH WE ARE GOING TO ADD AT THIS TIME IS CALLED THE TUNED CIRCUIT OR TUNING CIRCUIT AND ITS RELATION TO THE ANTENNA CIRCUIT IS CLEARLY ILLUSTRATED FOR YOU IN FIG. 8.

NOTICE THAT HERE WE HAVE TWO SEPARATE WINDINGS ON THE TUBULAR COIL FORM. THE WINDING WHICH IS CONNECTED IN THE ANTENNA CIRCUIT IS CALLED THE PRIMARY WINDING AND THE WINDING WHICH IS CONNECTED ACROSS THE PLATES

OF THE VARIABLE CONDENSER OR TUNING CONDENSER IS CALLED THE SECONDARY WINDING. THESE TWO WINDINGS, ALTHOUGH WOUND ON THE SAME HOLLOW PIECE OF TUBING, ARE NEVERTHELESS COMPLETELY INSULATED FROM EACHOTHER AND IN ADDITION, ARE SEPARATED FROM EACHOTHER BY A DISTANCE OF 1/8" OR SO. THIS COIL FORM WITH ITS TWO WINDINGS CONSTITUTES A RADIO FREQUENCY TRANSFORMER OR R.F. TRANSFORMER.

IN AN R.F. TRANSFORMER OF THE TYPE ILLUSTRATED IN FIG. 8, YOU WILL MOST GENERALLY FIND THE PRIMARY AND SECONDARY WINDINGS BOTH WOUND WITH THE SAME SIZE WIRE AND WHICH IS USUALLY INSULATED COPPER WIRE OF RATHER SMALL DIAMETER. THE SECONDARY WINDING, HOWEVER, CONSISTS OF A GREATER NUMBER OF TURNS, AS HERE SHOWN.

THE TUNING CONDENSER

THE TUNING CONDENSER CONSISTS OF TWO GROUPS OF METAL PLATES, AND WITH SEVERAL PLATES CONNECTED TOGETHER IN EACH GROUP. THE TWO PLATE GROUPS, HOWEVER, ARE THOROUGHLY INSULATED FROM EACHOTHER AND THE ONLY RELATION WHICH THEY BEAR TO EACHOTHER IS THAT THEY ARE MESHED WITH EACHOTHER IN THE MANNER PICTURED IN FIG. 8.

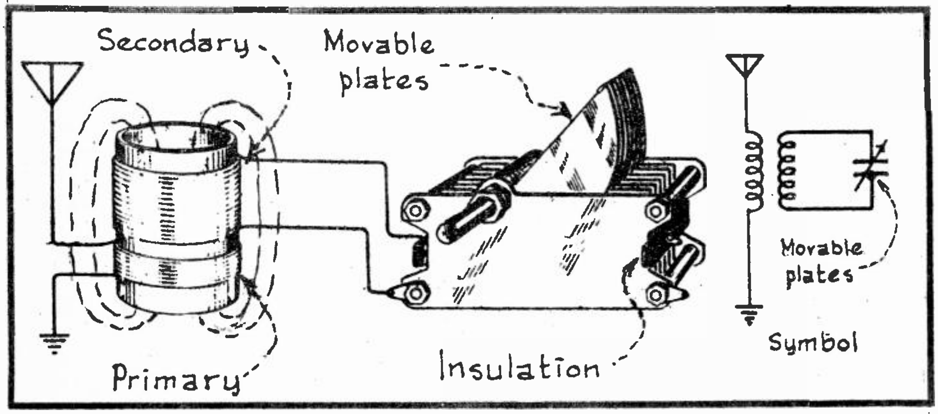

FIG. 8

The tuned circuit coupled to the antenna circuit.

ALL OF THE PLATES IN ONE OF THE CONDENSER'S PLATE GROUPS ARE FASTENED RIGIDLY TO THE FRAME OF THE UNIT BUT INSULATED FROM IT. THIS GROUP OF PLATES IS SPOKEN OF AS THE STATIONARY PLATE GROUP OR STATOR PLATE GROUP.

THE OTHER SET OF CONDENSER PLATES ARE ELECTRICALLY CONNECTED TOGETHER AND FIRMLY MOUNTED ON A SHAFT WHICH IS SUPPORTED IN BEARINGS FITTED INTO THE CONDENSER FRAME. THIS SET OF PLATES CONSTITUTES THE MOVABLE OR ROTOR PLATE GROUP.

THE ROTOR AND STATOR PLATES OF THE TUNING CONDENSER ARE SO SPACED THAT EACH STATOR PLATE WILL BE "SANDWICHED" BETWEEN TWO ROTOR PLATES BUT ALL OF THE PLATES WILL BE SEPARATED FROM EACHOTHER BY A SLIGHT AIR-SPACE. THE MOUNTING OF THE ROTOR PLATES ON THE SHAFT IS SUCH THAT IF THE SHAFT IS ROTATED IN ONE DIRECTION, THE ROTOR PLATES WILL MOVE FARTHER INTO MESH WITH THE STATOR PLATES, THEREBY ENGAGING A LARGER ROTOR PLATE AREA WITH THE STATOR PLATES. BY TURNING THE SHAFT IN THE OPPOSITE DIRECTION, THE ROTOR PLATES WILL MOVE FARTHER OUTWARD, THEREBY REDUCING THE AMOUNT OF ROTOR PLATE AREA WHICH IS ENGAGED WITH THE STATOR PLATES. TWO TER-

MINALS ARE PROVIDED ON THE CONDENSER FRAME. ONE OF THESE PERMITS A CIRCUIT CONNECTION TO BE MADE TO THE ROTOR PLATE GROUP AND THE OTHER TERMINAL PERMITS A CIRCUIT CONNECTION TO BE MADE TO THE STATOR PLATE GROUP.

ONE END OF THE R.F. TRANSFORMER'S SECONDARY WINDING IS CONNECTED TO THE STATOR PLATE TERMINAL OF THE TUNING CONDENSER, WHILE THE OTHER END OF THIS SAME WINDING IS CONNECTED TO THE ROTOR PLATE TERMINAL OF THE TUNING CONDENSER AS SHOWN IN FIG. 8. THE SECONDARY WINDING AND THE TUNING CONDENSER TOGETHER FORM THE TUNED OR TUNING CIRCUIT.

AT THE RIGHT OF FIG. 8, YOU WILL SEE THE SAME ANTENNA AND TUNING CIRCUIT ILLUSTRATED IN DIAGRAM FORM, USING STANDARD RADIO SYMBOLS. STUDY THESE SYMBOLS VERY CAREFULLY, SO THAT THERE WILL BE NO QUESTION IN YOUR MIND AS TO HOW THE ANTENNA, GROUND, R.F. TRANSFORMER AND THE TUNING CONDENSER ARE **REPRESENTED** IN RADIO DIAGRAMS.

IT WILL BE WELL TO POINT OUT IN REGARDS TO THE SYMBOL OF THE TUNING CONDENSER THAT THE ENTIRE STATOR PLATE GROUP IS REPRESENTED BY A SINGLE HORIZONTAL LINE AND THE ENTIRE ROTOR PLATE GROUP BY ANOTHER HORIZONTAL LINE. THE DIAGONAL ARROW THROUGH THESE HORIZONTAL LINES INDICATES THE FACT THAT THIS PARTICULAR CONDENSER IS ADJUSTABLE. QUITE OFTEN, YOU WILL FIND A BLACK DOT USED ON ONE OF THE HORIZONTAL LINES OF THE TUNING CONDENSER SYMBOL TO INDICATE THE ROTOR PLATE GROUP. (SEE DIAGRAM IN FIG. 8.)

HOW THE TUNED CIRCUIT WORKS

NOW THAT YOU KNOW WHAT THE TUNED CIRCUIT IS, YOUR NEXT STEP WILL BE TO FIND OUT HOW IT WORKS AND TO EXPLAIN THIS, WE WILL AGAIN REFER BACK TO OUR CIRCUIT IN FIG. 8.

SO FAR, WE HAVE OUR RADIO FREQUENCY CURRENTS (R.F. CURRENTS) REVERSING THEIR DIRECTION OF FLOW THROUGH THE PRIMARY WINDING OF THE R.F. TRANSFORMER AT A TREMENDOUS RATE. AS THIS CURRENT FLOWS THROUGH THIS WINDING IN ONE DIRECTION, IT WILL BUILD UP A MAGNETIC FIELD AROUND THE PRIMARY WINDING AND WHICH WILL AT THE SAME TIME SURROUND THE SECONDARY WINDING. THEN AS THE CURRENT THROUGH THE PRIMARY WINDING RAPIDLY REVERSES ITS DIRECTION OF FLOW, THIS MAGNETIC FIELD WILL SUDDENLY COLLAPSE AND THEN IMMEDIATELY BUILD UP AGAIN BUT AT THIS TIME, ITS POLARITY WILL BE REVERSED IN ACCORDANCE WITH THE REVERSAL IN CURRENT FLOW. THUS IT FOLLOWS, THAT AS LONG AS THE R.F. CURRENTS CONTINUE TO FLOW THROUGH THE PRIMARY WINDING, CORRESPONDING MAGNETIC FIELDS OF REVERSING POLARITY WILL BE ESTABLISHED.

THE MAGNETIC LINES OF FORCE, THUS PRODUCED, WILL INDUCE VOLTAGES OF CORRESPONDING FREQUENCY INTO THE SECONDARY WINDING OF THE R.F. TRANSFORMER, AND IN THIS WAY CAUSE A RADIO FREQUENCY CURRENT TO FLOW THROUGH THE SECONDARY CIRCUIT. THE FREQUENCY OF THIS INDUCED CURRENT IN THE SECONDARY CIRCUIT WILL BE IDENTICAL TO THAT IN THE ANTENNA CIRCUIT AND WHICH YOU WILL REMEMBER AS CORRESPONDING TO THE CARRIER FREQUENCY OF THE RADIO WAVE BEING RECEIVED.

BY MEANS OF THE TUNING CONDENSER, THE TUNED CIRCUIT CAN BE ADJUSTED SO THAT ITS CHARACTERISTICS WILL BE SUCH AS TO PERMIT A CURRENT OF ANY ONE PARTICULAR FREQUENCY TO CIRCULATE THROUGH IT MUCH MORE FREELY THAN CURRENTS OF ANY OTHER FREQUENCY. FOR EXAMPLE, IF THE ROTOR PLATES OF THE TUNING CONDENSER ARE TURNED FARTHER INTO MESH WITH THE STATOR PLATES, THEN THE TUNED CIRCUIT WILL HAVE A NATURAL TENDENCY TO PERMIT CURRENTS OF A

LOWER FREQUENCY TO FLOW THROUGH IT. ON THE OTHER HAND, IF THE ROTOR PLATES OF THE TUNING CONDENSER ARE TURNED FARTHER OUT OF MESH WITH THE STATOR PLATES, THEN THE TUNED CIRCUIT WILL HAVE A NATURAL TENDENCY TO PERMIT CURRENTS OF A HIGHER FREQUENCY TO FLOW THROUGH IT.

THIS IS THE PRINCIPLE OF RADIO TUNING, FOR NO MATTER HOW MANY STATIONS ARE IMPRESSING THEIR CARRIER FREQUENCY UPON THE ANTENNA CIRCUIT OF THE RECEIVER, THE TUNED CIRCUIT WILL ONLY ACCEPT THAT FREQUENCY FOR WHICH IT IS ADJUSTED. ALL OTHER FREQUENCIES WILL HAVE NO EFFECT UPON THE TUNED CIRCUIT AND THUS IT IS THAT WE SEPARATE THE STATION WHICH WE WISH TO HEAR FROM ALL OTHERS.

ANOTHER IMPORTANT POINT TO CONSIDER AT THIS TIME IS THAT THE SIGNAL VOLTAGE AND CURRENT IN THE TUNED CIRCUIT IS MUCH GREATER THAN THAT IN THE ANTENNA CIRCUIT. ONE REASON FOR THIS IS THAT THE R.F. TRANSFORMER HAS MANY MORE TURNS OF WIRE IN ITS SECONDARY WINDING THAN IN THE PRIMARY WINDING AND THIS CONDITION OFFERS A STEP-UP IN VOLTAGE THROUGH INDUCTION. ANOTHER REASON WHY A GREATER SIGNAL ENERGY IS AVAILABLE IN THE TUNED CIRCUIT THAN IN THE ANTENNA CIRCUIT IS THAT THE TUNED CIRCUIT IS TUNED TO THE FREQUENCY BEING RECEIVED WHEREAS THE ANTENNA CIRCUIT IS NOT.

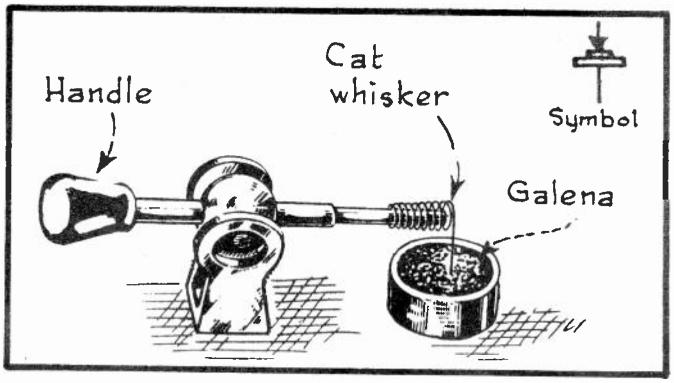

FIG. 9

The complete crystal detector.

THE CRYSTAL DETECTOR

AS YOU WILL RECALL, THE WAVE WHICH IS RADIATED BY THE TRANSMITTER IS MODULATED. THAT IS, THE CARRIER FREQUENCY HAS AN AUDIO WAVE FORM SUPERIMPOSED UPON IT AND IT IS THIS MODULATED WAVE FORM WHICH INDUCES THE CURRENT FLOW IN THE TUNED CIRCUIT OF THE RECEIVER. THIS MEANS THAT THE AUDIO FREQUENCIES ARE STILL COMBINED WITH THE RADIO FREQUENCIES WHEN THE SIGNAL CURRENTS ARE SET-UP IN THE TUNED CIRCUIT OF THE RECEIVER.

WITH THE SIGNAL CURRENTS IN THIS CONDITION, THE SIGNALS COULD NOT BE HEARD IF A SET OF HEADPHONES WERE CONNECTED DIRECTLY INTO THE TUNED CIRCUIT. THE REASON FOR THIS BEING THAT THE MECHANICAL CONSTRUCTION OF THE HEADPHONES DOES NOT PERMIT THE HEADPHONE DIAPHRAM TO OPERATE FAST ENOUGH TO KEEP UP WITH THE RAPID REVERSALS OF THE RADIO FREQUENCY CURRENTS WHICH WOULD IN THIS CASE BE FLOWING THROUGH ITS WINDINGS. BESIDES THIS, OUR EARS WOULD NOT RESPOND TO SUCH HIGH FREQUENCIES SO THAT WE WOULD NOT BE CAPABLE OF RECOGNIZING ANY TRACE OF SOUND.

WHAT WE MUST DO THEN IS TO SEPARATE THE SOUND FREQUENCIES FROM THE CARRIER FREQUENCY AFTER THE SIGNAL HAS BEEN "TUNED-IN" AND THEN PASS THE CURRENTS OF SOUND FREQUENCY ONLY THROUGH THE WINDINGS OF THE HEADPHONES. TO ACCOMPLISH THIS TASK, WE USE A UNIT WHICH IS KNOWN AS A DETECTOR.

THE SIMPLEST TYPE OF DETECTOR EXISTS IN THE FORM OF A MINERAL

WHICH WE GENERALLY REFER TO AS A CRYSTAL. SEVERAL MINERALS ARE SUITABLE FOR THIS PURPOSE BUT GALENA IS THE MOST COMMONLY USED. CHEMICALLY SPEAKING, GALENA IS THE SAME THING AS SULPHIDE OF LEAD.

WHEN EMPLOYING SUCH A CRYSTAL AS A DETECTOR, IT IS CUSTOMARY TO PLACE A PIECE OF THE MINERAL IN A METAL CUP AS SHOWN IN FIG. 9. THE CUP AND THE CRYSTAL THEN CONSTITUTE ONE SIDE OF THE DETECTOR CIRCUIT.

THE OTHER SIDE OF THE DETECTOR IS MADE IN THE FORM OF A PIVOTED ARM WITH A HANDLE ON IT. A THIN BUT RATHER STIFF BARE WIRE IS MOUNTED ON ONE END OF THIS ARM AND THIS WIRE IS QUITE OFTEN CALLED THE "CAT WHISKER"

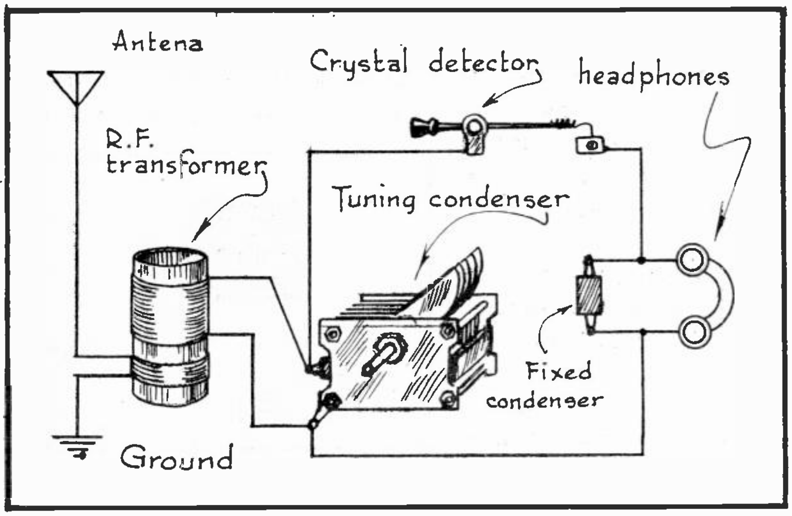

FIG. 10

The complete crystal receiver.

THE ARM CAN THEN BE MOVED ABOUT ON ITS PIVOT SO THAT THE CAT-WHISKER CAN BE MADE TO CONTACT DIFFERENT POINTS ON THE SURFACE OF THE CRYSTAL. THE REASON FOR PROVIDING THIS ADJUSTABLE FEATURE IS THAT MOST CRYSTALS ARE NOT EQUALLY SENSITIVE THROUGHOUT THEIR ENTIRE SURFACE AND SO BY MEANS OF THIS ADJUSTMENT THE CAT-WHISKER CAN BE MADE TO CONTACT THE MOST SENSITIVE POINT. YOU IN

NOTICE THE SYMBOL FOR THE CRYSTAL DETECTOR WHICH IS ALSO SHOWN FIG. 9.

THE COMPLETE RECEIVER

FIG 10 SHOWS YOU HOW THE CRYSTAL DETECTOR AND THE HEADPHONES ARE CONNECTED IN THE CIRCUIT OF THE RECEIVER. NOTICE IN THIS ILLUSTRATION THAT NO ELECTRICAL ENERGY CAN PASS FROM THE TUNED CIRCUIT TO THE HEADPHONES WITHOUT HAVING TO PASS THROUGH THE CRYSTAL DETECTOR.

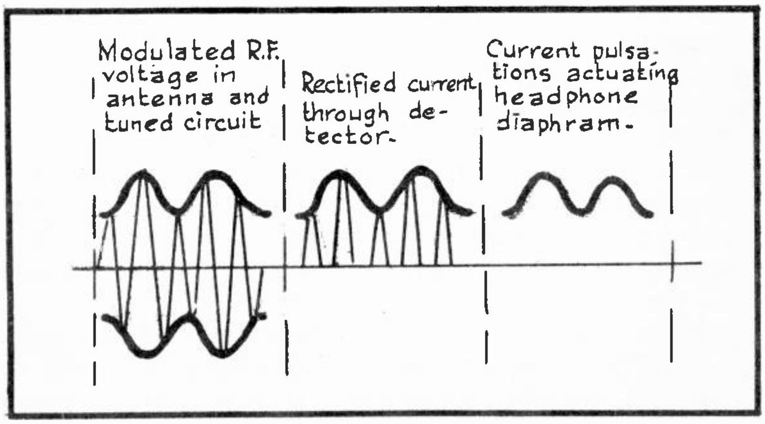

FIG. 11

Changes in electrical energy occurring in the receiver.

THE HIGH FREQUENCY VOLTAGE OF THE INCOMING SIGNAL IS IMPRESSED ACROSS THE TWO PLATE GROUPS OF THE TUNING CONDENSER AND ITS RESPECTIVE TERMINALS AND THERE WOULD THEREFORE BE A NATURAL TENDENCY FOR A HIGH FREQUENCY ALTERNATING CURRENT TO FLOW THROUGH THE HEADPHONE CIRCUIT. THE CRYSTAL DETECTOR HOWEVER, WILL ONLY PERMIT A CURRENT TO FLOW THROUGH IT IN ONE DIRECTION and that is from the cat-whisker to the crystal but not from the crystal to the cat-whisker. This means that one half of the A. C. alternations will be cut off or eliminated. We then say that the alternating current has been RECTIFIED and the crystal detector could be classified as a RECTIFIER.

Fig. 11 will serve to more clearly illustrate how the detector affects the high frequency current. At the left of this illustration, we have the curve representation of the modulated R. F. signal voltagewhich exists in the antenna and tuned circuit. This will of course be in the form of high frequency alternations in respect to both the voltage and the current.

Since the crystal detector only permits the flow of current in one direction, it will literally "cut-off" one half the alternations, with the result that we then have the rectified current as pictured at the center of Fig. 11 and which is then passed on to the headphone circuit.

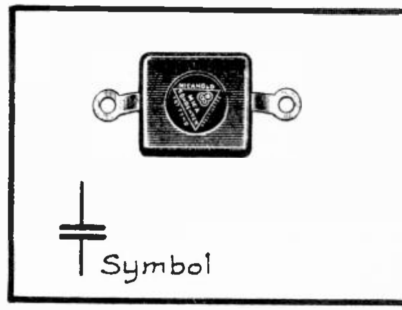

FIG. 12
The fixed condenser.

This rectified current, when passed through the headphone windings, will produce a vibration of the diaphram which corresponds to the peak values of the rectified pulsating current, and thus causes the production of sound waves which are practically an exact duplicate of those originating in the broadcast studio. These current pulsations which are actually responsible for the operation of the headphone diaphram would be of the nature as represented by the curve at the extreme right of Fig. 11.

THE PHONE CONDENSER

You have no doubt been wondering about the FIXED CONDENSER which is connected across the headphone terminals in Fig. 10. A close-up view of a fixed condenser, such as commonly used in radio is shown you in Fig. 12, together with its symbol.

Condensers of this type generally consist of two or more surfaces or plates of tin foil, thin copper, brass or other suitable metal completely insulated from eachother by means of paraffine paper, mica or any other good insulator. Two terminal connections are provided on a unit as this, each of them being connected to a plate group. The condenser as a whole is sealed in a container for the sake of convenience.

The electrical property possessed by condensers is called CAPACITY. In the case of the tuning condenser, the capacity of the condenser can be changed by operating the control shaft. On the condenser of Fig. 12, however, no provision is made for changing the capacity from the value "fixed" by the manufacturer and hence the name FIXED CONDENSER.

Notice that the symbol of the fixed condenser is quite similar to that of the variable or tuning condenser. The only marked difference being that no arrow is drawn diagonally through the fixed condenser symbol. Other than this, the symbol of a variable and fixed condenser are

IDENTICAL.

BY CONNECTING SUCH A FIXED CONDENSER ACROSS THE HEADPHONE TERMINALS OF OUR CRYSTAL RECEIVER, THE TONE QUALITY AND QUITE OFTEN THE VOLUME OF SOUND IS SOMEWHAT IMPROVED. THE REASON FOR THIS BEING THAT THROUGH THE USE OF THIS CONDENSER, THE HEADPHONE DIAPHRAM FOLLOWS THE RECTIFIED SIGNAL CURRENT MORE UNIFORMLY. THAT IS, IT MORE CLOSELY RESPONDS TO THE PORTION OF THE WAVE-FORM WHICH IS DRAWN HEAVY IN THE CENTER PORTION OF FIG. 11 AND WHICH WE GENERALLY REFER TO AS THE ENVELOPE.

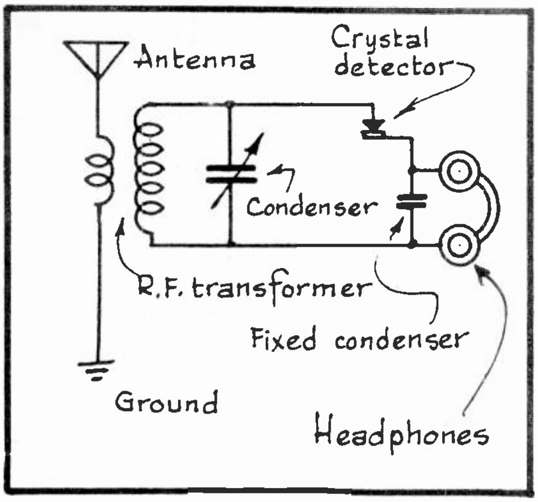

FIG. 13
Diagram of the receiver.

THE RECTIFIED CURRENTS, WHICH FLOW THROUGH THE WINDINGS OF THE HEADPHONES, ARE CALLED AUDIO FREQUENCY CURRENTS OR SIMPLY A. F. CURRENTS.

IN FIG. 13, YOU HAVE A CIRCUIT DIAGRAM OF THE RECEIVER WHICH WAS JUST EXPLAINED TO YOU, WHEREAS IN FIGS. 14 AND 15, YOU HAVE THE RECEIVER IN ITS COMPLETED FORM, SHOWING JUST EXACTLY HOW IT LOOKS FROM BOTH THE FRONT AND BACK.

SHOULD YOU BE INTERESTED IN CONSTRUCTING A SIMPLE CRYSTAL RECEIVER AS THIS FOR EXPERIMENTAL PURPOSES, THEN YOU WILL FIND THE FOLLOWING DATA OF CONSIDERABLE VALUE:

THE TUNING CONDENSER HAS A RATED CAPACITY OF .00035 MICROFARADS. THIS WOULD BE EQUIVALENT TO A VARIABLE CONDENSER HAVING 17 PLATES INCLUDING THE STATOR AND ROTOR PLATES. THE FIXED CONDENSER, WHICH IS CONNECTED ACROSS THE HEADPHONE TERMINALS, HAS A CAPACITY RATING OF .001 MICROFARADS. (THE FARAD IS THE UNIT OF ELECTRICAL CAPACITY AND ONE MICROFARAD IS EQUAL TO THE ONE MILLIONTH PART OF A FARAD. YOU WILL RECEIVE MORE DETAILED INSTRUCTION CONCERNING ELECTRICAL CAPACITY A LITTLE LATER ON.)

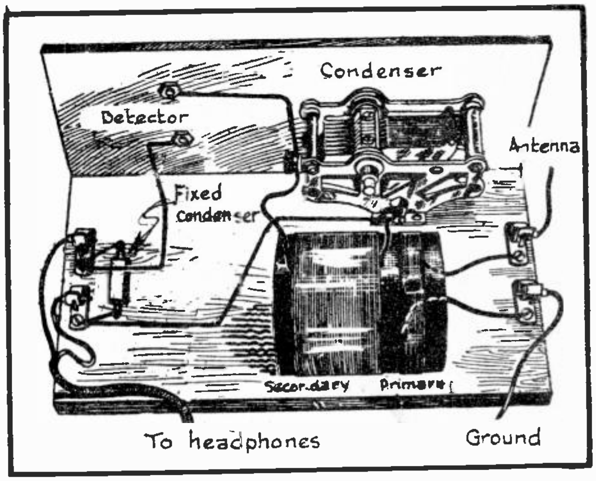

FIG. 14
Rear view of the receiver.

THE WINDINGS OF THE R. F. TRANSFORMER CAN BE WOUND ON A SECTION OF CARDBOARD TUBING, HAVING A DIAMETER OF APPROXIMATELY 3". THE PRIMARY WINDING OF THE R. F. TRANSFORMER MAY THEN CONSIST OF 15 TURNS OF #21 B&S SIZE SINGLE COTTON COVERED MAGNET WIRE. THE SECONDARY WINDING MAY CONSIST OF 60 TURNS OF #21 B&S SIZE SINGLE COTTON COVERED MAGNET WIRE.

THE ADJACENT TURNS OF EACH WINDING SHOULD BE WOUND NEATLY SIDE BY SIDE SO AS TO TOUCH EACH OTHER, AND THERE SHOULD BE A SEPARATION OF ABOUT 1/8" TO 1/4" BETWEEN THE PRIMARY AND SECONDARY WINDINGS.

HOLES CAN BE PUNCHED THROUGH THE CARDBOARD TUBING AT CONVENIENT POINTS THROUGH WHICH THE ENDS OF THE WINDINGS CAN BE DRAWN SO AS TO PREVENT THE COILS FROM UNWINDING.

THE CIRCUITS CAN BE WIRED WITH #18 B & S SIZE RADIO HOOK-UP WIRE AND ALL CONNECTIONS MUST BE SECURELY SOLDERED.

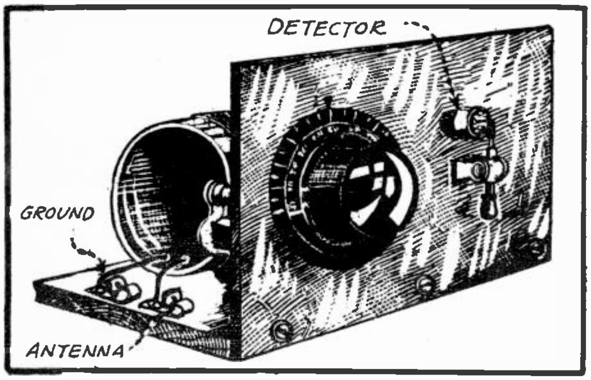

Fig. 15
Front View of the Receiver.

HAVING COMPLETED THIS LESSON, YOU NO DOUBT NOW FIND YOURSELF IN THE POSSESSION OF A CLEARER UNDERSTANDING OF WHAT GOES ON WITHIN THE SIMPLE CRYSTAL TYPE OF RECEIVER SO AS TO ENABLE US TO "LISTEN-IN" ON RADIO PROGRAMS. YOU ALSO WILL QUITE LIKELY NOW AGREE THAT THERE ISN'T ANYTHING SO MYSTERIOUS ABOUT THIS PROCESS AFTER ALL AND THAT RADIO IS REALLY EASY TO MASTER, PROVIDED THAT YOU GO ABOUT IT IN THE RIGHT MANNER.

ALTHOUGH THE CRYSTAL RECEIVER, AS DESCRIBED IN THIS LESSON, SERVES WELL TO EXPLAIN SOME OF THE MORE SIMPLE FUNDAMENTALS, THE CRYSTAL DETECTOR CIRCUIT IS NEVERTHELESS NO LONGER USED IN MODERN RECEIVERS. INSTEAD, A VACUUM TUBE SERVES THE PURPOSE OF THE CRYSTAL.

IN THE NEXT LESSON, YOU WILL BECOME ACQUAINTED WITH THE CONSTRUCTION AND OPERATION OF THE VACUUM TUBE, AND ALSO WITH ITS APPLICATION TO A SIMPLE RECEIVER.

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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Practical • J. A. ROSENKRANZ, Pres. • Training
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LESSON NO. 5

THE RADIO TUBE AND ITS APPLICATION TO RECEIVER CIRCUITS

A crystal receiver, well designed and carefully constructed, will reproduce radio signals clearly and with good tonal quality. The chief disadvantage of this receiver, however, is that it is rather limited as to sensitivity. That is, it is only capable of "picking-up" signals from transmitters which are located relatively close to the receiver or what we generally consider as LOCAL RECEPTION.

To overcome this difficulty, the present day receivers no longer employ a crystal detector, but instead use a vacuum tube in a circuit specially designed for this purpose.

The first radio tubes were two-element tubes called Fleming valves, after their inventor. However, it was not until marked improvements were made upon this original tube by Dr. Lee De Forest that the tube became the 3-element tube, practical enough to meet modern requirements. Today, the AUDION TUBE or VACUUM TUBE, as it is frequently called, is considered to be the "heart" of the radio receiver. In fact, the vacuum tube is not confined solely to radio receivers but is also used extensively in sound amplifiers, transmitters, etc.

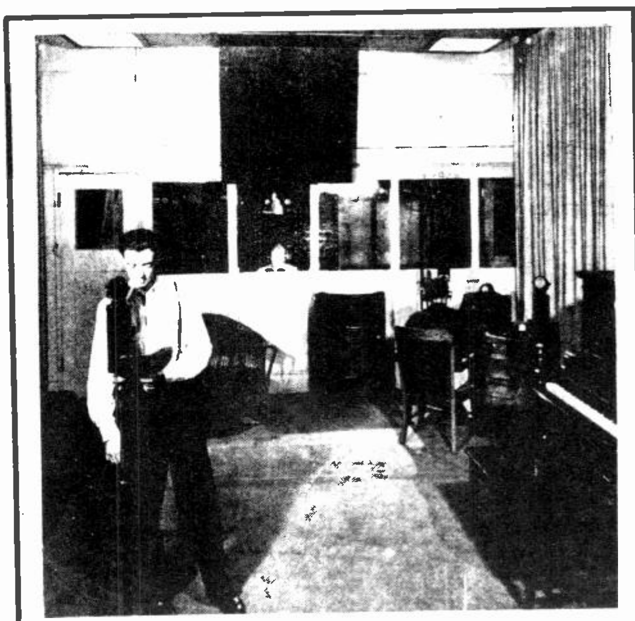

Fig. 1
Student's Working In National's Broadcast Studio.

A tremendous number of different tube types are now available, so that at the pres-

ENT TIME THERE IS A SPECIALLY-DESIGNED TUBE TO MEET ALMOST EVERY RADIO REQUIREMENT. IN FACT, SO MANY RADICAL IMPROVEMENTS HAVE BEEN MADE ON TUBES OF RECENT DESIGN THAT THE ENTIRE RADIO INDUSTRY HAS BEEN REVOLUTIONIZED DURING THE PAST FEW YEARS -- AND STILL NEW TUBES APPEAR ON THE MARKET BY THE SCORE.

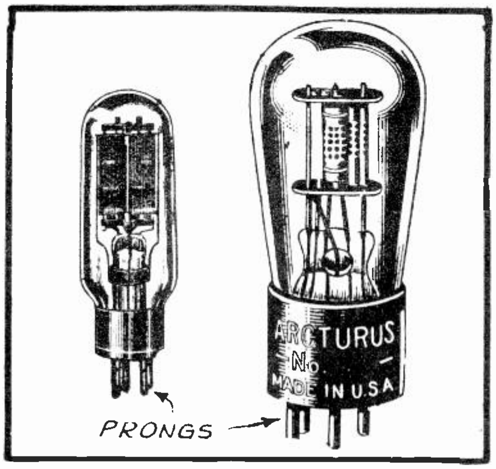

FIG. 2
TWO COMMON TUBE TYPES.

THESE NEW TUBES ARE COMPLICATING CIRCUIT DESIGNS CONSIDERABLY. THIS MEANS THAT THOSE MEN WHO HAVE NO TECHNICAL TRAINING ARE FINDING IT RATHER DIFFICULT TO KEEP UP WITH TUBE DEVELOPMENTS AND THEIR CORRESPONDING CIRCUITS. THIS FACT ALONE IS A REAL ADVANTAGE TO YOU, FOR WITH THE TYPE OF TRAINING WHICH YOU ARE RECEIVING YOU WILL BE ABLE TO SECURE AND TO HOLD THOSE JOBS WHICH THE MAN OF INSUFFICIENT TRAINING CANNOT HANDLE. ANOTHER THING WHICH YOU SHOULD KEEP IN MIND IS THAT THE TRAINING AS OFFERED BY OUR INSTITUTION IS KEPT UP TO THE MINUTE BY OUR TECHNICAL STAFF THROUGH FREQUENT REVISION OF AND ADDITION TO EXISTING LESSONS.

SINCE YOU ARE JUST BEGINNING YOUR STUDY OF RADIO TUBES IT IS LOGICAL THAT WE START WITH A SIMPLE TYPE, THAT IS, WITH THE THREE-ELEMENT TUBE, GENERALLY CLASSIFIED AS THE TRIODE.

CONSTRUCTION OF TRIODES

IN FIG. 2 YOU WILL SEE TWO COMMON TYPES OF TRIODES. AS YOU WILL OBSERVE, EACH CONSISTS OF A GLASS BULB MOUNTED ON A BAKELITE BASE FROM WHICH CONTACT PRONGS PROTRUDE. ALL AIR HAS BEEN REMOVED FROM WITHIN THE GLASS BULB, SO THAT THE ELEMENTS CONTAINED HEREIN WILL BE IN A VACUUM.

THERE ARE MANY DIFFERENT TYPES OF TRIODES AND ALTHOUGH MANY MAY APPEAR QUITE SIMILAR AT FIRST GLANCE, YET EACH IS DESIGNED FOR A SPECIAL PURPOSE. THEREFORE, TO AVOID CONFUSION, A STANDARD SYSTEM HAS BEEN ADOPTED BY THE RADIO INDUSTRY WHEREBY EACH TYPE OF TUBE IS IDENTIFIED BY A NUMBER AND LETTER CODE. FOR EXAMPLE, WE HAVE THE TYPE 30, WHICH CAN BE USED AS A DETECTOR, AN R.F. AMPLIFIER, OR AN A.F. AMPLIFIER. THEN WE HAVE A TYPE 31 WHICH IS INTENDED TO BE USED AS A POWER AMPLIFIER TUBE, -- ETC. THIS IDENTIFICATION CODE IS GENERALLY MARKED ON THE BASE OF THE TUBE BY THE MANUFACTURER.

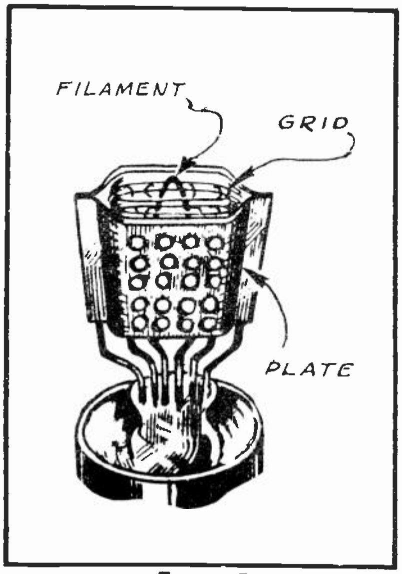

FIG. 3
ARRANGEMENT OF THE ELEMENTS.

A LITTLER LATER YOU WILL RECEIVE DETAILED INFORMATION ABOUT EACH PARTICULAR TUBE TYPE AND ITS CORRESPONDING CODE. FOR THE PRESENT WE

SHALL ONLY CONSIDER THE CONSTRUCTION AND OPERATION OF TRIODES IN A MORE GENERAL MANNER.

FIG. 3 SHOWS A DETAILED VIEW OF THE ELEMENTS WITHIN THE GLASS BULB OF THE TUBE, AND THEIR RELATIVE POSITIONS. AS YOU WILL OBSERVE, THE THREE ELEMENTS ARE CALLED FILAMENT, GRID, AND PLATE.

THE FILAMENT IS GENERALLY MADE OF TUNGSTEN WIRE ALLOYED WITH THORIUM OR COATED WITH OXIDES OF BARIUM, STRONTIUM OR OTHER SUITABLE CHEMICAL ELEMENT. THE FILAMENT, YOU WILL OBSERVE IN FIG. 3, IS LOCATED AT THE CENTER OF THE ASSEMBLY,AND SURROUNDED BY THE GRID WHICH IS CONSTRUCTED IN THE FORM OF AN OPEN MESH OF MOLYBDENUM WIRE. THE PLATE SURROUNDS BOTH FILAMENT AND GRID, AND IS MADE OF A SHEET OR SCREEN OF METAL -- NICKLE FREQUENTLY BEING USED FOR THIS PURPOSE. THE IMPORTANT FACTS TO REMEMBER ABOUT THIS TUBE IS THAT THE GRID IS LOCATED BETWEEN THE FILAMENT AND THE PLATE, THAT THESE THREE ELEMENTS ARE ALL INSULATED FROM EACH OTHER,AND THAT THERE IS A DEFINITE SPACING BETWEEN THEM.

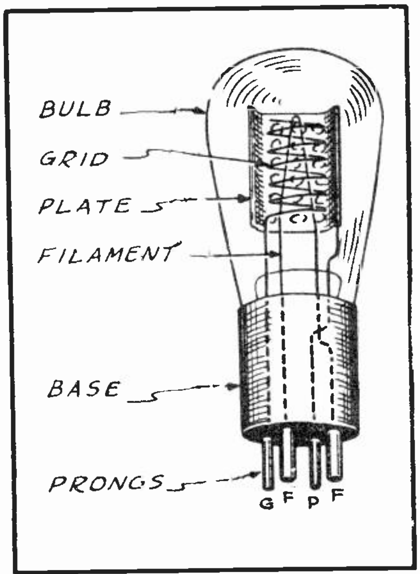

FIG. 4
CONSTRUCTION OF THE TUBE.

FIG. 4 SHOWS HOW THE THREE ELEMENTS ARE CONNECTED TO THE CONTACT PRONGS AT THE BASE OF THE TUBE. NOTICE THAT EACH END OF THE FILAMENT IS CONNECTED TO A BASE PRONG. ONE END OF THE SPIRALLY-WOUND GRID IS CONNECTED TO AN INDIVIDUAL BASE PRONG, WHILE ITS OTHER END IS FREE. THE PLATE ALSO HAS AN INDIVIDUAL BASE PRONG CONNECTED TO IT.

ALTOGETHER THEN, THERE ARE FOUR BASE PRONGS -- TWO FOR THE FILAMENT, ONE FOR THE GRID AND ONE FOR THE PLATE. THE TWO PRONGS WHICH CORRESPOND TO THE ENDS OF THE FILAMENT ARE LARGER IN DIAMETER THAN THE OTHER TWO. IN FIG. 4, THE FILAMENT PRONGS ARE MARKED WITH THE LETTER "F", THE GRID PRONG WITH THE LETTER "G" AND THE PLATE PRONG WITH THE LETTER "P".

THE SYMBOL FOR SUCH A TUBE IS SHOWN YOU IN FIG. 5. NOTICE ESPECIALLY HOW THE RELATIVE POSITIONS OF THE THREE ELEMENTS ARE INDICATED IN THIS SYMBOL.

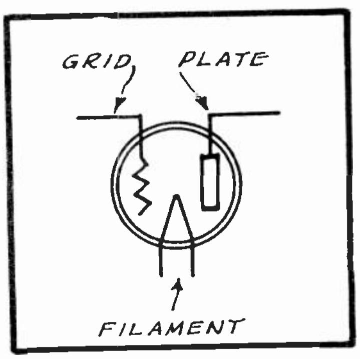

FIG. 5
SYMBOL OF THE TUBE.

TO FACILITATE THE INSTALLATION OF THE TUBE IN RADIO CIRCUITS WE USE TUBE SOCKETS SUCH AS ILLUSTRATED IN FIG.6, MADE OF SOME SUCH INSULATING MATERIALS AS BAKELITE, HARD RUBBER,OR A SPECIAL FIBROUS MATERIAL IN THE MAJORITY OF COMMERCIAL RECEIVERS.

FOUR HOLES ARE PROVIDED IN THE CENTRAL PORTION OF THE SOCKET TO ACCOMMODATE THE PRONGS OF THE TUBE, AND FOUR CORRESPONDING TERMINALS ARE MOUNTED ON THE SOCKET TO WHICH THE CIRCUIT CONNECTIONS MAY BE MADE. THESE TERMINAL HOLES ARE MARKED IN FIG. 6.

It is of special importance to note the positions of the grid and plate terminals with respect to the filament terminals of the socket, so that the circuit connections will be made correctly. The tube can only be installed in its socket in one position, due to the arrangement of the socket holes and tube base prongs.

To install the tube it is only necessary to line up the tube base prongs with the corresponding holes of the socket and then to press the tube downward into position. Spring clips or fingers then grip the tube prongs, thereby holding the tube firmly in place while at the same time establishing good electrical contact between the tube prongs and the terminals of the socket.

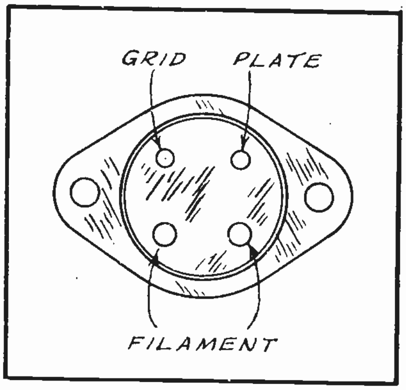

Fig. 6
The Tube Socket.

To remove the tube, pull upward on it sufficiently hard to overcome the spring tension in the socket. When removing tubes in this way, it is advisable to grasp the tube at the base rather than at the glass bulb, so that in case the socket fit should be somewhat tight, you will not injure the glass bulb.

Now that you are familiar with the construction of this tube, the next step will be to investigate the manner in which it operates. However, for you to acquire a clear understanding of the operating principles of the radio tube, it is necessary first to tell you something about the ELECTRON THEORY.

THE ELECTRON THEORY

Scientists now agree that the electron theory best explains the nature of electricity. To begin with, everything in existence is considered as MATTER. For example, water, wood, iron, air, etc., are all different forms of matter, and although the average person considers these things as being made up of a single material or one individual unit, this is not true.

All forms of matter are made up of billions of tiny particles which we call MOLECULES. To give you a better idea of a molecule, let us analyze a grain of ordinarily table salt. In chemical terms this is a chemical compound called "sodium chloride," which means that it is a combination of the metallic element sodium and the gas chlorine.

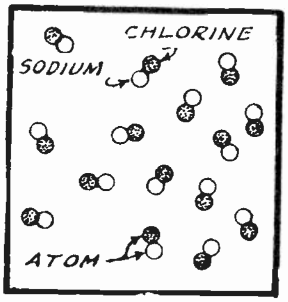

Fig. 7
Salt Molecules.

Now let us reduce this grain of salt to the smallest particles possible. Regardless of how small these particles may appear, they nevertheless still retain the properties of salt. The smallest particle which it is thus possible to make, without causing it to loose the properties or characteristics of salt, is called a molecule. In other words, a molecule is the smallest particle into which any substance can be divided without its losing the original properties of the substance.

The molecule, however, can be broken up still further by chemical means, into the ATOMS of which the molecule is composed. For instance, if the salt molecule is broken up, we will have one atom of sodium and one atom of chlorine. To make this clearer for you to visualize, we have prepared the illustration in Fig. 7, where a number of different salt molecules are each represented as consisting of one sodium and one chlorine atom. Neither the chlorine nor the sodium atom alone possesses the distinctive properties of salt, but if atoms of each are chemically combined with eachother, then each molecule thereby formed will have all the properties which are recognized in salt.

The next thing in which you will be interested is to know the difference between an atom of sodium and an atom of chlorine. This can be explained as follows: The atom of any element consists of a NUCLEUS or PROTON which has a positive electrical potential, and a definite number of negatively charged particles called ELECTRONS. In terms of this theory, the only difference between the atom of one element and that of ny other element is the number and arrangement of the electrons around the nucleus.

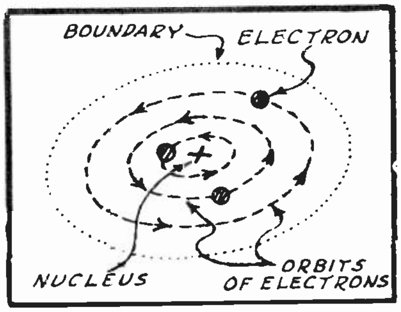

Fig. 8
An Atom With 3 Electrons.

An atom of hydrogen, for example, consists of one electron rotating around its nucleus, whereas, an atom of zinc has 30 electrons rotating around a nucleus.

Although the atom of each element consists of a different number and arrangement of electrons, yet there are only 92 distinct arrangements. In other words, there are only 92 elements or different types of atoms which are used in combinations to form everything material in the universe.

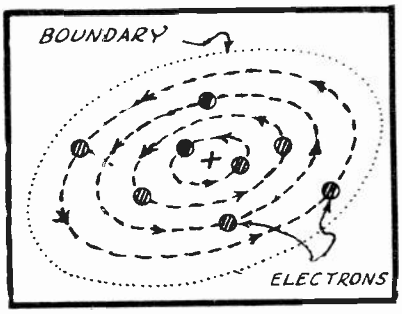

Fig. 9
An Atom With 8 Electrons.

In comparison to the size of an atom, an electron is so small that if the atom was considered as being as large as the world, the electron would then be only about as large as an ordinary baseball. Since in reality an atom cannot be seen even with the most powerful microscope, you may have an idea as to how small an electron must be.

As yet, scientists have not definitely determined of what the nucleus and electrons of the atomic structure are made, but as far as now known, the nucleus is nothing more than a positive electrical charge and the electron a negative electrical charge.

Although the electrons are exceptionally small in size, yet they are very active and move around the nucleus of the atom at a tremendous rate of speed. They are supposed to travel in orbits or circular paths around the nucleus, as illustrated in Fig. 8 and 9, in much the same manner as the earth and the other planets move in orbits around the sun, though some scientists consider the motion to be vibrating or oscil-

LATORY, RATHER THAN ROTARY. THE SIZE OF ANY GIVEN ATOM IS DETERMINED BY THE BOUNDARY WHICH INDICATES THE MAXIMUM DISTANCE AWAY FROM THE NUCLEUS WHICH THE ELECTRONS ATTAIN DURING THEIR CONSTANT MOTION.

IN FIG. 8 YOU WILL SEE A DRAWING WHICH REPRESENTS AN ATOM CONTAINING THREE ELECTRONS IN ADDITION TO THE NUCLEUS; WHEREAS, IN FIG.9 A SIMILAR ILLUSTRATION APPEARS, SHOWING AN ATOM MADE UP OF EIGHT ELECTRONS WHICH ROTATE (SUPPOSEDLY) IN ORBITS AROUND THE NUCLEUS.

UNDER ORDINARY CONDITIONS, THE SUM OF THE NEGATIVE CHARGES IN ANY ONE ATOM IS EXACTLY EQUAL TO THE POSITIVE CHARGE OF THE NUCLEUS OF THE SAME ATOM, AND THEREFORE THE TWO CHARGES NEUTRALIZE EACH OTHER. FOR THIS REASON, THE ATOM DOES NOT SHOW ANY ELECTRICAL POTENTIAL.

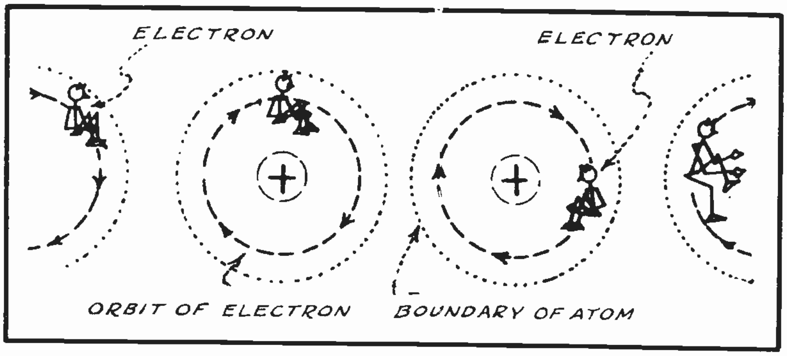

FIG. 10
ELECTRONS CONFINED TO THE ATOM.

IT SO HAPPENS, HOWEVER, THAT THE ELECTRONS IN THE ATOMIC STRUCTURE OF CERTAIN METALS ARE SOMEWHAT "LOOSE". THAT IS, THERE IS NOT QUITE SO MUCH "HOLDING POWER" IN THE ATOM, SO THAT UNDER CERTAIN CONDITIONS THE ELECTRON CAN ESCAPE FROM THE BOND OF THE ATOM WITH COMPARATIVE EASE. IN SUCH CASES, WE FIND THAT IF WE CONNECT A SOURCE OF E.M.F. TO SUCH A METAL, SO AS TO USE THIS METAL AS A CONDUCTOR AND THEREBY COMPLETE AN ELECTRICAL CIRCUIT, THE POSITIVE POLE OF THE E.M.F. SOURCE WILL ATTRACT THE NEGATIVELY CHARGED ELECTRONS TOWARDS IT. (UNLIKE ELECTRICAL CHARGES ATTRACT EACH OTHER AND LIKE ELECTRICAL CHARGES REPEL EACH OTHER, SIMILAR TO THE LAW OF MAGNETIC POLES).

SINCE THE NUCLEUS OF THE ATOM DOES NOT READILY TOLERATE THE LOSS OF AN ELECTRON, IT WILL "STEAL" AN ELECTRON FROM AN ADJOINING ATOM TO REPLACE EACH ELECTRON WHICH IT LOSES ON ACCOUNT OF THE E.M.F'S INFLUENCE. THUS AS THE ELECTRONS ARE BEING PASSED ALONG THE LINE FROM ONE ATOM TO THE NEXT NEARLY SIMULTANEOUSLY THROUGHOUT THE ENTIRE CIRCUIT, WE HAVE AN ACTUAL FLOW OF ELECTRONS FROM THE NEGATIVE POLE OF THE E.M.F. TOWARDS THE POSITIVE POLE OF THE E.M.F. WE CALL THIS FLOW OF ELECTRONS AN ELECTRIC CURRENT.

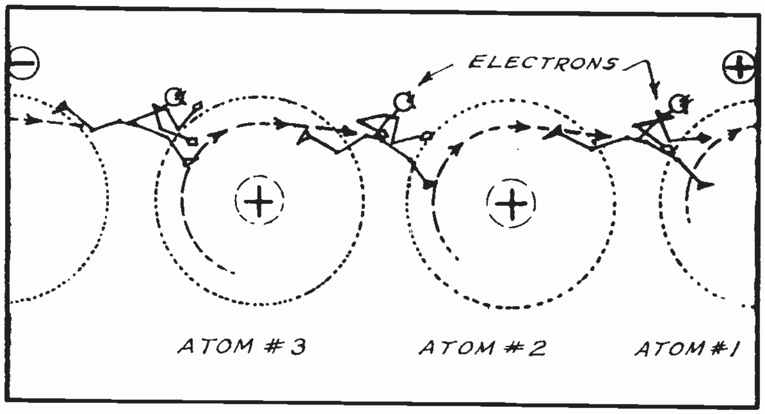

FIG. 11
A CURRENT OF ELECTRONS.

FIGS. 10 AND 11 WILL ILLUSTRATE THIS POINT SOMEWHAT BETTER. HERE YOU ARE LOOKING AT A GROUP OF ATOMS WHICH MAKE UP THE STRUCTURE OF A METAL BEING USED AS AN ELECTRICAL CON-

DUCTOR. FOR THE SAKE OF SIMPLICITY WE SHALL CONSIDER EACH OF THESE ATOMS AS CONSISTING OF A NUCLEUS ATTENDED BY ONE ELECTRON.

IN FIG. 10 NO SOURCE OF E.M.F. IS CONNECTED TO THE CONDUCTOR AND THEREFORE ALL OF THE ELECTRONS REMAIN CONFINED TO THEIR RESPECTIVE ATOMS AND ARE CONTENT TO MOVE AROUND THE NUCLEUS. NOW IF AN E.M.F. IS CONNECTED TO THIS CONDUCTOR SO THAT THE POSITIVE POLE OF THE E.M.F. IS AT THE RIGHT AND THE NEGATIVE POLE OF THE E.M.F. AT THE LEFT, AS PICTURED IN FIG. 11, THEN THE ELECTRON OF ATOM #2 WILL BE ATTRACTED TOWARDS THE POSITIVE POLE OF THE E.M.F. AT THIS SAME TIME, AN ELECTRON WILL LEAVE ATOM #3 TO REPLACE THE ONE WHICH HAS BEEN LOST BY ATOM #2, ETC. IN THIS WAY A CONSTANT FLOW OF ELECTRONS FROM THE NEGATIVE POLE OF THE CIRCUIT TOWARDS THE POSITIVE POLE TAKES PLACE, AND ALTHOUGH INDIVIDUAL ELECTRONS ARE SHOWN HERE FOR THE SAKE OF SIMPLICITY, YET IN REALITY BILLIONS OF ELECTRONS CONSTITUTE THIS FLOW.

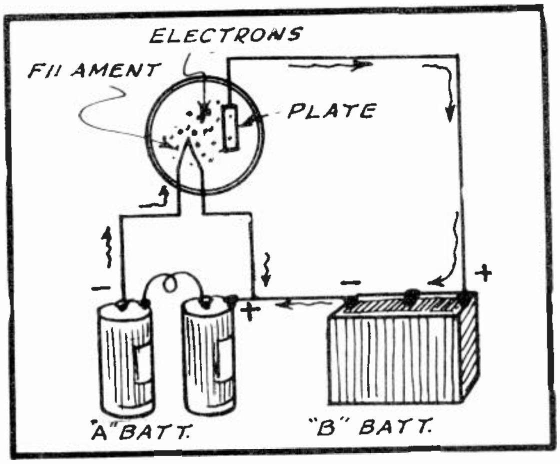

FIG. 12
THE TWO ELEMENT TUBE.

QUITE LIKELY YOU ARE NOW SOMEWHAT PUZZLED AS TO HOW IT IS THAT WE CONSIDER A FLOW OF ELECTRONS AS BEING FROM NEGATIVE TOWARDS POSITIVE AND YET AN ELECTRIC CURRENT, WHICH IS THE SAME THING AS A FLOW OF ELECTRONS, IS GENERALLY CONSIDERED AS FLOWING FROM POSITIVE TO NEGATIVE.

THE REASON FOR THE CONFLICT BETWEEN THESE TWO THEORIES IS THAT LONG AGO, BEFORE ANYTHING WAS KNOWN ABOUT THE ELECTRON THEORY, AN ELECTRIC CURRENT WAS ASSUMED TO FLOW FROM POSITIVE TO NEGATIVE AND CONSEQUENTLY ELECTRICAL MEN DEVELOPED THE CUSTOM OF TRACING ELECTRICAL CIRCUITS FROM THE POSITIVE SOURCE OF E.M.F. THROUGH TO THE NEGATIVE SOURCE OF E.M.F., AND IT BECAME CUSTOMARY TO SPEAK OF CURRENT DIRECTION AS BEING FROM + TO - IN THE EXTERNAL CIRCUIT (CIRCUIT OUTSIDE THE GENERATOR OR BATTERY, OR OTHER SOURCE OF E.M.F.). BY THE TIME THAT J.J. THOMSON SHOWED IN 1897 THAT THE CURRENT PASSING THROUGH A CATHODE RAY TUBE CONSISTED OF A STREAM OF NEGATIVELY CHARGED CORPUSCLES (LATER CALLED ELECTRONS) MOVING FROM NEGATIVE TO POSITIVE, AND WHEN OTHER SCIENTIST ENGINEERS PROVED THAT EVERY ELECTRIC CURRENT CONSISTS OF SUCH A STREAM OF ELECTRONS MOVING FROM NEGATIVE TO POSITIVE, THIS CUSTOM OF TRACING CURRENT FROM POSITIVE TO NEGATIVE HAD BE-

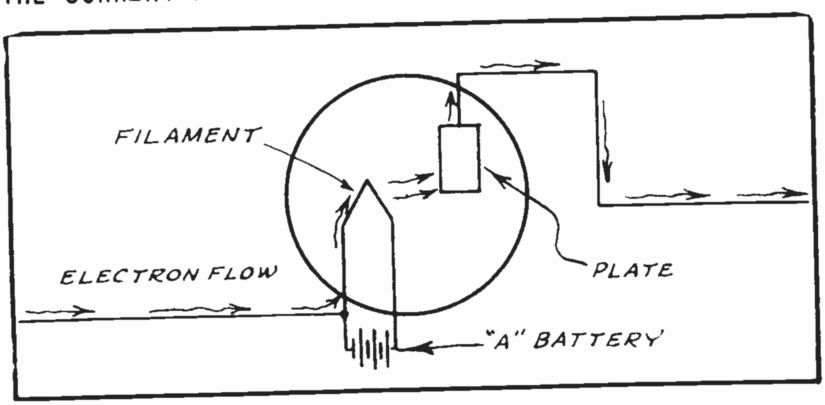

FIG. 13
THE DIODE ACTING AS A VALVE.

COME SO WIDE-SPREAD IN THE ELECTRICAL INDUSTRY THAT IT HAS PERSISTED THROUGHOUT THE INTERVENING YEARS. FORTUNATELY, HOWEVER, PRACTICAL CALCULATIONS CAN BE ACCURATELY PERFORMED WITHOUT TAKING INTO ACCOUNT THE DIRECTION IN WHICH CURRENT HAPPENS TO BE FLOWING.

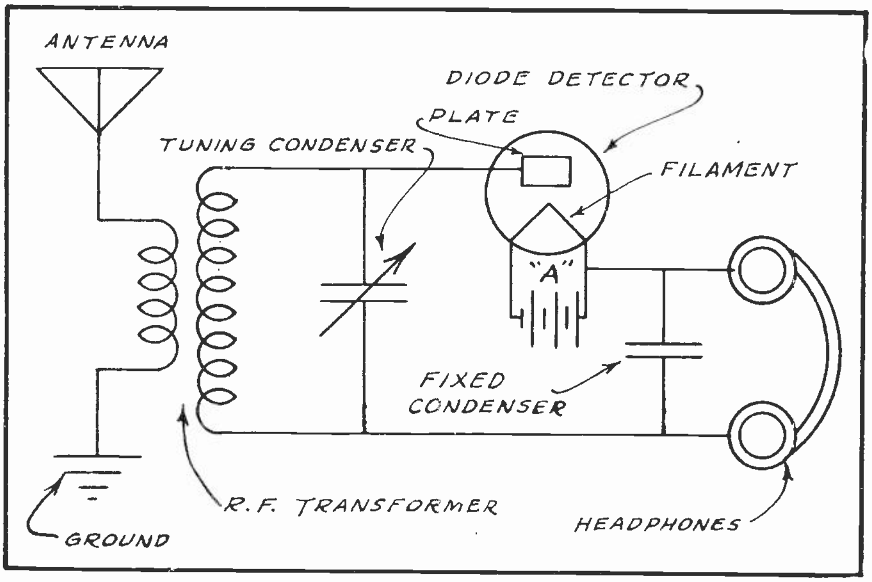

FIG. 14
RECEIVER USING A VACUUM TUBE.

JUST AS A PERSON CAN TAKE A STREET CAR RIDE AND EITHER LOOK FORWARD OR BACKWARD AS HE CHOOSES, SO CAN THE INTELLIGENT RADIO TECHNICIAN TRACE HIS CIRCUITS FROM POSITIVE TO NEGATIVE WHEN DEALING WITH ELECTRICAL MACHINERY, BATTERY SYSTEMS, OR DISTRIBUTION SYSTEMS; AND WITH EQUAL FACILITY TRACE HIS CIRCUITS FROM NEGATIVE TO POSITIVE WHEN DEALING WITH RADIO TUBES, CATHODE RAY OSCILLOSCOPES, OR OTHER "ELECTRONIC" DEVICES. IT IS NECESSARY, HOWEVER, TO BE CONSISTENT, AND NOT CHANGE THE SYSTEM USED IN THE MIDDLE OF A CIRCUIT.

EMISSION OF ELECTRONS

IF ANY METAL IS HEATED, THE VELOCITY AT WHICH THE ELECTRONS MOVE IS INCREASED. WHEN A CERTAIN CRITICAL TEMPERATURE IS REACHED THEIR VELOCITY WILL BECOME SO GREAT THAT MANY OF THESE FAST-MOVING ELECTRONS WILL OVERCOME THE ATTRACTION TENDING TO HOLD THEM WITHIN THE ATOM AND THEY WILL FLY OUT INTO THE SPACE ADJACENT TO THE METAL. THIS PHENOMENON IS NOT UNLIKE THE PROCESS OF EVAPORATION, AND IS SPOKEN OF AS THERMIONIC EMISSION.

THE METAL THUS EMITTING ELECTRONS MAY BE HEATED BY SENDING AN ELECTRIC CURRENT THROUGH IT, IN WHICH CASE A SMALL FILAMENT SIMILAR TO THAT OF AN ELECTRIC LAMP IS USED. HOWEVER, IN MODERN RADIO TUBES, A SMALL METAL CYLINDER IS HEATED BY A SEPARATE HEATER FILAMENT WHICH IS PLACED INSIDE OF AND INSULATED FROM THE CYLINDER ITSELF.

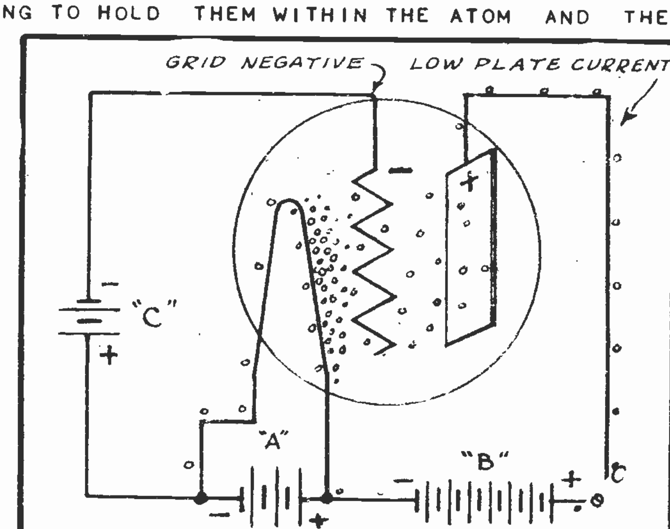

FIG. 15
THE EFFECT OF A NEGATIVE GRID POTENTIAL.

IN EITHER CASE THE ELECTRON-EMITTING SURFACE IS SPOKEN OF AS A CATHODE. GENERALLY SPEAKING, INCREASING THE TEMPERATURE OF THE CATHODE INCREASES THE AMOUNT OF EMISSION, WHILE ON THE OTHER HAND, A DECREASE IN CATHODE TEMPERATURE WILL REDUCE THE NUMBER OF ELECTRONS EMITTED IN A GIVEN TIME.

IN FIG. 12 IS SHOWN A SIMPLE FORM OF TUBE, CONTAINING ONLY A FILAMENT AND A PLATE INSTALLED WITHIN A GLASS BULB FROM WHICH ALL AIR HAS BEEN REMOVED. A TWO-ELEMENT TUBE AS THIS IS KNOWN AS A DIODE. TWO SERIES CONNECTED DRY CELLS ARE CONNECTED ACROSS THE FILAMENT TO FORCE AN ELECTRON FLOW THROUGH THE FILAMENT IN THE DIRECTION INDICATED BY THE ARROWS. THIS CURRENT WILL CAUSE THE FILAMENT TO BECOME WHITE HOT, AND THEREBY TO EMIT ELECTRONS.

IN RADIO WE CALL THE BATTERY WHICH FURNISHES THE E.M.F. FOR THE TUBE FILAMENT, THE "A" BATTERY.

ANOTHER BATTERY, CALLED THE "B" BATTERY, HAS ITS POSITIVE TERMINAL CONNECTED TO THE PLATE OF THE TUBE IN FIG. 12, WHILE THE NEGATIVE TERMINAL OF THIS SAME BATTERY IS CONNECTED TO THE POSITIVE TERMINAL OF THE "A" BATTERY.

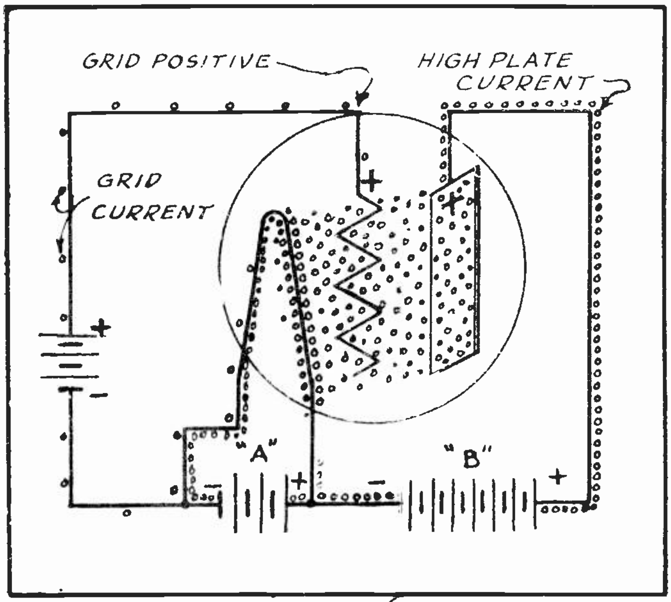

FIG. 16
THE EFFECT OF A POSITIVE GRID POTENTIAL.

IN THIS WAY A POSITIVE ELECTRICAL POTENTIAL WILL BE APPLIED TO THE PLATE OF THE TUBE AND SINCE A POSITIVE POTENTIAL WILL ALWAYS ATTRACT ELECTRONS, WE FIND THAT THE ELECTRONS WHICH LEAVE THE HEATED FILAMENT BY THERMIONIC EMISSION ARE ATTRACTED OVER TO THE PLATE OF THE TUBE. THUS A CONTINUOUS STREAM OF ELECTRONS PASSES FROM FILAMENT TO PLATE, CONSTITUTING WHAT IS KNOWN AS THE PLATE CURRENT. THE COMPLETE PATH FOLLOWED BY THIS PLATE CURRENT IS CALLED THE PLATE CIRCUIT. THIS PATH, STARTING FROM THE NEGATIVE TERMINAL OF THE "B" BATTERY, LEADS TO THE FILAMENT CIRCUIT AND THEREBY TO THE FILAMENT, THROUGH THE TUBE TO THE PLATE AND THENCE TO THE POSITIVE TERMINAL OF THE "B" BATTERY.

THE E.M.F. WHICH ACTUATES THE PLATE CURRENT ORIGINATES IN THE "B" BATTERY. AN INCREASE IN THIS E.M.F. WILL INCREASE THE PLATE CURRENT, WHILE A DECREASE IN "B" VOLTAGE WILL RESULT IN A DECREASE IN PLATE CURRENT.

IF WE SHOULD REVERSE THE POLARITY OF THE "B" BATTERY, CONNECTING THE POSITIVE TERMINAL TO THE FILAMENT OF THE TUBE AND THE NEGATIVE TERMINAL TOWARD THE PLATE, NO PLATE CURRENT WOULD FLOW BECAUSE ELECTRONS ARE NOT EMITTED BY THE COLD METAL OF THE PLATE.

IF A DIODE BE CONNECTED IN A CIRCUIT AS SHOWN IN FIG. 13, IT WILL

ACT AS A VALVE, PERMITTING ELECTRONS TO PASS THROUGH IT TOWARD THE RIGHT BUT BLOCKING ANY FLOW OF ELECTRONS TOWARD THE LEFT. THIS VALVE ACTION ENABLES US TO USE THE DIODE AS A DETECTOR, INSTEAD OF THE CRYSTAL DETECTOR DESCRIBED IN LESSON #4.

THE DIODE DETECTOR

FIG. 14 SHOWS A RECEIVER IN WHICH DIODE DETECTION IS EMPLOYED. BY COMPARING THIS CIRCUIT WITH THE CRYSTAL RECEIVER CIRCUIT IN THE PRECEDING LESSON YOU WILL NOTE THAT THEY ARE PRACTICALLY IDENTICAL WITH THE EXCEPTION THAT IN FIG. 14 THE DIODE (TUBE) REPLACES THE CRYSTAL.THE DIODE THUS SERVES THE SAME PURPOSE OF RECTIFICATION AS DOES THE CRYSTAL.

AS WE HAVE MENTIONED BEFORE, THE ELECTRODE WHICH EMITS ELECTRONS IS CALLED THE CATHODE, WHILE THE POSITIVELEY CHARGED ELECTRODE TO WHICH THE ELECTRONS ARE ATTRACTED IS CALLED THE ANODE, OR SOMETIMES THE PLATE.

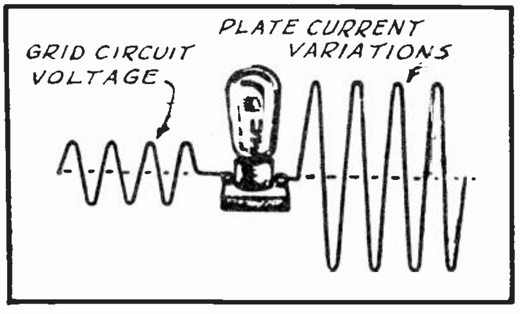

FIG. 17
THE TUBE AS AN AMPLIFIER.

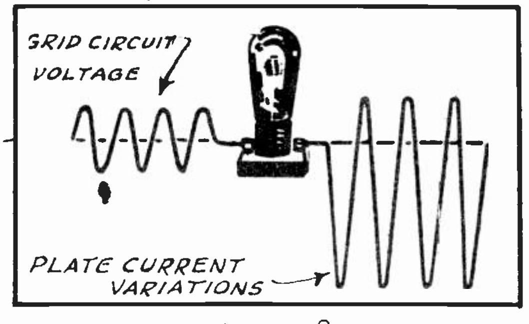

FIG. 18
THE TUBE AS A DETECTOR.

ACTION WITH THE TRIODE

THE THREE-ELEMENT TUBE, OR TRIODE, OPERATES UPON THE SAME ELECTRONIC PRINCIPLES AS DOES THE DIODE; THE THIRD ELECTRODE, CALLED THE CONTROL GRID, BEING INTRODUCED BETWEEN THE CATHODE AND THE PLATE. THIS GRID CONSISTS OF A WIRE MESH OR GRATING SO CONSTRUCTED THAT IT OFFERS BUT LITTLE OBSTRUCTION, FROM THE MECHANICAL POINT OF VIEW, TO THE FLIGHT OF ELECTRONS FROM THE CATHODE TO THE PLATE.HOWEVER, IF THE GRID BE CHARGED ELECTRICALLY (THAT IS, MADE MORE POSITIVE OR MORE NEGATIVE) WITH RESPECT TO THE CATHODE, IT WILL HAVE A REMARKABLE EFFECT UPON THE MAGNITUDE OF THE PLATE CURRENT. A NEGATIVELY CHARGED GRID WILL REDUCE PLATE CURRENT,WHILE A POSITIVELY CHARGED GRID WILL INCREASE PLATE CURRENT.

APPLYING A NEGATIVE GRID POTENTIAL

IN FIG. 15, IS SHOWN THE COMPLETE THREE ELEMENT TUBE, WITH THE "A" BATTERY FURNISHING THE FILAMENT CURRENT AND A "B" BATTERY TO PROVIDE THE POSITIVE POTENTIAL FOR THE PLATE. IN ADDITION, A THIRD BATTERY, WHICH WE CALL THE "C" BATTERY, IS CONNECTED BETWEEN THE GRID AND THE FILAMENT OF THE TUBE. IT IS IMPORTANT TO NOTE IN THIS ILLUSTRATION THAT THE (-) OR NEGATIVE TERMINAL OF THE "C"BATTERY IS NOW CONNECTED TO THE GRID OF THE TUBE, AND THEREFORE MAKES THE GRID NEGATIVE WITH RESPECT TO THE CATHODE OR FILAMENT.

THIS NEGATIVELY CHARGED GRID REPELS THE NEGATIVE ELECTRONS EMITTED BY THE CATHODE FOR THE SIMPLE REASON THAT LIKE ELECTRICAL CHARGES REPEL EACH OTHER. THUS IT CAN BE SEEN THAT MANY OF THESE ELECTRONS WILL BE DRIVEN BACK TOWARD THE FILAMENT. IN FACT, BY MAKING THE NEGATIVE GRID

VOLTAGE SUFFICIENTLY HIGH, IT IS POSSIBLE TO CUT OFF THE PLATE CURRENT ALTOGETHER. HOWEVER, THE TUBE IS USUALLY OPERATED SO THAT SOME OF THE ELECTRONS WILL FIND THEIR WAY THROUGH THE OPEN MESH OF THE GRID AND FINALLY REACH THE PLATE.

APPLYING A POSITIVE GRID POTENTIAL

NOW LET US REVERSE THE "C" BATTERY CONNECTIONS SO THAT THE (+)TERMINAL OF THE "C" BATTERY WILL BE CONNECTED TO THE GRID, AS ILLUSTRATED IN FIG. 16. UNDER THESE CONDITIONS, WE FIND THAT BECAUSE UNLIKE CHARGES ATTRACT, THE POSITIVELY CHARGED GRID WILL ADD ITS ATTRACTION TO THAT OF THE POSITIVELY CHARGED PLATE AND WILL GREATLY INCREASE THE NUMBER OF EMITTED ELECTRONS FLYING ACROSS TO THE PLATE. OF COURSE, A SMALL PROPORTION OF THE EMITTED ELECTRONS WILL STRIKE THE SLENDER METAL BARS OF THE GRID, SO THAT A SMALL GRID CURRENT WILL FLOW THRU THE "C" BATTERY CIRCUIT AND SOME OF THE ELECTRONS WILL THUS RETURN TO THE FILAMENT FROM WHENCE THEY CAME. THIS FACT IS ALSO POINTED OUT IN FIG. 16.

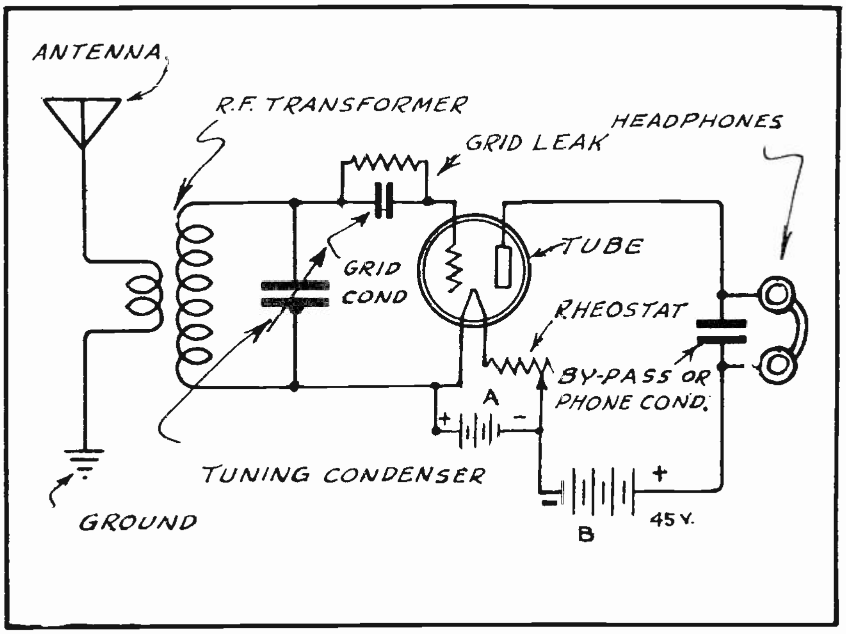

FIG. 19
CIRCUIT DIAGRAM OF THE ONE-TUBE RECEIVER.

WHAT THE POSITIVE GRID REALLY ACCOMPLISHES IS ONLY TO ASSIST AND TO ACCELERATE THE FLOW OF ELECTRONS OVER TO THE PLATE AND THEREBY PRODUCE AN INCREASE IN THE FLOW OF PLATE CURRENT.

SUMMING UP THIS EFFECT OF THE GRID POTENTIAL, WE SEE THEN THAT A NEGATIVE GRID POTENTIAL RETARDS THE ELECTRON FLOW BETWEEN FILAMENT AND PLATE AND THEREBY REDUCES THE PLATE CURRENT; WHEREAS, A POSITIVE GRID POTENTIAL ACCELERATES AND INCREASES THE FLOW OF ELECTRONS FROM FILAMENT TO THE PLATE, AND IN THIS WAY INCREASES THE PLATE CURRENT.

APPLYING A.C. VOLTAGES TO THE GRID

WITH NO SIGNAL VOLTAGE APPLIED TO THE GRID OF THE TUBE A CERTAIN PLATE CURRENT WILL FLOW AND WE CALL THIS THE NORMAL OR NO-SIGNAL PLATE CURRENT OF THE TUBE. NOW LET US SEE WHAT HAPPENS WHEN A.C. SIGNAL VOLTAGES ARE IMPRESSED UPON THE GRID.

IF THE GRID SIGNAL VOLTAGE IS POSITIVE AT ONE INSTANT, THE PLATE CURRENT WILL INCREASE OVER ITS NORMAL VALUE BY A DEFINITE AMOUNT, AND IF THE E.M.F. IS NEGATIVE AT ANOTHER PARTICULAR INSTANT, THE PLATE CURRENT

WILL DROP BELOW ITS NORMAL VALUE. WE WILL THEN HAVE A CONDITION AS ILLUSTRATED IN FIG. 17 WHEREIN THE ALTERNATING E.M.F. AS APPLIED TO THE GRID OF THE TUBE IS SHOWN AT THE LEFT, AND THE CORRESPONDING PLATE CURRENT VARIATION IS INDICATED BY THE CURVE AT THE RIGHT. THE HORIZONTAL LINE, WHICH IS DRAWN THROUGH THE PLATE CURRENT CURVE, REPRESENTS THE NORMAL PLATE CURRENT WHICH FLOWS THROUGH THE TUBE WHEN NO VOLTAGE IS APPLIED TO THE GRID.

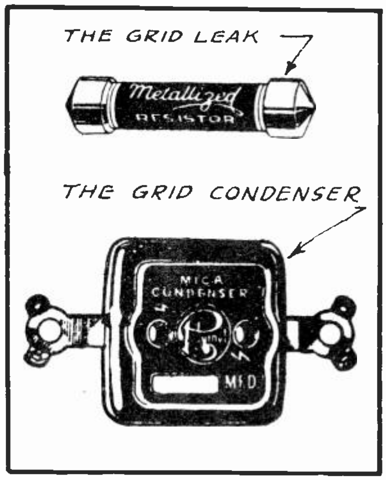

FIG. 20
THE GRID CONDENSER AND LEAK.

IF THE TUBE IS OPERATED IN A CIRCUIT UNDER SUCH CONDITIONS THAT THE INCREASES IN PLATE CURRENT ARE EQUAL TO THE DECREASES IN PLATE CURRENT AS IS THE CASE IN FIG. 17, THEN THE TUBE IS BEING OPERATED AS AN AMPLIFIER. ON THE OTHER HAND, IF THE TUBE IS OPERATED IN A CIRCUIT UNDER SUCH CONDITIONS SO THAT THE INCREASES IN PLATE CURRENT ARE NOT EQUAL TO THE DECREASES IN PLATE CURRENT, AS IS THE CASE IN FIG. 18, THEN THE TUBE IS BEING OPERATED AS A DETECTOR.

THE OPERATING VOLTAGES FOR ANY GIVE TUBE WHICH ARE REQUIRED TO OPERATE THAT PARTICULAR TUBE, EITHER AS AN AMPLIFIER OR AS A DETECTOR, ARE SPECIFIED BY THE TUBE MANUFACTURERS AND YOU WILL RECEIVE INFORMATION REGARDING THESE SPECIFICATIONS IN THE NEXT LESSON.

A ONE TUBE RECEIVER

WE HAVE ALREADY SHOWN HOW A DIODE CAN BE USED IN A SIMPLE RECEIVER CIRCUIT TO REPLACE THE CRYSTAL DETECTOR. IN FIG. 19 WE HAVE A ONE-TUBE RECEIVER EMPLOYING A TRIODE, WHICH HAS AN ADVANTAGE OVER THE DIODE IN THAT IT NOT ONLY ACTS AS A DETECTOR BUT AT THE SAME TIME, IT ALSO AMPLIFIES OR INCREASES THE SIGNAL INTENSITY.

UPON STUDYING THIS DIAGRAM VERY CAREFULLY YOU WILL NO DOUBT IMMEDIATELY OBSERVE THAT THE ANTENNA AND THE TUNED CIRCUIT ARE THE SAME AS USED FOR THE SIMPLE CRYSTAL OR DIODE RECEIVER. THE REST OF THE CIRCUIT, HOWEVER, IS QUITE DIFFERENT.

THE GRID OF THE TUBE, FOR INSTANCE, IS CONNECTED TO ONE END OF THE TUNED CIRCUIT THROUGH A FIXED CONDENSER, ACROSS WHICH A RESISTOR IS CONNECTED. A RESISTOR IS A UNIT WHICH OFFERS CONSIDERABLE OPPOSITION TOWARDS A FLOW OF CURRENT, BUT WILL NOT COMPLETELY STOP THE FLOW OF CURRENT. RESISTORS USED FOR RADIO PURPOSES ARE USUALLY CONSTRUCTED OF A CARBON COMPOSITION OR OF NICHROME WIRE.

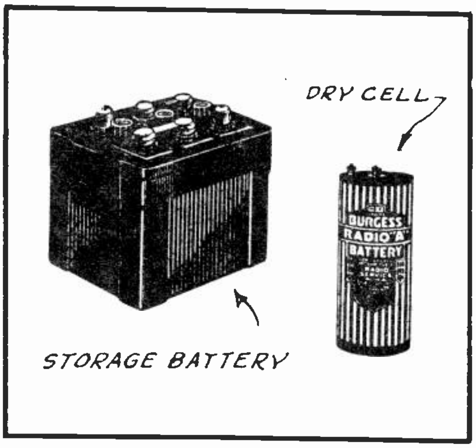

FIG. 21
TYPICAL "A" SUPPLIES.

WHEN A RESISTOR IS USED IN THE MANNER ILLUSTRATED IN FIG. 19, WE GENERALLY CALL IT A GRID LEAK OR LEAK RESISTOR, AND THE FIXED CONDENSER WHEN USED IN THE GRID

CIRCUIT OF A TUBE, AS IN FIG. 19, IS GENERALLY SPOKEN OF AS BEING A GRID CONDENSER. THE TUBE, WHEN USED IN THIS CIRCUIT, IS KNOWN AS A GRID-LEAK DETECTOR.

IN FIG. 20 YOU ARE SHOWN A PHOTOGRAPH OF BOTH THE GRID CONDENSER AND THE GRID LEAK SO THAT YOU CAN BECOME FAMILIAR WITH THEIR ACTUAL APPEARANCES.

THE "A" BATTERY IS CONNECTED ACROSS THE FILAMENT OF THE TUBE, WITH A RHEOSTAT IN SERIES, AS SHOWN IN FIG. 19. THE "A" SUPPLY WHICH IS GENERALLY USED FOR BATTERY-OPERATED RECEIVERS IS EITHER A 6-VOLT STORAGE BATTERY OR A PAIR OF DRY CELLS WHICH ARE CONNECTED TOGETHER IN SERIES, THAT IS, WITH THE POSITIVE TERMINAL OF ONE OF THE CELLS CONNECTED TO THE NEGATIVE TERMINAL OF THE OTHER CELL. BOTH OF THESE TWO COMMONLY USED "A" SUPPLIES ARE ILLUSTRATED FOR YOU IN FIG. 21.

THE RHEOSTAT, WHICH IS CONNECTED IN THE FILAMENT CIRCUIT, OFFERS A MEANS WHEREBY THE CURRENT WHICH HEATS THE FILAMENT CAN BE CONTROLLED. IN THIS WAY ELECTRON EMISSION IS REGULATED, THUS PROVIDING VOLUME CONTROL IN THE SIMPLE CIRCUIT WHICH IS BEING CONSIDERED.

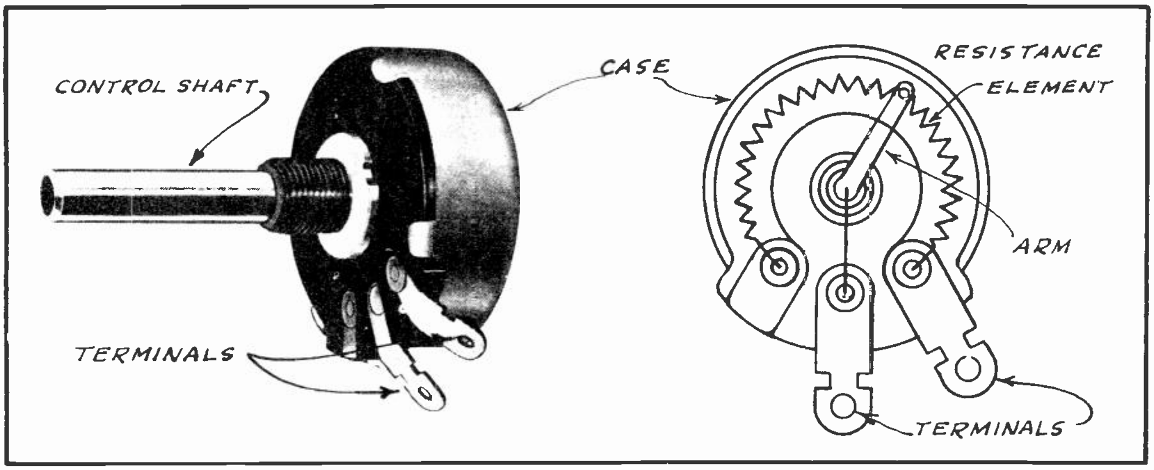

FIG. 22
THE RHEOSTAT.

THE RHEOSTAT IS ILLUSTRATED IN DETAIL IN FIG.22. THIS UNIT CONSISTS OF A BODY WHICH IS MADE OF SOME SUCH GOOD INSULATING MATERIAL AS BAKELITE. A RESISTANCE ELEMENT IS THEN FORMED BY WINDING A LONG PIECE OF BARE NICHROME RESISTANCE WIRE ON A STRIP OF INSULATING MATERIAL SO THAT ADJACENT TURNS ARE SLIGHTLY SEPARATED FROM EACH OTHER. THE STRIP CONTAINING THE RESISTANCE WIRE IS THEN BENT INTO THE SHAPE OF A CIRCLE AND FASTENED TO THE BODY OF THE UNIT. ONE END OF THE RESISTOR ELEMENT IS ATTACHED TO ONE TERMINAL AND ITS OTHER END IS LEFT FREE.

AN ADJUSTABLE ARM CAN BE ROTATED BY MEANS OF A SHAFT TO WHICH A CONTROL KNOB IS FIRMLY ATTACHED. THIS ARM IS ELECTRICALLY CONNECTED TO THE SECOND TERMINAL WHICH IS MOUNTED ON THE ASSEMBLY.

BY ROTATING THE CONTROL KNOB OF THIS RHEOSTAT, THE ARM WILL BE CAUSED TO CONTACT DIFFERENT POINTS ALONG THE RESISTOR AND IN THIS WAY TO VARY THE EFFECTIVE LENGTH OF THE RESISTANCE IN THE CIRCUIT TO WHICH ITS TERM-

INALS ARE CONNECTED, AND THE CURRENT FLOW THROUGH THE CIRCUIT WILL THEREFORE BE REDUCED ACCORDINGLY.

THE ACTUAL APPEARANCE OF THE "B" BATTERY, WHICH IS USED IN THIS CIRCUIT, IS SHOWN IN FIG. 23. IT IS EQUIPPED WITH THREE TERMINALS, ONE MARKED (-), ONE (+22½) AND THE THIRD (+45). IN OTHER WORDS, IF THE (-) AND (+22½) TERMINALS OF THIS BATTERY ARE CONNECTED TO A CIRCUIT, IT WILL FURNISH AN E.M.F. OF 22½ VOLTS; WHEREAS, IF THE (-) AND (+45) TERMINALS ARE CONNECTED TO A CIRCUIT, IT WILL FURNISH AN E.M.F. OF 45 VOLTS.

IN THE CASE OF THE CIRCUIT IN FIG. 19, THE (-) TERMINAL OF THE "B" BATTERY IS CONNECTED TO THE (-) TERMINAL OF THE "A" BATTERY, WHILE THE (+45) TERMINAL OF THE "B" BATTERY IS CONNECTED TO THE PLATE OF THE TUBE THROUGH THE WINDINGS OF THE HEADPHONES, AND THEREFORE THE PLATE VOLTAGE WILL BE APPROXIMATELY 45 VOLTS.

FIG. 23
THE "B" BATTERY.

IT IS ALSO OF GREAT IMPORTANCE IN THIS CIRCUIT TO HAVE ONE END OF THE TUNED CIRCUIT CONNECTED TO THE (+) TERMINAL OF THE "A" BATTERY. (IT IS CUSTOMARY TO REFER TO THIS END OF THE GRID CIRCUIT AS THE GRID RETURN CIRCUIT). THE FIXED CONDENSER CONNECTED ACROSS THE HEADPHONES IS THE SAME FIXED CONDENSER WHICH WE USED FOR THIS PURPOSE IN THE PREVIOUS LESSON.

IN FIG. 24, YOU WILL SEE THIS ONE-TUBE RECEIVER IN ITS COMPLETE FORM, SHOWING THE RELATIVE POSITIONS OF ALL PARTS AND THE EXACT MANNER IN WHICH THE WIRING CONNECTIONS ARE MADE.

AS TO THE CONSTRUCTIONAL DATA FOR THIS PARTICULAR RECEIVER, THE SAME R.F. TRANSFORMER, TUNING CONDENSER AND PHONE CONDENSER CAN BE USED AS WERE SPECIFIED FOR THE CRYSTAL RECEIVER IN THE PREVIOUS LESSON.

THE SOCKET SHOULD BE OF THE "UX OR 4-PRONG TYPE, WHILE THE GRID CONDENSER SHOULD HAVE A CAPACITY RATING OF .00025 MFD.; THE GRID LEAK RESISTOR A VALUE OF 2 MEGOHMS (ONE MEGOHM IS EQUAL TO 1,000,000 OHMS) AND THE RHEOSTAT SHOULD HAVE A RESISTANCE RATING OF ABOUT 20 OHMS. IF A TYPE 30 TUBE IS USED, IT IS THEN ADVISABLE TO EMPLOY TWO SERIES-CONNECTED #6 DRY CELLS FOR THE "A" SUPPLY AND A 45-VOLT "B" BATTERY FOR THE "B" SUPPLY.

OPERATION OF THE ONE-TUBE RECEIVER

THE SIGNAL CURRENTS ARE GENERATED IN THE ANTENNA CIRCUIT OF THIS RECEIVER AND TRANSFERRED BY INDUCTION OVER INTO THE TUNED CIRCUIT IN EXACTLY THE SAME MANNER AS ALREADY DESCRIBED IN OUR DISCUSSION OF THE SIMPLE CRYSTAL RECEIVER. THUS WE WILL HAVE SIGNAL VOLTAGES GENERATED ACROSS THE TUNED CIRCUIT. SINCE ONE END OF THIS TUNED CIRCUIT IS CONNECTED TO THE GRID OF THE TUBE THROUGH THE GRID CONDENSER AND LEAK RESISTOR, WHILE THE OTHER END OF THE TUNED CIRCUIT IS CONNECTED TO ONE SIDE OF THE TUBE FILAMENT, IT IS CLEAR THAT THE SIGNAL VOLTAGES WILL ALSO BE EFFECTIVE ACROSS THE GRID AND FILAMENT OF THE TUBE.

Since these signals are high frequency A.C. voltages, the potential of the grid with respect to the filament will be varied accordingly. That is, the grid will alternately become positively and negatively charged, and it will therefore vary the flow of plate current through the tube correspondingly. Then since the windings of the headphones are connected between the "B" battery and the plate of the tube, or in the plate circuit, this variation in plate current will react upon the headphone diaphragm electromagnetically, the same as in the case of the crystal receiver.

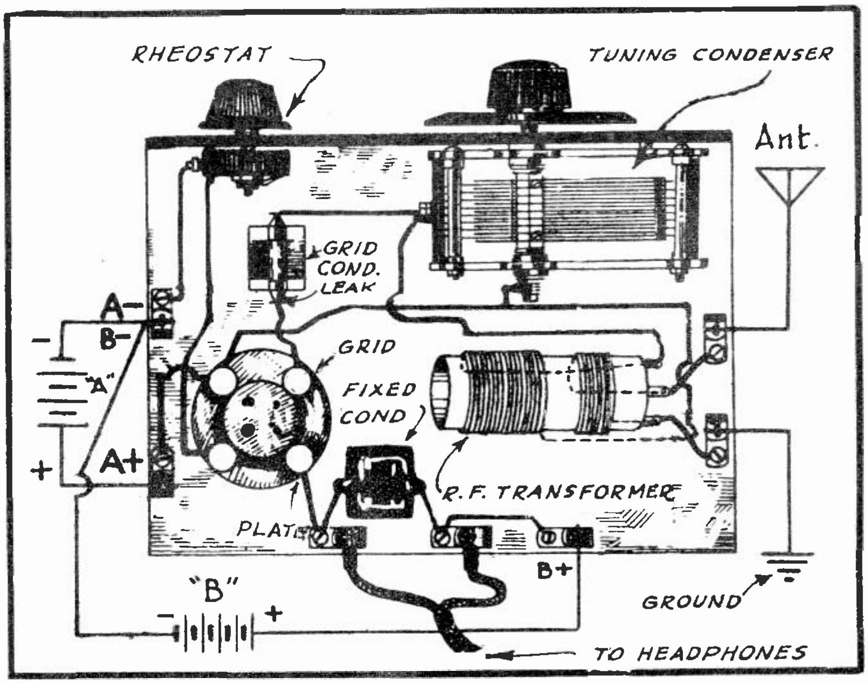

Fig. 24
The One Tube Receiver In Its Complete Form.

By using the plate and filament voltages as specified, in addition to the grid condenser and leak resistor combination which was also described, it so happens that the decreases in plate current below its normal value are much greater than the increases in plate current, as the grid potential becomes alternately positive and negative in accord with the applied signal voltage. In other words, this particular type of circuit will cause the plate current variation to be like that illustrated in Fig. 18 and thus provide us with detection.

In this way, the tube as used in this circuit will perform the same task as the crystal detector, except that the current which actuates the headphones comes from a local source of E.M.F (the "B" battery) rather than from energy picked up by the antenna. Note, however, that the flow of plate current originating in the "B" battery is at all times under the control of the signal voltages applied to the grid of the tube. Moreover, this variation in plate current, which is responsible for the operation of the headphone diaphragms, will correspond to the audio frequency voltage and current variations which were used at the transmitter to modulate the carrier frequency. Therefore, this plate current variation will operate the headphone diaphragms in the correct manner to reproduce the original sounds which were impressed upon the microphone of the transmitter.

You should now have a good basic knowledge of the construction and operation of radio tubes so that you will be prepared to understand fully the more technical explanations regarding tubes and their use which will

BE BROUGHT BEFORE YOU IN THE FOLLOWING LESSONS.

No DOUBT YOU ARE STILL WONDERING JUST EXACTLY HOW THE GRID CONDENSER AND LEAK RESISTOR WORK IN THE CIRCUIT, BUT THIS, AS WELL AS ALL OTHER DETAILS OF A RATHER TECHNICAL NATURE, WILL BE EXPLAINED THOROUGHLY TO YOU IN A MORE ADVANCED LESSON. THIS PRESENT LESSON HAS SERVED ONLY AS YOUR INTRODUCTION TO RADIO TUBES.

IN THE NEXT LESSON WE WILL CONT NUE THE INVESTIGATION OF RADIO TUBES BY STUDYING THE OPERATING CHARACTERISTIC'S OF "BATTERY-TYPE" TUBES.

RADIO - TELEVISION

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

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LESSON NO. 6

Battery-Type Triodes

By battery-type tubes, we mean those tubes which are designed to have their filament supply furnished by batteries. Although it is true that most of the receivers which are now being used derive their operating power direct from the A.C. and D.C. lighting circuits so that batteries are not required, yet there are still many battery operated receivers being manufactured for those people who live in districts where no other power supply is available. Thus, you see, that it is absolutely necessary for you to have a thorough knowledge of battery-type receivers as well as A.C. and D.C. operated receivers.

We are simply investigating battery-type receivers first, for the simple reason that their circuits are not as complex as those used in A.C. receivers. In this way, you will find it easier to grasp the fundamental principles of radio which can also be applied directly to A.C. receivers as you shall see a little later on.

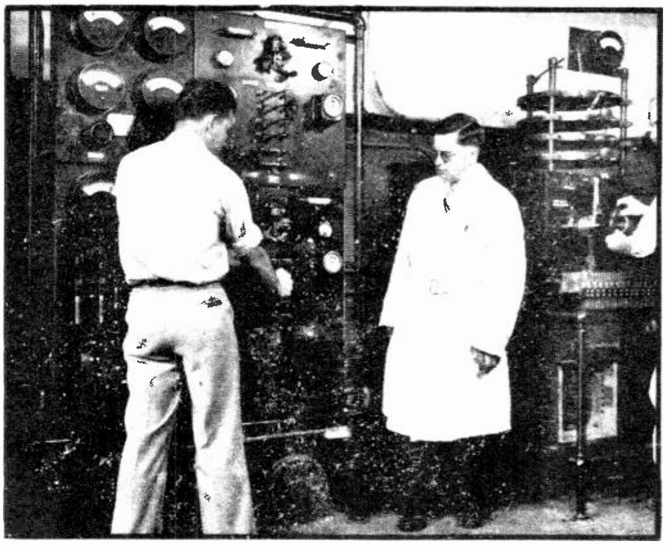

Fig. 1
Commercial-Type Transmitter
Installed At National.

Some of the tubes which are described to you in this lesson are somewhat old and not being used in receivers of later design. Nevertheless, it is advisable that you familiarize yourself with these older tubes as well as with the more recent ones which are also explained in this lesson.

You never can tell when you will be called upon to service a receiver in which

RATHER OLD TYPE TUBES ARE EMPLOYED AND YOU WOULD FIND YOURSELF IN AN EMBARRASSING POSITION IF YOU HAD NEVER HEARD OF THEM BEFORE. SO CONSIDERING CONDITIONS FROM THIS POINT OF VIEW, YOU CAN READILY SEE THAT IN ORDER TO HAVE A COMPLETE KNOWLEDGE OF TUBES, THE THING FOR YOU TO DO IS TO BECOME ACQUAINTED WITH BOTH THE OLD AND NEW TYPES.

MANUFACTURING TUBES

BEFORE CONTINUING WITH THE OPERATING CHARACTERISTICS OF THE VARIOUS TYPES OF TUBES, YOU WILL NO DOUBT BE INTERESTED IN LEARNING ABOUT SOME OF THE VARIOUS PROCESSES THROUGH WHICH RADIO TUBES PASS WHILE BEING MANUFACTURED.

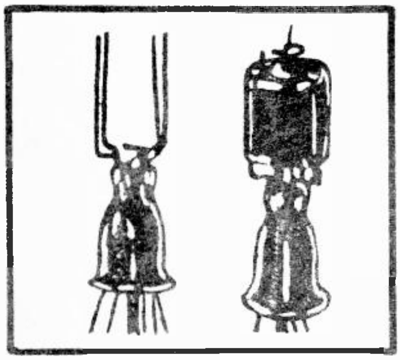

FIG. 2
Mounting the elements.

THE FIRST STEP IN THE MANUFACTURE OF RADIO TUBES IS TO MAKE THE GLASS SUPPORT UPON WHICH THE ELEMENTS ARE TO BE MOUNTED, AND WHICH IS ILLUSTRATED FOR YOU IN FIG. 2. THIS GLASS SUPPORT IS FORMED BY A SPECIAL MACHINE AND ITS UPPER END IS COMPRESSED WHILE ITS LOWER END IS FLARED, SO THAT IT RESEMBLES A BELL. THE LARGE WIRES WHICH ARE USED TO SUPPORT THE ELEMENTS, AS WELL AS THE SMALLER WIRES FOR MAKING THE ELECTRICAL CONNECTIONS AT THE ELEMENTS, ALL PASS THROUGH THIS GLASS SUPPORT OR STEM AND ARE IMBEDDED IN THE GLASS SO THAT THEY WILL BE HELD IN PLACE FIRMLY.

AT ONE POINT, A HOLE EXTENDS THRU THE WALL OF THE GLASS SUPPORT AND A THIN PIECE OF GLASS TUBING IS FUSED TO THIS HOLE WHILE ITS REMAINING LENGTH EXTENDS DOWNWARD THRU THE HOLLOW INNER PORTION OF THE SUPPORT.

THE NEXT STEP IS TO PLACE THE ELEMENTS IN THEIR PROPER POSITION AND TO FASTEN THEM TO THEIR RESPECTIVE SUPPORTS. THIS IS A VERY EXACTING PROCESS BECAUSE IT IS OF EXTREME IMPORTANCE TO PROVIDE THE EXACT SEPARATION BETWEEN THE ELEMENTS AS REQUIRED BY THE DESIGNING ENGINEERS. FOR THIS REASON, SPECIAL MACHINES AND DELICATE INSTRUMENTS ARE EMPLOYED TO ASSIST IN THIS WORK. THE CONNECTING WIRES ARE THEN WELDED TO THE ELEMENTS AND THE UNIT IN THIS STAGE OF ITS DEVELOPMENT IS SHOWN YOU AT THE RIGHT OF FIG. 2.

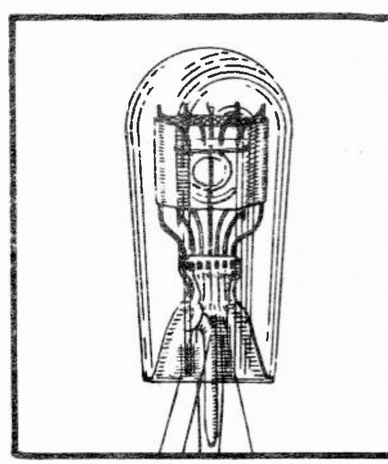

FIG. 3
The glass bulb in position.

THE GLASS BULB IS NOW PLACED OVER THE ELEMENTS AND ITS LOWER EDGE IS FUSED TO THE LOWER PORTION OF THE GLASS SUPPORT SO AS TO FORM A SINGLE UNIT. THE TUBE WILL THEN APPEAR AS SHOWN IN FIG. 3. NOTICE IN THIS ILLUSTRATION HOW THE PIECE OF GLASS TUBING PROJECTS FROM THE LOWER END OF THE ASSEMBLY.

A VACUUM PUMP IS NOW CONNECTED TO THE END OF THE GLASS TUBING AND SINCE THIS TUBING COMMUNICATES WITH THE INSIDE OF THE GLASS BULB, IT OFFERS A MEANS WHEREBY THE AIR CAN BE WITHDRAWN FROM THE INTERIOR OF THE

GLASS BULB. THIS PROCESS OF REMOVING THE AIR FROM THE TUBE IS ALSO A VERY CRITICAL TASK BECAUSE THE EFFICENCY OF THE TUBE DEPENDS GREATLY UPON THE DEGREE OF VACUUM WHICH EXISTS IN THE FINISHED TUBE.

IN ORDER TO OBTAIN THE BEST RESULTS, EVEN THE AIR WHICH ADHERES OR IS RETAINED BY THE GLASS AND THE METALLIC STRUCTURE WITHIN THE TUBE MUST BE REMOVED. TO ACCOMPLISH THIS, THE TUBE IS PLACED IN A SPECIAL OVEN AND HEATED, WHILE AT THE SAME TIME, A CURRENT IS PERMITTED TO FLOW THROUGH THE FILAMENT SO AS TO HEAT IT TO INCANDESCENCE. A SPECIAL HIGH VOLTAGE TRANSFORMER IS THEN CONNECTED BETWEEN ONE SIDE OF THE FILAMENT, TO THE PLATE AND TO THE GRID. UNDER THESE CONDITIONS, THE GLASS STRUCTURE OF THE TUBE BECOMES VERY NEARLY SOFT FROM THE EXCESSIVE HEAT AND THE METALLIC ELEMENTS BECOME RED HOT. THIS HIGH TEMPERATURE SERVES TO DRIVE THE AIR OUT OF THE GLASS AND METAL SO THAT THIS AIR WILL ALSO BE WITHDRAWN FROM THE TUBE AS THE VACUUM PUMP CONTINUES ITS OPERATION.

WITH AS MUCH AIR AS POSSIBLE REMOVED FROM THE TUBE, THE GLASS TUBING IS SEALED SHUT AND A SUITABLE VACUUM WILL THEN EXIST WITHIN THE TUBE.

THE FINAL STEP IS TO MOUNT THE GLASS BULB ON THE HOLLOW BAKELITE BASE. THIS IS DONE BY FIRST RUNNING THE CONNECTION WIRES, COMING FROM THE ELEMENTS, THROUGH THE PRONGS OF THE SOCKET AND THEN CEMENTING THE GLASS BULB TO THE BASE WITH A SPECIAL CEMENT. THE SURPLUS LENGTH OF THE ELEMENT CONNECTION WIRES, WHICH PROJECT THROUGH THE BASEPRONGS, ARE THEN CUT OFF AND THE WIRES CAREFULLY SOLDERED TO THE PRONGS. THE TUBE IS THEN COMPLETE AS SHOWN IN FIG. 4 AND READY FOR ITS LABORATORY TEST.

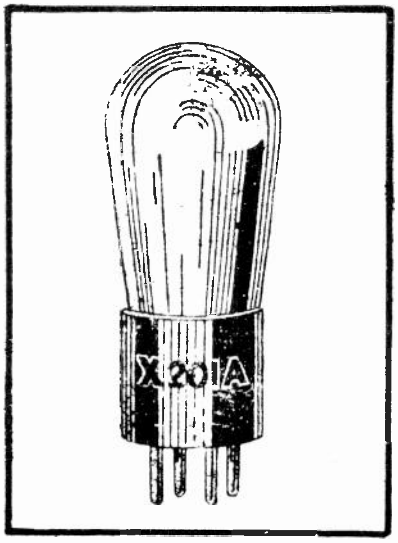

FIG. 4
The finished tube.

ALTHOUGH THE VARIOUS TUBE MANUFACTURERS MAY DIFFER SOMEWHAT AS REGARDS CERTAIN STEPS IN THE CONSTRUCTION OF TUBES, YET IN GENERAL, ALL TUBES ARE MANUFACTURED AS JUST EXPLAINED TO YOU.

THE AMPLIFICATION FACTOR OF A TUBE

WHEN DEALING WITH THE OPERATING CHARACTERISTICS OF TUBES, YOU WILL FREQUENTLY COME ACROSS THE EXPRESSION "AMPLIFICATION FACTOR". THEREFORE, IT WILL BE WELL FOR YOU TO BECOME FAMILIAR WITH THIS TERM BEFORE YOU ARE REQUIRED TO USE IT.

ONE OF THE MOST IMPORTANT FEATURES OF RADIO TUBES IS THE FACT THAT IT ONLY TAKES A VERY SMALL VARIATION IN VOLTAGE AT THE GRID TO PRODUCE A RATHER LARGE VARIATION OR CHANGE IN THE FLOW OF PLATE CURRENT. THAT IS, THE TUBE POSSESSES AMPLIFICATION QUALITIES.

THE APPLICATION OF THE SIGNAL VOLTAGE TO THE GRID OF THE TUBE WILL THEN ALSO CAUSE CORRESPONDING VOLTAGE VARIATIONS TO APPEAR IN THE PLATE CIRCUIT OF THE TUBE BUT THESE PLATE CIRCUIT VOLTAGE VARIATIONS, ALTHOUGH BEING A REPRODUCTION OF THE SIGNAL VOLTAGE VARIATIONS AS APPLIED TO THE GRID, ARE NEVERTHELESS MUCH GREATER IN MAGNITUDE AS ILLUS-

TRATED IN FIG. 5.

BESIDES A CHANGE IN GRID POTENTIAL BEING CAPABLE OF PRODUCING A CHANGE IN THE FLOW OF PLATE CURRENT, IT IS ALSO POSSIBLE TO PRODUCE A CHANGE IN THE FLOW OF PLATE CURRENT BY ALTERING THE PLATE VOLTAGE. HOWEVER, IT REQUIRES MUCH LESS POTENTIAL VARIATION AT THE GRID THAN AT THE PLATE TO PRODUCE A GIVEN CHANGE IN PLATE CURRENT. IF, FOR EXAMPLE, THE CONSTRUCTION OF A CERTAIN TUBE IS SUCH THAT ITS PLATE CURRENT WILL IN CREASE BY 5 MILLIAMPERES (.005 AMPERE) IF THE GRID VOLTAGE IS MADE MORE POSITIVE BY 10 VOLTS AND IT TAKES 30 VOLTS MORE PLATE VOLTAGE TO PRODUCE THIS SAME 5 MILLIAMPERES INCREASE IN PLATE CURRENT, THEN IT CAN READILY BE SEEN THAT THREE TIMES AS MUCH CHANGE IN POTENTIAL IS REQUIRED AT THE PLATE OF THE TUBE THAN AT THE GRID IN ORDER TO PRODUCE A 5 MILLIAMPERE CHANGE IN PLATE CURRENT. THIS TUBE WILL THEN BE SAID TO HAVE AN AMPLIFICATION FACTOR OF "3". THE AMPLIFICATION FACTOR OF ANY TUBE THEN IS THE RATIO BETWEEN THE CHANGE IN PLATE VOLTAGE TO THE CHANGE IN GRID VOLTAGE WHICH IS REQUIRED TO PRODUCE A GIVEN CHANGE IN THE PLATE CURRENT. IT IS COMMON TO SPEAK OF THE AMPLIFICATION FACTOR AS THE "MU" OF THE TUBE AND IT IS ABREVIATED AS μ.

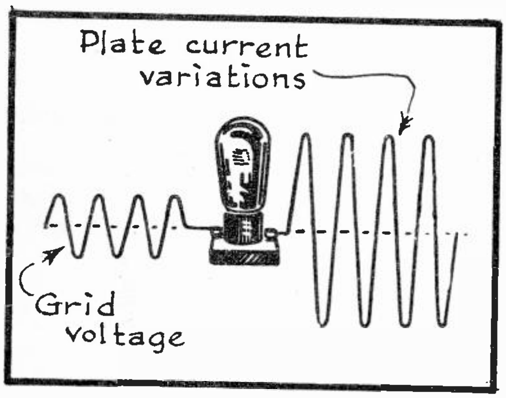

FIG. 5
The tube as an amplifier.

TUBE IDENTIFICATION NUMBERS

AS WAS ALREADY MENTIONED TO YOU IN THE PREVIOUS LESSON, EACH TYPE OF TUBE IS IDENTIFIED BY MEANS OF A NUMBER. HOWEVER, THE SYSTEM OF NUMBERING AS ADOPTED BY ALL OF THE DIFFERENT TUBE MANUFACTURERS IS NOT THE SAME. FOR INSTANCE, THE TYPE CX-301A "CUNNINGHAM" TUBE IS THE SAME TYPE OF TUBE AS THE ER-201A "RAYTHEON", OR THE 401A "DEFOREST" ETC. ALTHOUGH THESE NUMBERS FOR THE SAME TYPE OF TUBE ARE DIFFERENT, YET THERE IS A SIMILARITY BETWEEN THEM AND THIS SIMILARITY EXISTS IN THE LAST TWO DIGITS OF THE NUMBER, AS WELL AS THE FINAL LETTER. IN OTHER WORDS, "01A" IN CONTAINED IN ALL THREE OF THESE TUBE NUMBERS AND THIS IS IN REALITY THE TUBE TYPE IDENTIFICATION OF THE CODE NUMBER, WHILE THE REST OF THIS CODE NUMBER SERVES TO IDENTIFY THE MANUFACTURER.

THE PREFIX "X", AS USED BY MOST TUBE MANUFACTURERS, INDICATES THAT THE TUBE IN QUESTION HAS A FOUR PRONG BASE, WHEREAS THE PREFIX "Y", AS IN UY-227, INDICATES THAT THE TUBE HAS A FIVE PRONG BASE.

SINCE THE LATTER PORTION OF THE TUBE CODE NUMBER IDENTIFIES THE TYPE OF TUBE, RADIO MEN GENERALLY ONLY USE THIS PART OF THE NUMBER WHEN SPEAKING OF ANY PARTICULAR TYPE OF TUBE AND IN OUR LESSONS, WE SHALL DO THE SAME. FOR EXAMPLE, A UX-226 CAN BE CALLED SIMPLY -26, A UY-227 CAN BE CALLED A -27, A UX-112A CAN BE CALLED A -12A ETC. THIS SIMPLIFIES MATTERS A GREAT DEAL WHILE AT THE SAME TIME, IT DOES NOT SPECIFY ANY PARTICULAR MAKE OF TUBE BUT ONLY THE TYPE AND FOR OUR STUDIES, THE TYPE IS OF GREATEST IMPORTANCE.

WE WILL NOW STUDY THE OPERATING CHARACTERISTICS OF EACH OF THE VARIOUS BATTERY-TYPE TUBES IN DETAIL, STARTING WITH THE OLDER DESIGNS FIRST AND THEN GRADUALLY WORKING UP TO THE LATEST TUBES BEING USED.

THE TYPE D-11 AND X-12 TUBES

THE TYPES D-11 AND X-12 TUBES ARE IDENTICAL IN THEIR INTERNAL CONSTRUCTION BUT DIFFER IN RESPECT TO THE CONSTRUCTION OF THEIR BASES. THAT IS, THE D-11 HAS A SPECIAL BASE WHICH REQUIRES A SOCKET OF SPECIAL CONSTRUCTION, WHEREAS THE X-12 HAS A STANDARD "X" BASE SO THAT IT CAN BE INSTALLED IN THE CONVENTIONAL TYPE "X" OR FOUR-PRONG SOCKET. THE X-12 IS SHOWN AT THE LEFT OF FIG. 6, WHILE THE D-11 APPEARS AT THE RIGHT OF THIS SAME ILLUSTRATION.

BOTH OF THESE TUBES ARE DESIGNED TO BE USED AS DETECTORS OR AUDIO FREQUENCY AMPLIFIERS AND ARE ADAPTED TO BATTERY-OPERATED RECEIVERS IN THAT THEIR FILAMENT REQUIRES ONLY 1.1 VOLTS (1 1/10 VOLTS) AND AT THIS APPLIED VOLTAGE, THE FILAMENT WILL DRAW A CURRENT OF .25 AMPERE(¼AMPERE) THIS PERMITS THE USE OF THE ORDINARY TYPE OF #6 DRY CELLS FOR THE "A" SUPPLY.

FILAMENT:- THE FILAMENT WHICH IS USED IN THESE TUBES IS PROVIDED WITH AN OXIDE DEPOSIT THATPERMITS AN AMPLE EMISSION OF ELECTRONS IN SPITE OFTHE LOW FILAMENT VOLTAGE AND CURRENT. DUE TO THE LOW CURRENT CONSUMPTION OF THE FILAMENT, NO APPRECIABLE AMOUNT OF LIGHT WILL BE EMITTED BY IT WHEN THE TUBE IS IN OPERATION. THE FILAMENT NORMALLY OPERATES WITH A DULL RED GLOW, WHICH IS HARDLY PERCEPTIBLE THROUGH THE GLASS OF SOME OF THE TUBES.

OPERATION AS A DETECTOR:-WHEN USING THIS TUBE AS A DETECTOR, IT SHOULD BE USED IN CONJUNCTION WITH A GRID CONDENSER HAVING A CAPACITY RATING OF .00025 MFD. AND A 2 MEGOHM GRID LEAK RESISTOR. THE GRID RETURN CIRCUIT SHOULD BE CONNECTED TO THE POSITIVE SIDE OF THE "A" BATTERY. A PLATE VOLTAGE OF 22.5 VOLTS IS RECOMMENDED FOR THIS TUBE BUT IT CAN BE INCREASED TO 45 VOLTS IN CASE THE RECEIVED SIGNALS ARE QUITE STRONG. BY EXPERIMENT, THE BEST PLATE VOLTAGE CAN BE DETERMINED FOR ANY PARTICULAR CASE.

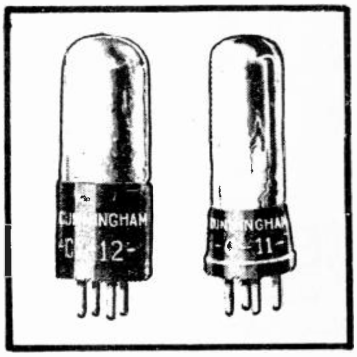

FIG. 6

A type D-11 & X-12 tube.

OPERATION AS AN AMPLIFIER:-THIS TUBE IS ADAPTED TO A.F. AMPLIFIERS IN WHICH TRANSFORMER COUPLING IS EMPLOYED AND REQUIRES NO "C" BIAS VOLTAGE UNLESS THE PLATE VOLTAGE EXCEEDS 67.5 VOLTS. THE GRID RETURN CIRCUIT SHOULD BE CONNECTED TO THE NEGATIVE SIDE OF THE "A" BATTERY. IF GREATER OUTPUT IS REQUIRED, THEN THE PLATE VOLTAGE CAN BE INCREASED TO 90 VOLTS BUT UNDER THESE CONDITIONS, A NEGATIVE GRID BIAS VOLTAGE OF 4.5 VOLTS SHOULD BE APPLIED TO THE GRID OF THE TUBE. (BY A "C" BIAS VOLTAGE, WE MEAN THAT A NEGATIVE D.C. POTENTIAL IS APPLIED TO THE GRID OF THE TUBE SO AS TO KEEP THE GRID SLIGHTLY NEGATIVE AT ALL TIMES AND IN BATTERY OPERATED RECEIVERS, THIS BIAS VOLTAGE IS GENERALLY OBTAINED BY CONNECTING SMALL "C" BATTERIES BETWEEN THE GRID CIRCUIT OF THE TUBE AND THE FILAMENT. THE NEGATIVE TERMINAL OF THE "C" BATTERY IS CONNECTED TO THE GRID SIDE OF THE CIRCUIT AND IN THE FOLLOWING LESSONS YOU WILL FIND COMPLETE DETAILS REGARDING THE USE OF "C" BIAS VOLTAGES IN RECEIVER CIRCUITS). THE D-11 AND X-12 BOTH HAVE AN AMPLIFICATION FACTOR OF 6.6 AND 3 MILLIAMPERES OF PLATE CURRENT.

ALTHOUGH THEY CAN BE USED IN R.F. AMPLIFIERS OF THE "NEUTRODYNE" type, yet they do not perform entirely satisfactory in circuits preceding the detector. They are no longer being installed in receivers but you may have occassion to come across them when servicing old sets.

THE - 99 TUBE

The type - 99 tubes were designed expressly for the purpose of reducing the size of the required "A" battery and because of this ability, they were used considerably in portable receivers, as well as in other installations where no appreciable "A" battery drain could be tolerated. These tubes can be operated either as detectors, R.F. amplifiers or A.F. amplifiers.

There are two distinct forms in which the - 99 tube is manufactured. One of these forms bears the code number C-99 and the other X-99. The only difference between these two forms exists in the bases, for the C-99 has very short prongs as shown at the right of Fig. 7 and therefore requires a special socket with a slot to receive a pin which is mounted on one side of the tube base. The X-99 has exactly the same internal construction as the C-99 but it has a standard four prong base as shown at the left of Fig. 7 so that it can be installed in any standard four-prong socket.

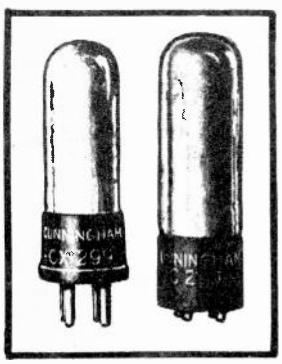

FIG.7
The -99 tubes.

FILAMENT:- A tungsten filament is used in the -99 tubes and it only draws a current of .063 ampere at an applied filament voltage of 3.3 volts. Three series connected #6 dry cells are generally employed for the "A" supply when wiring tubes of this type. Three dry cells connected in this manner will offer a voltage of 4.5 volts and this can be reduced to the required 3.3 volts by including a 30 to 60 ohm rheostat in the filament circuit.

OPERATION AS A DETECTOR:- To employ this tube as a detector, the grid return circuit should be connected to the positive side of the "A" battery and a grid condenser of .00025 mfd and a grid leak resistor of 3 megohms should be included in its grid circuit. The plate voltage should not exceed 45 volts.

One of the chief disadvantages of the -99 tube is that it is "microphonic." That is, any little vibration will cause its elements to vibrate also and thus cause a disagreeable howling noise to be emitted by the speaker. For this reason, it is advisable to mount the detector tube socket in soft rubber so as to absorb the vibration, thereby eliminating the tubes' tendency towards producing howls.

OPERATION AS AN AMPLIFIER:- The -99 tube can be used as an R.F. or A.F. amplifier and when the plate voltage does not exceed 67.5 volts, no "C" battery is required. The grid return circuit in this case, however, should be connected to the negative side of the "A" battery.

If a greater amplification is desired, then 90 volts can be applied to the plate and a "C" battery should be employed to impress a negative bias of 4.5 volts upon the grid of the tube. The amplification factor of the -99 is 6.6 and the normal plate current is 2.5 milliamperes.

THE TYPE - 01 A TUBE

THE TYPE -01A TUBE WAS FOR MANY YEARS A VERY POPULAR TUBE IN BATTERY OPERATED RECEIVERS, AS WELL AS BEING USED FOR A WHILE IN SOME OF THE EARLIER MODEL A.C. RECEIVERS. ITS CONSTRUCTION IS SUCH, THAT IT CAN BE USED AS A DETECTOR, R.F. AMPLIFIER, OR AS AN A.F. AMPLIFIER.

THIS TUBE IS ILLUSTRATED FOR YOU IN FIG. 8, AND AS YOU WILL OBSERVE, IT IS FITTED WITH A STANDARD FOUR PRONG BASE. THE GLASS BULB IS PEAR-SHAPED AND ITS INNER SURFACE IS COATED WITH A SILVER COLORED DEPOSIT WHICH MAKES IT DIFFICULT TO SEE THE ELEMENTS WITHIN THE TUBE. THIS DEPOSIT IS CAUSED BY A CHEMICAL (GENERALLY MAGNESIUM) WHICH IS FLASHED WITHIN THE TUBE AT THE TIME OF MANUFACTURE SO AS TO COMBINE WITH ANY REMAINING TRACES OF AIR AND THUS MAKE A MORE PERFECT VACUUM POSSIBLE.

FILAMENT:- A TUNGSTEN FILAMENT IS USED IN THE -01A AND IT IS DESIGNED TO BE OPERATED AT A VOLTAGE OF 5 VOLTS AND DRAWS .25 AMPERE OF CURRENT. A 6 VOLT STORAGE BATTERY IS GENERALLY USED FOR THE "A" SUPPLY IN CONJUNCTION WITH A RHEOSTAT.

OPERATION AS AN AMPLIFIER:- THE -01A MAY BE OPERATED AS AN AMPLIFIER WITH 90 VOLTS APPLIED TO THE PLATE AND A NEGATIVE GRID BIAS OF 4.5 VOLTS, DRAWING 2.5 MILLIAMPERES OF PLATE CURRENT. IT CAN ALSO BE OPERATED WITH 135 VOLTS APPLIED TO THE PLATE AND A NEGATIVE GRID BIAS OF 9 VOLTS, DRAWING 3 MILLIAMPERES OF PLATE CURRENT. IT HAS AN AMPLIFICATION FACTOR OF 8.

OPERATION AS A DETECTOR:- THE PLATE VOLTAGE MAY BE ANYWHERE FROM 22.5 TO 67.5 VOLTS BUT 45 VOLTS IS MOST GENERALLY USED. THE GRID CONDENSER SHOULD HAVE A CAPACITY RATING OF .00025 MFD. AND THE GRID LEAK A RATING OF 2 MEGOHMS.

FIG. 8
The - 01A

THE -00 A.

THE -00A WAS DESIGNED ESPECIALLY FOR USE AS A DETECTOR AND IT HAS PRACTICALLY DISAPPEARED FROM THE INDUSTRY. THE SPACE WITHIN THE GLASS BULB OF THE -00A IS NOT ONLY FREE FROM AIR BUT IN ADDITION, IT CONTAINS AN ALKALI VAPOR WHICH CAUSES A BLUE COLORED DEPOSIT TO FORM ON THE SIDE OF THE TUBE.

THE FILAMENT OF THIS TUBE IS IDENTICAL TO THAT OF THE -01A IN THAT IT REQUIRES THE SAME VOLTAGE AND DRAWS THE SAME CURRENT. THE PLATE VOLTAGE MAY BE VARIED BETWEEN 22.5 AND 45 VOLTS WHILE THE GRID CONDENSER SHOULD HAVE A RATING OF .00025 MFD. AND THE GRID LEAK A VALUE OF 2 MEGOHMS. THE AMPLIFICATION FACTOR OF THE -00A IS 20, WHICH IS CONSIDERABLY GREATER THAN THAT OF THE -01A. THE NORMAL PLATE CURRENT IS 1.5 MILLIAMPERES.

THE TYPE - 40 TUBE

THIS TUBE IS SHOWN YOU IN FIG. 10 AND IT WAS DESIGNED ESPECIALLY TO BE USED AS AN A.F. AMPLIFIER WHEN RESISTANCE-CAPACITY OR IMPEDANCE-CAPACITY INTER-STAGE COUPLING IS USED INSTEAD OF TRANSFORMERS. AS YET, YOU ARE NOT FAMILIAR WITH THESE CIRCUITS BUT THEY WILL ALL BE EXPLAINED TO YOU IN DETAIL A LITTLE LATER ON.

FOR THE PRESENT, SIMPLY REMEMBER THAT THE -40 TUBE WAS DESIGNED FOR THESE CIRCUITS IN PARTICULAR AND THAT IT HAS THE RELATIVELY HIGH AMPLIFICATION FACTOR OF 30.

FILAMENT:- ITS FILAMENT CONSTRUCTION IS IDENTICAL TO THAT OF THE -10A AND THEREFORE IT DRAWS $\frac{1}{4}$ AMPERE OF FILAMENT CURRENT AT 5 VOLTS.

FIG. 9
The -00A

OPERATION:- AS ALREADY MENTIONED, IT WILL ONLY FUNCTION SATISFACTORILY IN CIRCUITS DESIGNED ESPECIALLY FOR IT. A PLATE VOLTAGE OF 135 VOLTS MAY BE USED WITH A NEGATIVE GRID BIAS VOLTAGE OF 1.5 VOLTS. HOWEVER, IT IS ALSO PERMISSIBLE TO EMPLOY A PLATE VOLTAGE OF 180 VOLTS BUT UNDER THESE CONDITIONS, THE NEGATIVE GRID BIAS VOLTAGE SHOULD BE INCREASED TO A VALUE OF 3 VOLTS. THE NORMAL PLATE CURRENT IS .2 MILLIAMPERE.

SO FAR, WE HAVE INVESTIGATED THE OLDER BATTERY TYPE TUBES WHICH CAN BE USED AS DETECTORS, R.F. AMPLIFIERS OR A.F. AMPLIFIERS AND THIS BRINGS US UP TO ANOTHER GROUP OF TUBES WHICH WERE DESIGNED ESPECIALLY FOR USE IN THE LAST OR FINAL STAGE OF AUDIO FREQUENCY AMPLIFICATION, SO THAT A LOUDSPEAKER CAN BE OPERATED WITH CONSIDERABLE VOLUME. WE CLASSIFY TUBES OF THIS TYPE AS POWER AMPLIFIER TUBES AND SO NOW LET US STUDY THE OPERATING CHARACTERISTICS FOR THE VARIOUS TYPES OF POWER AMPLIFIER TUBES WHICH WERE USED IN THE EARLIER MODEL RECEIVERS.

THE TYPE-20 POWER AMPLIFIER

THE TYPE-20 POWER AMPLIFIER TUBE IS ILLUSTRATED FOR YOU IN FIG.11 AND AS YOU WILL OBSERVE, IT IS SIMILAR IN APPEARANCE TO THE -99. HOWEVER, IT IS SLIGHTLY TALLER THAN THE -99 AND DESIGNED ESPECIALLY FOR USE IN THE FINAL STAGE OF THE A.F. AMPLIFIER IN RECEIVERS EMPLOYING SEVERAL TUBES.

FILAMENT:- THE FILAMENT OF THE -20 IS QUITE LIKE THAT USED IN THE -99 WITH THE EXCEPTION THAT IT IS SOMEWHAT LONGER AND OF GREATER CROSS-SECTIONAL AREA. IT REQUIRES A FILAMENT VOLTAGE OF 3.3 VOLTS AND DRAWS A FILAMENT CURRENT OF .132 AMPERES. THIS TUBE IS INTENDED TO BE USED AS A POWER AMPLIFIER IN MULTI-TUBE RECEIVERS IN WHICH THE REST OF THE TUBES ARE OF THE -99 TYPE.

FIG. 10
The -40

PLATE AND GRID CIRCUIT REQUIREMENTS:- A PLATE VOLTAGE OF 135 VOLTS IS RECOMMENDED FOR THE -20 TUBE AND THE NEGATIVE GRID BIAS VOLTAGE SHOULD BE 22.5 VOLTS. IT HAS AN AMPLIFICATION FACTOR OF 3.3 AND DRAWS A NORMAL PLATE CURRENT OF 6.5 MILLIAMPERES.

POWER AMPLIFIER TUBES ARE ALSO RATED AS TO HOW MUCH SIGNAL POWER OR "OUTPUT" WHICH THEY ARE CAPABLE OF DELIVERING TO THE LOUD SPEAKER. THE UNIT OF ELECTRICAL POWER IS THE WATT BUT QUITE OFTEN, THE MILLIWATT IS USED TO EXPRESS THE POWER

OUTPUT OF AMPLIFIER TUBES. ONE MILLIWATT IS EQUAL TO THE ONE-THOUSANDTH PART OF ONE WATT. THE -20 TUBE, FOR EXAMPLE, WILL DELIVER AN OUTPUT OF 110 MILLIWATTS.

THE TYPE -12 A POWER AMPLIFIER

THIS TUBE IS DESIGNED TO BE USED AS THE POWER AMPLIFIER IN RECEIVERS EMPLOYING TYPE -01A TUBES IN THE OTHER STAGES. HOWEVER, IT CAN ALSO BE OPERATED AS A DETECTOR OR AS AN R. F. AMPLIFIER BUT ONLY UNDER SPECIAL CONDITIONS.

FILAMENT:- ITS FILAMENT IS SIMILAR BUT LARGER THAN THAT USED IN THE -01A TUBES AND ALSO DRAWS ¼ AMPERE AT 5 VOLTS.

OPERATION AS A DETECTOR:- IT WILL SERVE AS A DETECTOR IF A VOLTAGE OF 45 VOLTS BE APPLIED TO THE PLATE AND IF A GRID CONDENSER OF .00025 MFD. IS USED IN CONJUNCTION WITH A GRID LEAK RESISTOR OF 2 MEGOHMS.

OPERATION AS A RADIO FREQUENCY AMPLIFIER:- TO OPERATE FOR THIS PURPOSE, A PLATE VOLTAGE EXCEEDING 67½ VOLTS SHOULD NOT BE USED UNLESS A SUFFICIENT NEGATIVE "C" BIAS VOLTAGE IS EMPLOYED IN THE GRID CIRCUIT, OTHERWISE THE TUBE WILL DRAW TOO MUCH PLATE CURRENT.

FIG. 11
The type -20 tube.

OPERATION AS A POWER AMPLIFIER:- WHEN OPERATING THE TUBE FOR THIS PURPOSE, THE PLATE VOLTAGE MAY BE FROM 135 TO 180 VOLTS IN CONJUNCTION WITH A NEGATIVE GRID BIAS VOLTAGE OF 9 AND 13.5 VOLTS RESPECTIVELY. THE TUBE WILL THEN DRAW FROM 6.2 TO 7.6 MILLIAMPERES OF PLATE CURRENT AND WILL BE ABLE TO DELIVER FROM 115 TO 260 MILLIWATTS OF POWER TO THE SPEAKER. IT HAS AN AMPLIFICATION FACTOR OF 8.5.

THE TYPE-71A POWER AMPLIFIER

THIS TUBE IS DESIGNED ESPECIALLY TO BE USED AS A POWER AMPLIFIER BUT WILL DELIVER MORE SIGNAL POWER TO THE SPEAKER THAN A -12A TUBE. IT WILL NOT OPERATE SATISFACTORILY AS A DETECTOR OR INTERMEDIATE STAGE AMPLIFIER AND REQUIRES CONSIDERABLE SIGNAL ENERGY TO BE APPLIED TO ITS GRID. THAT IS, THE SIGNAL MUST ALREADY HAVE BEEN AMPLIFIED CONSIDERABLY IN PRECEDING STAGES BEFORE BEING APPLIED TO THE GRID OF THE -71A.

WHEN OPERATED IN A CIRCUIT OF PROPER DESIGN, THE -71A WILL OPERATE A LOUD SPEAKER AT CONSIDERABLE VOLUME.

FILAMENT:- THE FILAMENT OF THE -71A IS SIMILAR TO THAT USED IN THE -12A AND ALSO DRAWS ¼ AMPERE AT 5 VOLTS.

OPERATION:- DUE TO THE COMPARATIVELY LARGE PLATE CURRENT WHICH THIS TUBE DRAWS, IT IS PREFERABLE THAT IT DERIVE ITS PLATE VOLTAGE AND CURRENT FROM A "B" ELIMINATOR RATHER THAN FROM THE CONVENTIONAL "B" BATTERY. THE PLATE CURRENT DEMANDS OF THIS TUBE WILL DISCHARGE A "B" BATTERY IN A RELATIVELY SHORT TIME.

FIG. 12
The type -12A tube.

THE PLATE VOLTAGE AS APPLIED TO THIS TUBE MAY BE

FROM 90 TO 180 VOLTS. THE CORRESPONDING NEGATIVE GRID BIAS VOLTAGE AND PLATE CURRENT WILL THEN BE AS GIVEN IN THE FOLLOWING TABLE.

PLATE VOLTAGE	BIAS VOLTAGE	PLATE CURRENT
90	16.5	12 MILLIAMPERES
135	27.0	17.5 "
157.5	33.0	18 "
180	40.5	20 "

THE POWER OUTPUT DELIVERED BY THE TUBE WILL THEN RANGE FROM 125 TO 700 MILLIWATTS ACCORDING TO WHICH PLATE VOLTAGE AND GRID BIAS VOLTAGE COMBINATION IS USED. IN OTHER WORDS, THE HIGHER THE PLATE VOLTAGE, THE GREATER WILL BE THE OUTPUT POWER. THE -71A HAS AN AMPLIFICATION FACTOR OF 3.

MODERN BATTERY-TYPE TUBES

FIG.13
The -71 A Power amplifier tube.

ALL MODERN BATTERY-TYPE TUBES, WITH THE EXCEPTION OF THOSE DESIGNED ESPECIALLY FOR AUTOMOBILE RECEIVERS, ARE EQUIPPED WITH FILAMENTS REQUIRING A VOLTAGE OF 2 VOLTS, SO THAT ONLY TWO ORDINARY #6 DRY CELLS ARE REQUIRED FOR THE "A" SUPPLY. THESE NEW "TWO-VOLT" TUBES, AS THEY ARE GENERALLY CALLED, ARE VERY EFFICIENT AND DUE TO THEIR REASONABLE "A" AND "B" REQUIREMENTS, ARE ADAPTABLE TO PORTABLE RECEIVERS, AS WELL AS TO THE LARGER BATTERY-OPERATED CONSOLE RECEIVERS.

THESE NEW TWO-VOLT TUBES ARE DESCRIBED IN THE FOLLOWING PARAGRAPHS.

THE TYPE -30 TUBE

THIS TUBE IS DESIGNED TO SERVE AS A DETECTOR OR AS AN A.F. AMPLIFIER. IN GENERAL APPEARANCE, IT LOOKS SOMEWHAT LIKE THE -99 AND HAS A STANDARD FOUR-PRONG BASE.

FILAMENT:- THE FILAMENT IS DESIGNED TO OFFER LONG LIFE AND IS COATED WITH OXIDES WHICH WILL PROVIDE GOOD ELECTRON EMISSION AT THE LOW VOLTAGE AND CURRENT VALUES REQUIRED BY THE TUBE. THE FILAMENT VOLTAGE, AS ALREADY STATED, IS 2 VOLTS AND THE FILAMENT CURRENT DRAWN AMOUNTS TO ONLY .06 AMPERE (6/100 OF ONE AMPERE). TWO SERIES CONNECTED DRY CELLS WILL PROVIDE ON "A" VOLTAGE OF 3 VOLTS BUT THIS CAN BE REDUCED TO THE REQUIRED 2 VOLTS BY INSTALLING A RHEOSTAT IN THE FILAMENT CIRCUIT.

OPERATION AS A DETECTOR:- THIS TUBE WILL OPERATE EFFICIENTLY EITHER AS A GRID CONDENSER AND LEAK TYPE DETECTOR OR AS A POWER DETECTOR (POWER DETECTION WILL BE EXPLAINED TO YOU IN A LATER LESSON). FOR GRID CONDENSER AND LEAK TYPE DETECTION, THE GRID CONDENSER SHOULD HAVE A VALUE OF .00025 MFD. AND THE GRID LEAK CONDENSER, A VALUE OF 2 TO 5 MEGOHMS. THE GRID RETURN CIRCUIT SHOULD IN THIS CASE BE CONNECTED TO THE POSITIVE SIDE OF THE "A" BATTERY, AND A PLATE VOLTAGE OF 45 VOLTS SHOULD BE USED.

FOR OPERATION AS A POWER DETECTOR, THE PLATE VOLTAGE SHOULD BE 135 VOLTS IN CONJUNCTION WITH A NEGATIVE GRID BIAS VOLTAGE OF 7.5 VOLTS.

OPERATION AS AN AMPLIFIER:- TO OPERATE THE -30 TUBE AS AN AMPLIFIER, USE A PLATE VOLTAGE OF 90 VOLTS AND A NEGATIVE GRID BIAS VOLTAGE OF 4.5 VOLTS. UNDER THESE CONDITIONS THE TUBE WILL DRAW A NORMAL PLATE CURRENT OF 1.8 MILLIAMPERES AND ITS AMPLIFICATION FACTOR WILL BE 9.3.

THE TYPE 31 POWER TUBE

THE -31 IS A "TWO-VOLT" POWER AMPLIFIER TUBE WHICH IS DESIGNED ESPECIALLY FOR MULTI-TUBE RECEIVERS EMPLOYING "TWO-VOLT" TUBES IN ALL STAGES.

FILAMENT:- THE FILAMENT OF THE -31 IS SIMILAR TO THAT OF THE -30 AND ALSO REQUIRES 2 VOLTS FOR OPERATION BUT IT DRAWS MORE CURRENT. THE CURRENT DRAWN BY THE FILAMENT OF THE -31 IS EQUAL TO .13 AMPERES.

OPERATION:- A PLATE VOLTAGE OF 135 VOLTS AND NEGATIVE GRID BIAS VOLTAGE OF $22\frac{1}{2}$ VOLTS IS RECOMMENDED FOR THIS TUBE. IT WILL DRAW A NORMAL PLATE CURRENT OF 6.8 MILLIAMPERES, IT HAS AN AMPLIFICATION FACTOR OF 3.8 AND WILL DELIVER A POWER OUTPUT OF 150 MILLIWATTS.

FIG. 14
The Type 30

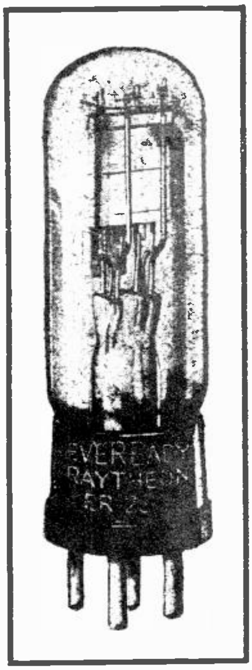

FIG. 15
The Type 31

OTHER TYPES OF TUBES

BESIDES THE TUBE TYPES DESCRIBED TO YOU IN THIS LESSON, WE ALSO HAVE THE SCREEN-GRID AND POWER-PENTODE BATTERY-OPERATED TYPES. THESE TUBES, HOWEVER, REQUIRE CIRCUITS WHICH ARE RATHER COMPLEX FOR YOU TO HANDLE AT THIS EARLY STAGE OF YOUR TRAINING. FIRST, YOU WILL BE SHOWN HOW THESE "TRIODES" ARE EMPLOYED IN RECEIVER CIRCUITS AND THEN A LITTLE LATER ON, WE WILL GO INTO SCREEN-GRID AND PENTODE CIRCUITS, ETC. THE SPECIFICATION FOR THE CORRESPONDING TUBES WILL THEN BE GIVEN.

IT IS NOT NECESSARY FOR YOU TO MEMORIZE ALL OF THE VARIOUS TUBE VOLTAGES, CURRENT VALUES, ETC., AS GIVEN IN THIS LESSON. YOU CAN ALWAYS REFER TO SUCH DATA IN YOUR LESSONS AND JOB SHEET TUBE CHARTS WHENEVER NECESSARY. AT PRESENT, WE ARE ONLY INTERESTED IN YOUR KNOWING SUCH DATA EXISTS, THAT YOU APPRECIATE ITS IMPORTANCE AND THAT YOU WILL BECOME SOMEWHAT ACQUAINTED WITH BATTERY TYPE TRIODES.

THE NEXT THING WILL BE TO USE THE TUBES EXPLAINED IN THIS LESSON IN THE PROPER CIRCUITS, SO THAT ALL OF THEIR SPECIFICATIONS WILL BE FULFILLED AND THEREBY ASSURE SATISFACTORY RECEIVER PERFORMANCE. YOUR FOLLOWING LESSONS ARE GOING TO SHOW YOU HOW THIS IS DONE.

RADIO - TELEVISION

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LESSON NO. 7

OHM'S LAW AND ITS APPLICATION TO RADIO CIRCUITS

When working with radio or television circuits it is frequently necessary to determine what value of resistor to use so that the voltage of a given source of E.M.F. may be reduced in order to meet the requirements of a particular circuit. It is the purpose of this lesson to show you how to solve basic problems of this type.

Before proceeding with the study of this lesson, however, it is advisable that you first review Lesson #3 so as to be absolutely certain that you have a clear understanding of voltage, current flow and resistance. This review will help you greatly in acquiring a clear understanding of the subject which you are now about to study.

THE STANDARD CELL

The VOLT, as you already know, is the unit of electromotive force and its value has more or less been arbitrarily fixed in much the same manner as the inch has been chosen as the unit of measurement.

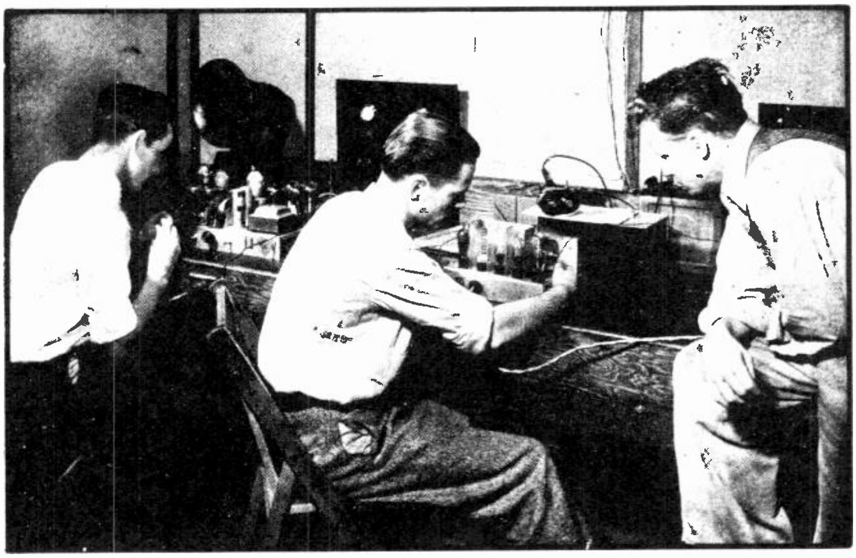


Fig. 1
Students Servicing Receivers In One Of Nationals' Sound-Proof Test Rooms.

The Bureau of Standards, as well as many laboratories and factories where electrical instruments are manufactured, use a

SPECIAL CELL WHICH FURNISHES AN EXACT VOLTAGE, WHOSE VALUE HAS BEEN APPROVED THROUGHOUT THE WORLD AS BEING SATISFACTORY TO SERVE AS A STANDARD FOR COMPARISON. THESE STANDARD CELLS, AS THEY ARE CALLED, ARE KEPT IN PERFECT CONDITION AND HANDLED WITH EXTRAORDINARY PRECAUTION SO AS TO PREVENT ANY VARIATION IN THEIR VOLTAGE AND THEIR USE IS CONFINED TO CALIBRATE THE SCALES OF PRECISION TYPE VOLTMETERS AND OTHER EXACTING WORK OF THIS NATURE.

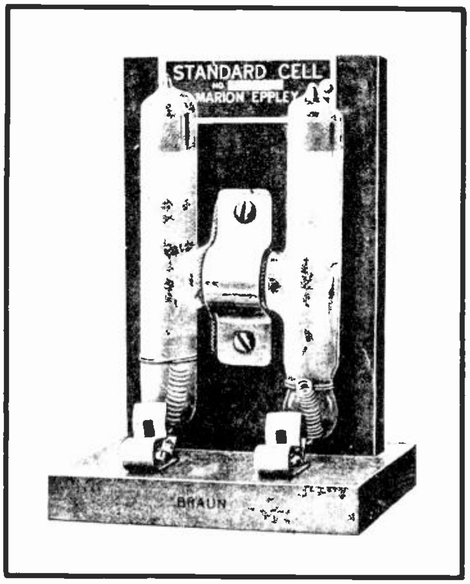


FIG. 2
A STANDARD CELL

ONE OF THESE STANDARD CELLS IS SHOWN IN FIG. 2, WHEREAS ITS INTERNAL CONSTRUCTION IS ILLUSTRATED IN DETAIL IN FIG. 3. QUITE OFTEN THESE CELLS ARE HOUSED WITHIN A CASE SO AS TO PROTECT THEM AGAINST MECHANICAL INJURY, AS WELL AS ABRUPT TEMPERATURE VARIATIONS.

THE "WESTON" STANDARD CELL, WHICH IS BEING EXTENSIVELY USED AT THE PRESENT TIME, MAINTAINS A CONSTANT VOLTAGE OF 1.0183 VOLTS AT ORDINARY TEMPERATURES AND DOES NOT VARY AFTER BEING IN SERVICE FOR SEVERAL YEARS, PROVIDED IT IS NOT REQUIRED TO FURNISH A CURRENT FLOW EXCEEDING .0001 AMPERES.

BESIDES THE VOLT, WE ALSO EMPLOY THE MILLIVOLT AND THE MICROVOLT, AS UNITS FOR MEASURING VERY SMALL VOLTAGES AND THE KILOVOLT FOR MEASURING VERY LARGE VOLTAGES. THE "MILLIVOLT" IS EQUIVALENT TO .001 VOLT (THE ONE-THOUSANDTH PART OF A VOLT) WHILE THE "MICROVOLT" IS EQUIVALENT TO .000001 VOLT (THE ONE-MILLIONTH PART OF A VOLT). THE "KILOVOLT" IS EQUIVALENT TO ONE THOUSAND VOLTS.

THE STANDARD OHM

WE ALSO HAVE A STANDARD UNIT, THE OHM, FOR MEASURING ELECTRICAL RESISTANCE AND ONE OHM IS EQUIVALENT TO THE ELECTRICAL RESISTANCE OR OPPOSITION WHICH IS OFFERED BY A COLUMN OF MERCURY WHICH IS 106.3 CENTIMETERS LONG AND HAVING A CROSS-SECTIONAL AREA OF 1 SQUARE MILLIMETER. (ONE CENTIMETER IS EQUAL TO APPROXIMATELY 0.4" AND ONE MILLIMETER IS EQUAL TO 0.04".)

WHEN REFERRING TO VERY SMALL RESISTANCE VALUES, WE EMPLOY THE MICRO-OHM AS THE UNIT FOR MEASUREMENT AND THE MICRO-OHM IS

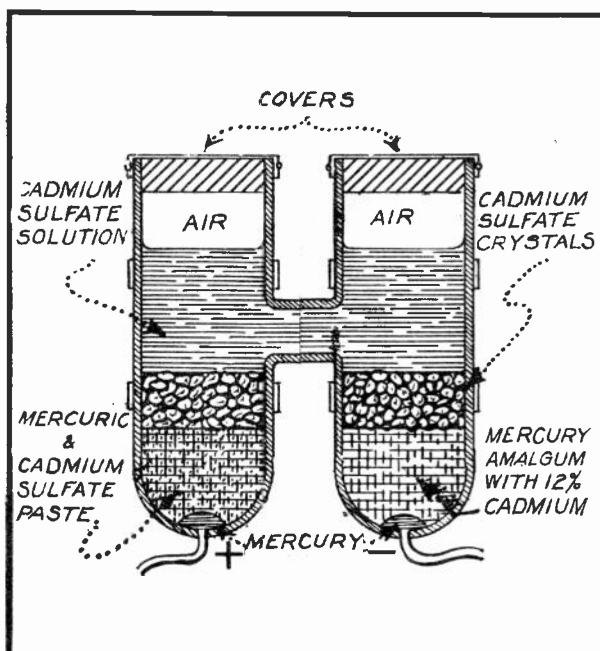


FIG. 3
CONSTRUCTION OF THE STANDARD CELL.

EQUIVALENT TO THE ONE MILLIONTH PART OF AN OHM. THE MEGOHM IS USED AS THE UNIT OF MEASUREMENT FOR VERY HIGH RESISTANCE VALUES AND IT IS EQUIVALENT TO ONE MILLION OHMS.

THE AMPERE

WE GENERALLY MEASURE THE FLOW OF WATER THROUGH A SYSTEM OF PIPES IN TERMS OF GALLONS PER SECOND OR GALLONS PER MINUTE, WHERE THE "GALLON" IS USED AS THE UNIT WHICH DESIGNATES THE QUANTITY OF WATER, AND THE SECOND OR MINUTE AS THE TIME UNIT.

THE QUANTITY OF WATER WHICH PASSES ANY GIVEN POINT IN THE PIPE SYSTEM PER UNIT TIME DESIGNATES THE RATE OF FLOW. THUS WE CAN SAY THAT WATER FLOWS THROUGH A CERTAIN SYSTEM AT THE RATE OF 50 GALLONS PER SECOND, 3000 GALLONS PER MINUTE, ETC.

FROM YOUR PREVIOUS STUDY OF THE ELECTRON THEORY YOU LEARNED THAT A FLOW OF ELECTRICITY, OR AN ELECTRIC CURRENT, IS IN REALITY A FLOW OR DRIFT OF ELECTRONS. YOU ALSO LEARNED AT THAT TIME THAT THE ELECTRON IS A NEGATIVE ELECTRICAL CHARGE AND A DEFINITE PART OF ALL MATTER IN EXISTENCE. IT IS ALSO TRUE THAT THE ELECTRON HAS WEIGHT, ALTHOUGH INCONCEIVABLY SMALL, AND IT CAN THEREFORE BE CONSIDERED AS REPRESENTING A DEFINITE QUANTITY OF MATTER.

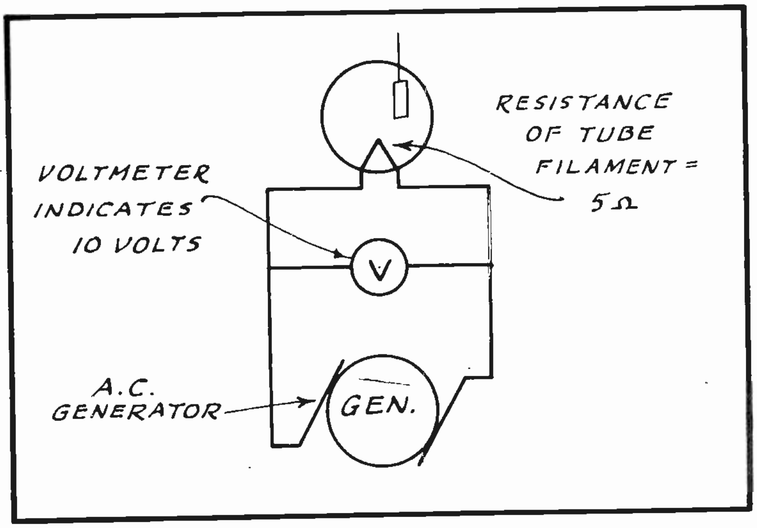


FIG. 4
DETERMINING CURRENT FLOW.

SINCE THE ELECTRON REPRESENTS SUCH AN EXCEEDINGLY SMALL QUANTITY OF MATTER IT IS NOT PRACTICAL TO SPEAK OF CURRENT FLOW IN TERMS OF A CERTAIN NUMBER OF ELECTRONS FLOWING THROUGH A CIRCUIT DURING A GIVEN INTERVAL OF TIME. FOR THIS REASON A LARGER UNIT, THE COULOMB, HAS BEEN SELECTED TO REPRESENT 6,280,000,000,000,000,000 ELECTRONS, AND A CURRENT FLOW OF ONE COULOMB PER SECOND HAS BEEN CALLED

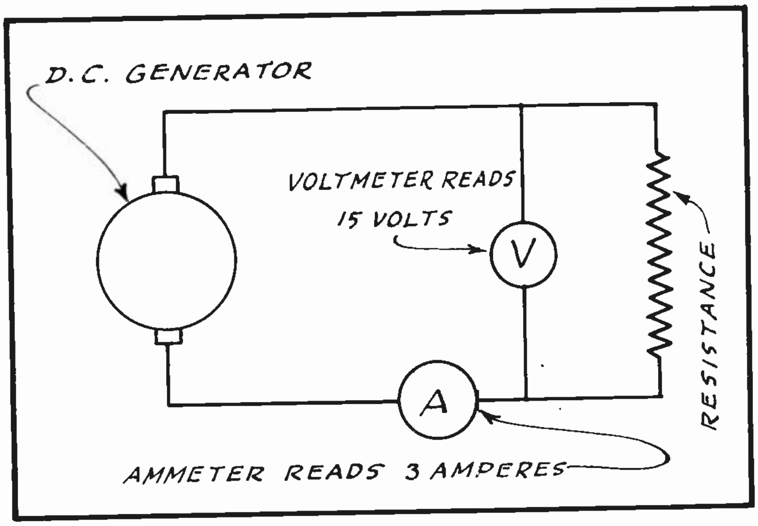


FIG. 5
CALCULATING THE RESISTANCE.

THE AMPERE. IT SHOULD BE NOTED IN PARTICULAR THAT THE TERM "AMPERE" IS INDICATIVE OF BOTH THE QUANTITY OF ELECTRICITY AND THE TIME INTERVAL OF ONE SECOND.

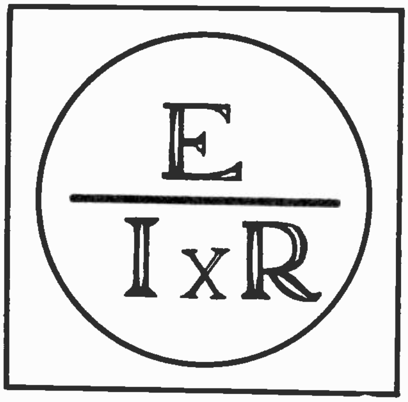


FIG. 6
THE "MEMORANDUM" FORMULA.

FROM THE EXPLANATION JUST GIVEN IT IS SEEN THAT WHERE WE SPEAK OF HYDRAULIC CURRENT FLOW IN TERMS OF GALLONS PER SECOND, WE REFER TO THE ELECTRICAL CURRENT FLOW THROUGH A CIRCUIT IN TERMS OF AMPERES (COULOMBS PER SECOND).

IT IS OF SPECIAL IMPORTANCE THAT YOU UNDERSTAND CLEARLY THAT THE VOLT, AMPERE AND OHM ARE THREE INDIVIDUAL UNITS OF ELECTRICAL MEASUREMENT AND THAT EACH REPRESENTS AN ENTIRELY DIFFERENT VALUE. THERE IS, HOWEVER, A DEFINITE MATHEMATICAL RELATION BETWEEN THESE THREE VALUES -- THIS RELATION IS KNOWN AS OHM'S LAW, IN HONOR OF THE SCIENTIST, DR. GEORGE SIMON OHM, WHO IS CREDITED WITH ITS DISCOVERY.

OHM'S LAW CAN BE STATED AS FOLLOWS: "AN ELECTROMOTIVE FORCE OF ONE VOLT IS CAPABLE OF CAUSING A CURRENT OF ONE AMPERE TO FLOW THROUGH A COMPLETE CIRCUIT WHICH HAS A RESISTANCE OF ONE OHM." THIS LAW IS A VERY VALUABLE TOOL IN RADIO AS WELL AS IN THE ENTIRE ELECTRICAL INDUSTRY BECAUSE IT ENABLES ONE TO CALCULATE EITHER THE VOLTAGE, CURRENT OR RESISTANCE OF ANY CIRCUIT IN TERMS OF THE OTHER TWO FACTORS.

OUR NEXT STEP WILL BE TO DEMONSTRATE THE APPLICATION OF OHM'S LAW TO PRACTICAL RADIO PROBLEMS.

CALCULATING THE CURRENT

TO CALCULATE THE CURRENT WHICH IS FLOWING THRU ANY GIVEN CIRCUIT WE APPLY OHM'S LAW IN THE FOLLOWING MANNER: "THE CURRENT FLOW THROUGH THE CIRCUIT IS EQUAL TO THE VOLTAGE DIVIDED BY THE RESISTANCE". EXPRESSED AS A FORMULA, THIS WOULD BE:

$$\text{CURRENT} = \frac{\text{VOLTAGE}}{\text{RESISTANCE}} \quad \text{OR} \quad I = \frac{E}{R}$$

WHERE "I" STANDS FOR CURRENT, "E" FOR ELECTROMOTIVE FORCE AND "R" FOR RESISTANCE.

LET US APPLY THIS FORMULA TO THE PROBLEM WHICH IS ILLUSTRATED IN FIG.4. HERE WE HAVE THE FILAMENT CIRCUIT OF A TRANSMITTER RECTIFIER TUBE IN WHICH THE RE-

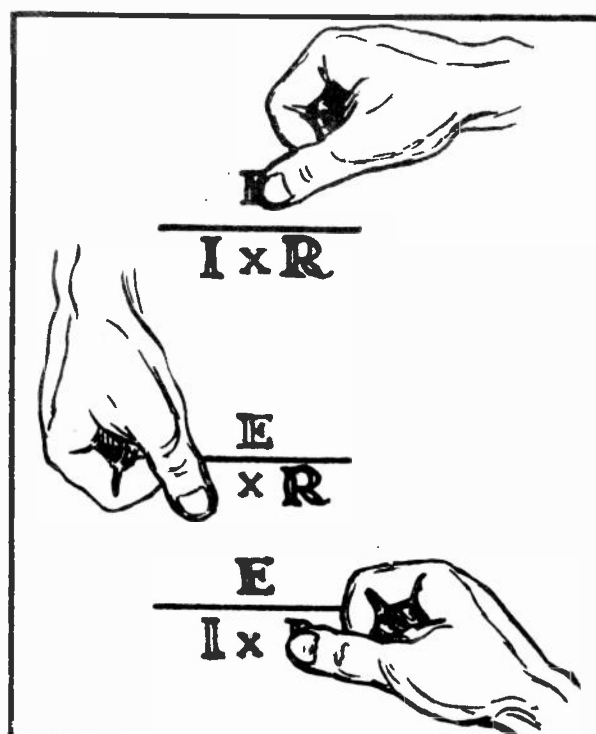


FIG. 7
USING THE MEMORANDUM FORMULA.

SISTANCE OF THE TUBE FILAMENT IS KNOWN TO BE 5 OHMS AND A VOLTMETER, WHICH IS CONNECTED ACROSS THE TUBE FILAMENT OFFERS A READING OF 10 VOLTS, THEREBY SHOWING THAT A VOLTAGE OF 10 VOLTS IS IMPRESSED DIRECTLY ACROSS THE FILAMENT TERMINALS OF THE TUBE.

THE PROBLEM NOW IS TO CALCULATE HOW MUCH CURRENT IS FLOWING THRU THE FILAMENT AND TO DETERMINE THIS, WE USE OUR FORMULA, $I = \frac{E}{R}$. SUBSTITUTING THE VALUE OF 10 VOLTS FOR "E" AND 5 OHMS FOR "R", WE THEN HAVE $I = \frac{E}{R} = \frac{10}{5} =$ 2 AMPERES. IN OTHER WORDS, A CURRENT OF 2 AMPERES IS FLOWING THROUGH THE FILAMENT OF THIS TUBE.

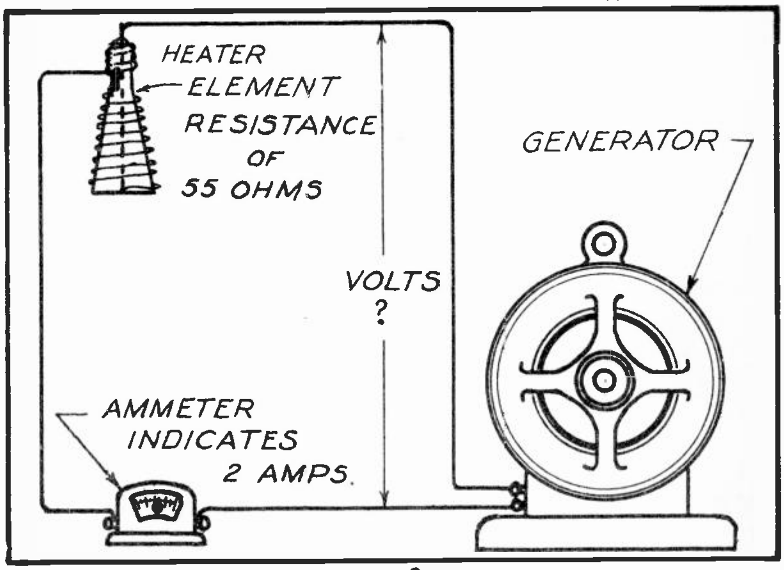


FIG. 8
THE HEATER CIRCUIT.

IT IS CUSTOMARY TO ABBREVIATE THE TERM AMPERE AS "AMP". AND AMPERES AS "AMPS". IT IS ALSO CONVENTIONAL TO EMPLOY THE SYMBOL (Ω) TO INDICATE OHMS, AS POINTED OUT IN FIG. 4.

CALCULATING THE RESISTANCE

IF YOU DESIRE TO CALCULATE THE RESISTANCE OF ANY PART OF A CIRCUIT, THEN APPLY OHM'S LAW IN THE FORM: "RESISTANCE IS EQUAL TO THE VOLTAGE DIVIDED BY THE CURRENT". THE FORMULA FOR THIS THEN, WOULD BE: RESISTANCE = $\frac{\text{VOLTAGE}}{\text{CURRENT}}$ OR $R = \frac{E}{I}$.

IN FIG. 5 IS SHOWN CIRCUIT IN WHICH A VOLTMETER IS CONNECTED ACROSS THE CIRCUIT IN SUCH MANNER AS TO SHOW THAT AN E.M.F. OF 15 VOLTS IS IMPRESSED ACROSS THE EXTREMITIES OF THE RESISTANCE. THE AMMETER INDICATES THAT A CURRENT OF 3 AMPERES FLOWS THROUGH THE CIRCUIT. THE PROBLEM IS TO DETERMINE THE VALUE OF THE RESISTANCE HERE SHOWN.

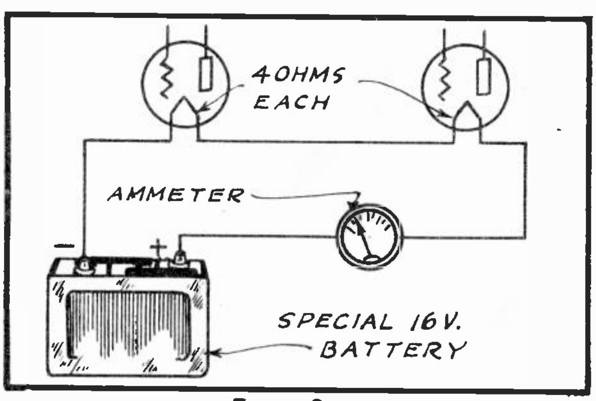


FIG. 9
THE SERIES CIRCUIT.

FROM THE FACTS ALREADY GIVEN WE KNOW THAT TERM E OF THE OHM'S LAW FORMULA IN THIS CASE HAS A VALUE OF 15 VOLTS AND I A VALUE OF 3 AMPERES. SUBSTITUTING THESE

VALUES IN THE FORMULA $R = \frac{E}{I}$ WE HAVE: $R = \frac{15}{3} = 5$ OHMS. THUS WE HAVE DETERMINED THAT THE RESISTANCE OF THE CIRCUIT ILLUSTRATED IN FIG. 5 HAS A VALUE OF 5 OHMS.

CALCULATING THE VOLTAGE

IN ORDER TO CALCULATE THE VOLTAGE WHICH IS APPLIED ACROSS A GIVEN CIRCUIT IN TERMS OF THE CIRCUITS' RESISTANCE AND THE CURRENT WHICH IS FLOWING THRU IT, WE USE OHMS' LAW IN THE FORM: "VOLTAGE IS EQUAL TO THE RESISTANCE OF THE CIRCUIT MULTIPLIED BY THE CURRENT WHICH IS FLOWING THROUGH IT". THAT IS, VOLTAGE = CURRENT x RESISTANCE OR $E = I \times R$.

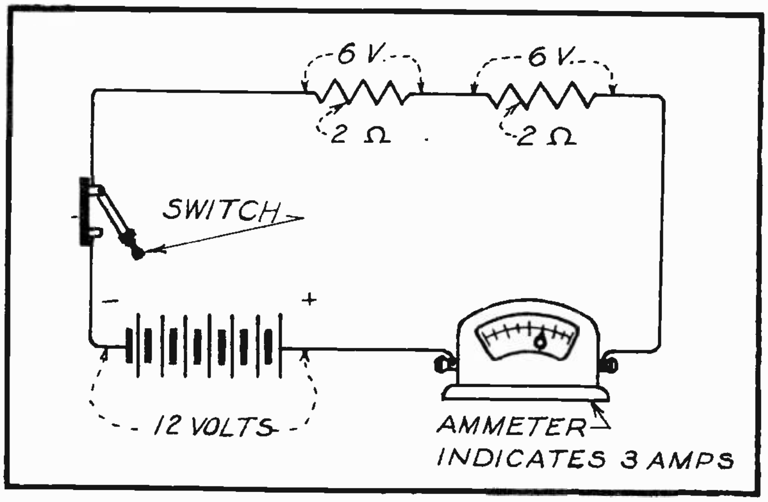


FIG. 10
VOLTAGE DISTRIBUTION IN SERIES CIRCUITS.

TO ILLUSTRATE THE APPLICATION OF OHM'S LAW IN THIS FORM, LET US CONSIDER THE FOLLOWING PROBLEM: THE FILAMENT OF A CERTAIN RADIO TUBE HAS A RESISTANCE OF 30 OHMS AND A CURRENT OF 1 AMPERE IS REQUIRED TO FLOW THROUGH IT IN ORDER TO PROVIDE SUFFICIENT ELECTRON EMISSION. WHAT VOLTAGE MUST BE APPLIED THE FILAMENT? TO DETERMINE THIS VOLTAGE, SUBSTITUTE THE VALUE OF 30 OHMS FOR "R" AND 1 AMPERE FOR "I" IN THE FORMULA $E = I \times R$. HENCE $E = 1 \times 30 = 30$ VOLTS.

AN EASY WAY TO REMEMBER OHM'S LAW

SHOULD YOU FIND IT SOMEWHAT DIFFICULT TO REMEMBER THE DIFFERENT FORMS IN WHICH OHM'S LAW MAY BE APPLIED, YOU WILL FIND THE SUGGESTIONS WHICH ARE OFFERED IN FIGS. 6 AND 7 TO BE SOMEWHAT HELPFUL. IN FIG. 6 WE HAVE THE EXPRESSION $\frac{E}{I \times R}$ ENCLOSED IN THE CIRCLE. THEN IF YOU WISH TO FIND "E" IN TERMS OF THE OTHER TWO VALUES, SIMPLY COVER UP THE "E" ILLUSTRATED AT THE TOP OF FIG. 7. AND YOU HAVE LEFT THE PORTION $I \times R$, WHICH MEANS THAT $E = I \times R$. SHOULD YOU WANT TO FIND "I" IN TERMS OF "E" AND "R", THEN COVER UP THE "I" AS IN THE CENTER OF FIG. 7 AND YOU WILL FIND THAT $I = \frac{E}{R}$. FINALLY, IF "R" IS THE VALUE SOUGHT, THEN COVER IT AND YOU HAVE $R = \frac{E}{I}$.

STILL FURTHER TO ASSIST YOU IN THE TASK OF LEARNING TO APPLY OHM'S LAW CORRECTLY TO BASIC PROBLEMS, THE FOLLOWING EXAMPLES ARE GIVEN:

<u>EXAMPLE #1:</u> THE FILAMENT OF A CERTAIN INCANDESCENT LAMP DRAWS A CURRENT OF 2 AMPERES WHEN CONNECTED ACROSS A CIRCUIT TO WHICH AN E.M.F. OF 100 VOLTS IS APPLIED. WHAT IS THE RE-

SISTANCE OF THE LAMP FILAMENT?

SOLUTION: To solve this problem we use the formula $R = \frac{E}{I}$ wherein $E = 100$ and $I = 2$. We thus obtain $R = \frac{100}{2} = 50$ ohms. That is to say, the lamp filament in question has a resistance of 50 ohms.

EXAMPLE #2: What current is produced if 300 volts is applied across the extremeties of a resistance having a value of 60 ohms?

SOLUTION: In this problem E has a value of 300 volts and R a value of 60 ohms. Substituting these values in the formula as follows: $I = \frac{E}{R}$ we have $I = \frac{300}{60} = 5$ amperes (answer).

EXAMPLE #3: In the circuit illustrated in Fig.8 the heater element has a resistance of 55 ohms and the ammeter shows that a current of 2 amperes is flowing through the resistance. What voltage is produced by the generator?

SOLUTION: To determine the voltage required to force a current of 2 amperes through this resistance of 55 ohms, we proceed as follows: $E = I \times R$, in which case $I = 2$ amps. and $R = 55$ ohms. Hence $E = 2 \times 55 = 110$ volts (answer). This means that the generator is impressing 110 volts across this circuit.

SERIES CIRCUITS

Any circuit, in which all of its parts or sections are connected in series or one after the other, is classified as a SERIES CIRCUIT. For instance, in Fig. 9 we have the filament of two tubes connected in the circuit in such a manner that the same current must flow thru all parts of the circuit. In other words, there is only one path for the current to follow from the (+) battery terminal in order to flow through the circuit and return to the (-) battery terminal, and the tube filaments are said to be connected in series.

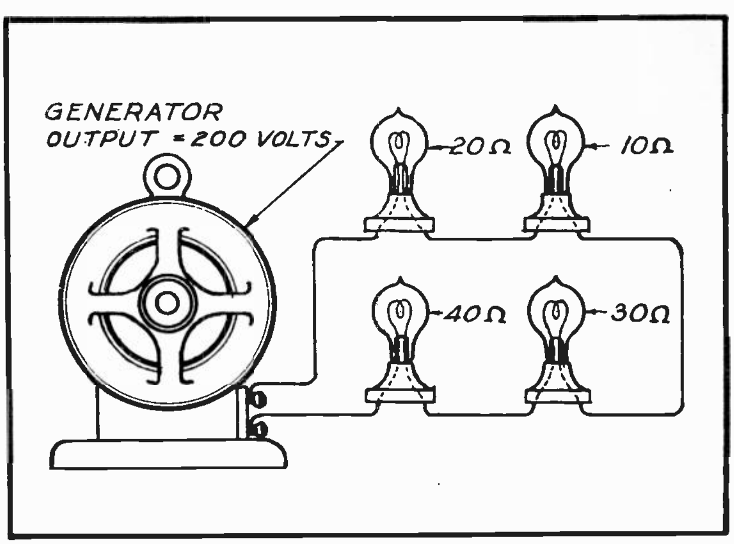


Fig. 11
Determining Current Flow In Series Circuits.

No matter at which point the circuit should be interrupted or opened, all current would immediately stop flowing and all parts of the circuit

WOULD BE "DEAD". THAT IS, EACH PART OF THE CIRCUIT IS DEPENDENT UPON THE SATISFACTORY OPERATION OF ALL THE OTHER PARTS OF THE CIRCUIT.

IN SERIES CIRCUITS, WE APPLY OHM'S LAW IN A SLIGHTLY DIFFERENT MANNER THAN IN OUR PREVIOUS EXAMPLES. FIG. 9 WILL SERVE TO DEMONSTRATE THE USE OF OHM'S LAW IN SERIES CIRCUITS.

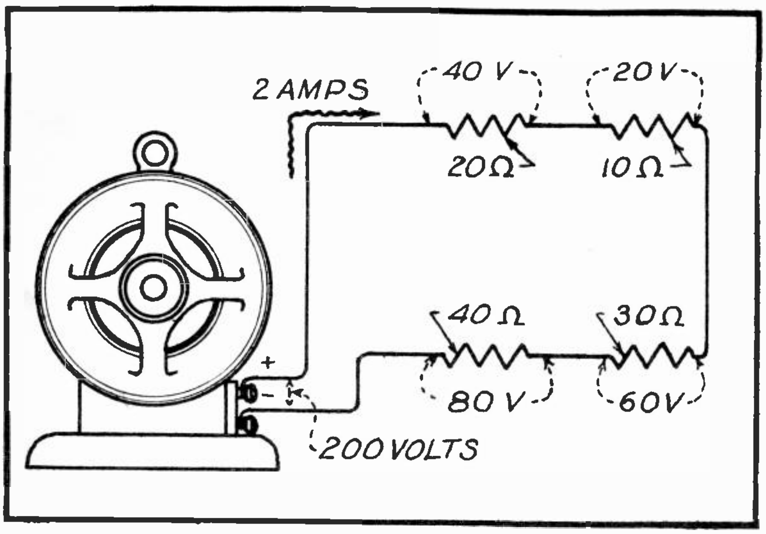


FIG. 12
DIAGRAM OF THE SERIES CIRCUIT.

IN FIG. 9 IT IS DESIRED TO CALCULATE THE CURRENT WHICH IS FLOWING THROUGH THE SERIES CIRCUIT. TO DO THIS, WE MUST FIRST DETERMINE THE TOTAL RESISTANCE OF THE CIRCUIT. IN ALL SERIES CIRCUITS THE TOTAL RESISTANCE IS EQUAL TO THE SUM OF THE INDIVIDUAL RESISTANCE VALUES WHICH ARE INCLUDED IN THE SERIES. FOR EXAMPLE, IN THE CASE OF FIG. 9 WE HAVE THE TWO FILAMENT RESISTANCES OF 4 OHMS EACH CONNECTED IN SERIES -- THIS MEANS THAT THE TOTAL RESISTANCE OF THE CIRCUIT WILL BE EQUAL TO 4 OHMS PLUS 4 OHMS OR 8 OHMS.

WITH THE TOTAL RESISTANCE THUS DETERMINED, WE CAN CALCULATE THE CURRENT WHICH IS FLOWING THROUGH THE CIRCUIT BY USING THE FORMULA AS FOLLOWS: $I = \frac{E}{R}$ AND IN WHICH CASE E = 16 VOLTS AND R = 8 OHMS. THUS $I = \frac{16}{8} = 2$ AMPS. THIS SAME CURRENT OF 2 AMPS WILL FLOW THROUGH ALL PARTS OF THE CIRCUIT.

VOLTAGE DISTRIBUTION IN SERIES CIRCUITS

THE NEXT POINT FOR YOUR CONSIDERATION IS THE MANNER IN WHICH THE VOLTAGE IS DISTRIBUTED THROUGHOUT A SERIES CIRCUIT. IN FIG. 10, FOR INSTANCE, WE HAVE TWO 2-OHM RESISTORS CONNECTED IN SERIES WITH A 12 VOLT BATTERY, A SWITCH, AND AN AMMETER. THE AMMETER INDICATES THAT A CURRENT OF 3 AMPERES FLOWS THROUGH THE CIRCUIT. (NOTE HOW RESISTANCE IS ILLUSTRATED IN DIAGRAM FORM).

SINCE THIS CURRENT OF 3 AMPERES MUST FLOW THROUGH BOTH OF

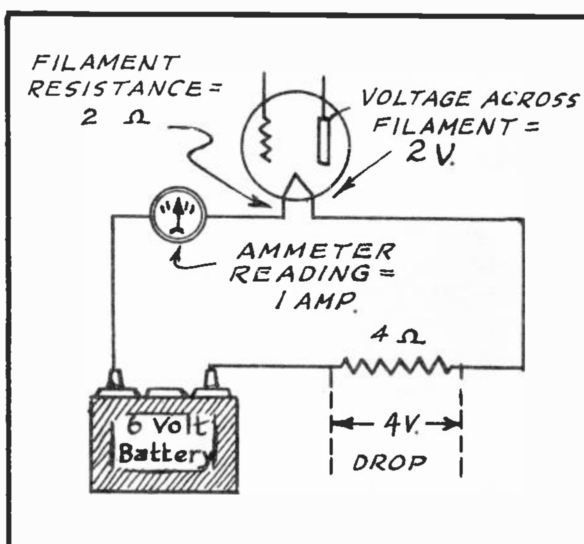


FIG. 13
THE FILAMENT CIRCUIT.

THESE 2-OHM RESISTORS, THE VOLTAGE WHICH IS EFFECTIVE ACROSS EACH OF THE 2-OHM RESISTORS CAN BE FOUND BY USING THE FORMULA $E = I \times R$, WHERE I IS 3 AMPS AND R IS 2 OHMS. HENCE $E = I \times R = 6V\ 3 \times 2 = 6$ VOLTS. IN OTHER WORDS, IF WE SHOULD MEASURE THE VOLTAGE ACROSS THE ENDS OF EACH 2-OHM RESISTOR WITH A VOLTMETER, THE INSTRUMENT WOULD INDICATE 6 VOLTS.

THE VOLTAGE NECESSARY TO FORCE THE CURRENT THROUGH EACH RESISTOR IS CALLED THE VOLTAGE DROP, BECAUSE THIS VOLTAGE WILL BE LTTERALLY SUBTRACTED FROM THE TOTAL CIRCUIT VOLTAGE. IN OTHER WORDS, WE HAVE A VOLTAGE DROP OF 6 VOLTS ACROSS THE FIRST RESISTOR SO THAT A VOLTAGE OF ONLY 12 MINUS 6, OR 6 VOLTS, IS AVAILABLE ACROSS THE SECOND RESISTOR.

IT IS ALSO IMPORTANT TO NOTICE THAT THE SUM OF THE VARIOUS VOLTAGE DROPS IN A SERIES CIRCUIT IS EQUAL TO THE TOTAL VOLTAGE APPLIED ACROSS THE CIRCUIT BY THE SOURCE OF E.M.F. THAT IS TO SAY, IN THE EXAMPLE ILLUSTRATED IN FIG. 10, THE SUM OF THE VOLTAGE DROPS IS 6 VOLTS PLUS 6 VOLTS, OR 12 VOLTS, WHICH IS EQUAL TO THE VOLTAGE OF THE BATTERY, THE SOURCE OF E.M.F. THE CURRENT FLOW AT EACH POINT IN A SERIES CIRCUIT IS THE SAME, HOWEVER, OR 3 AMPS. IN THE CASE OF FIG. 10.

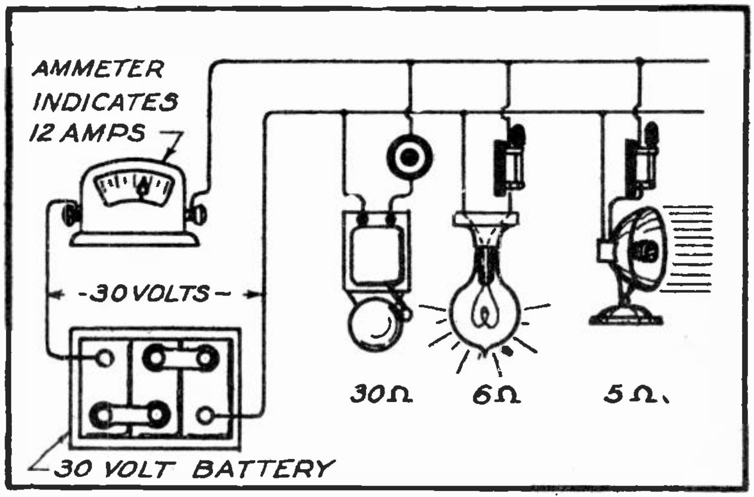


FIG. 14
A PARALLEL ELECTRICAL CIRCUIT.

CURRENT CALCULATION IN SERIES CIRCUITS

IN FIG. 11 WE HAVE ANOTHER CIRCUIT, CONSISTING OF FOUR LAMPS CONNECTED IN SERIES, AND THE ENTIRE SERIES ARRANGEMENT IS CONNECTED ACROSS THE TERMINALS OF A GENERATOR. THE LAMP FILAMENTS IN THIS CIRCUIT HAVE RESISTANCE VALUES OF 20; 10; 30 AND 40 OHMS RESPECTIVELY, AND THE GENERATOR IS SUPPLYING AN E.M.F. OF 200 VOLTS.

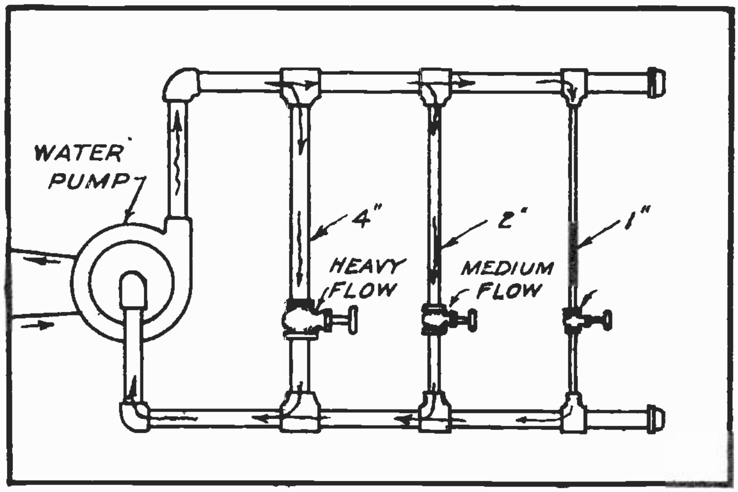


FIG. 15
A PARALLEL WATER CIRCUIT.

THE PROBLEM IS FIRST TO CALCULATE THE CURRENT FLOW THRU THIS CIRCUIT. TO DO THIS, WE FIRST DETERMINE THE TOTAL RESISTANCE OF THE CIRCUIT BY ADDING TOGETHER THE VARIOUS RESISTANCES INCLUDED IN

THE CIRCUIT, WHICH IN THIS CASE AMOUNTS TO 20 + 10 + 30 + 40 = 100 OHMS. THIS CIRCUIT IS THEREFORE EQUIVALENT TO A 100 OHM RESISTOR CONNECTED ACROSS THE GENERATOR TERMINALS.

TO FIND THE CURRENT FLOW IN THIS CIRCUIT, WE USE OHM'S LAW IN THE FORM I = E/R AND SINCE IN THIS PARTICULAR CASE E = 200 VOLTS AND R = 100 OHMS, WE HAVE $I = \frac{E}{R} = \frac{200}{100} = 2$ AMPS. THIS SAME 2 AMPERE CURRENT FLOWS THRU EVERY PORTION OF THE CIRCUIT.

HAVING DETERMINED THE CURRENT FLOW, THE NEXT STEP IS TO DETERMINE THE VOLTAGE DROP ACROSS THE INDIVIDUAL RESISTORS. TO SIMPLIFY THIS, THE SAME CIRCUIT IS AGAIN SHOWN IN FIG. 12 IN DIAGRAM FORM, WHEREIN EACH RESISTANCE IS REPRESENTED BY A SYMBOL.

SINCE THE CURRENT FLOW THROUGH EACH OF THESE RESISTANCES AMOUNTS TO 2 AMPS, THE VOLTS DROP ACROSS THE 20-OHM RESISTOR IS:

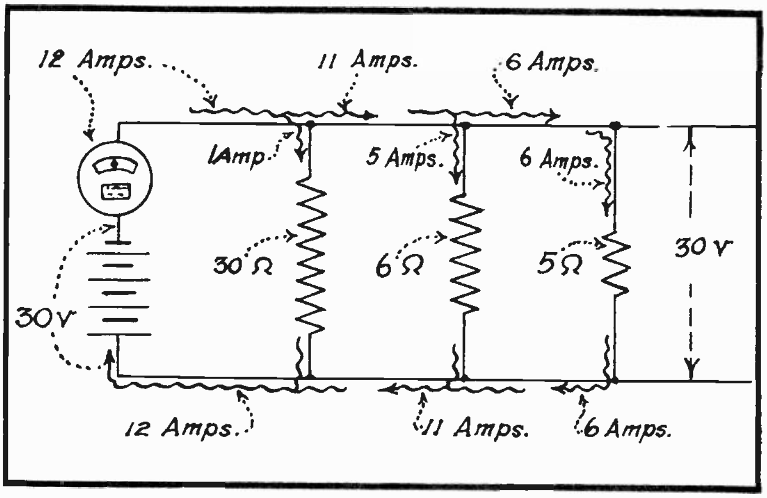


FIG. 16
DIAGRAM OF THE PARALLEL ELECTRICAL CIRCUIT.

E = I x R = 2 x 20 = 40 VOLTS. THE DROP ACROSS THE 10-OHM RESISTOR IS: E = I x R = 2 x 10 = 20 VOLTS. THE DROP ACROSS THE 30-OHM RESISTOR IS E = I x R = 2 x 30 = 60 VOLTS; AND THE DROP ACROSS THE 40-OHM RESISTOR IS E = I x R = 2 x 40 = 80 VOLTS.

BY ADDING TOGETHER THESE INDIVIDUAL VOLTAGE DROPS WE OBTAIN 40+20+60+80 = 200 VOLTS, WHICH YOU WILL NOTE IS EQUAL TO THE VOLTAGE DEVELOPED BY THE GENERATOR.

NOW LET US APPLY TO THE PRACTICAL RADIO PROBLEM IN FIG. 13 THE PRINCIPLE WHICH YOU HAVE JUST LEARNED.

IN FIG. 13 WE HAVE THE FILAMENT OF A TUBE CONNECTED IN SERIES WITH A 6 VOLT STORAGE BATTERY AND A 4 OHM RESISTOR. A CURRENT OF 1 AMP. FLOWS THROUGH THE CIRCUIT.

SINCE THIS CURRENT OF 1 AMP. MUST FLOW THROUGH THE 4 OHM RESISTOR AS WELL AS THROUGH THE TUBE FILAMENT, THE VOLTAGE WHICH IS EFFECTIVE ACROSS THE 4 OHM RESISTOR CAN BE FOUND BY USING THE FORMULA E = I x R. HERE "I" WILL BE 1 AMP. AND "R" WILL BE 4 OHMS AND THENCE E = 1 x 4 = 4 VOLTS. IN OTHER WORDS, IF WE SHOULD MEASURE THE VOLTAGE ACROSS THE ENDS OF THIS 4 OHM RESISTOR WITH A VOLTMETER, THE INSTRUMENT WOULD OFFER A READING OF 4 VOLTS.

THE VOLTAGE ACROSS THE FILAMENT TERMINALS CAN ALSO BE FOUND BY AP-

PLYING THE FORMULA $E = I \times R$, ONLY THAT IN THIS CASE, $I = 1$ AMP. AND $R = 2$ OHMS. THEREFORE, $E = 1 \times 2 = 2$ VOLTS. NOTICE ESPECIALLY THAT THE SUM OF THE VOLTAGE ACROSS THE FILAMENT AND THAT ACROSS THE 4 OHM RESISTOR IS EQUAL TO THE TOTAL VOLTAGE WHICH IS APPLIED ACROSS THE ENTIRE CIRCUIT. THAT IS, 2 VOLTS PLUS 4 VOLTS EQUALS THE 6 VOLTS OF THE STORAGE BATTERY. THIS IS VERY IMPORTANT BECAUSE IT SHOWS YOU HOW A RESISTOR CAN BE USED TO LOWER THE VOLTAGE OF THE "A" SUPPLY TO A VALUE WHICH IS SUITABLE FOR THE TUBE FILAMENT. IN OTHER WORDS, WE HAVE A VOLTAGE DROP, LOSS, OR REDUCTION OF 4 VOLTS ACROSS THE 4 OHM RESISTOR, SO THAT ONLY 2 OF THE ORIGINAL 6 VOLTS REMAIN TO BE UTILIZED BY THE TUBE FILAMENT.

ANOTHER COMMON RADIO PROBLEM WHICH IS SIMILAR TO THE PREVIOUS ONE, IS THE CASE WHERE A GIVEN TUBE AND "A" SUPPLY IS AVAILABLE AND THE CORRECT RESISTANCE VALUE IS REQUIRED SO AS TO REDUCE THE "A" SUPPLY BY THE PROPER AMOUNT FOR FILAMENT USE. FOR EXAMPLE, LET US SUPPOSE THAT WE ARE REQUIRED TO CONNECT THE FILAMENT OF A CERTAIN TUBE INTO A CIRCUIT IN WHICH THE "A" SUPPLY FURNISHES AN E.M.F. OF 8 VOLTS.

THE PARTICULAR TUBE REQUIRES A FILAMENT VOLTAGE OF 5 VOLTS AND DRAWS 1 AMPERES OF FILAMENT CURRENT. THIS MEANS THAT A RESISTOR MUST BE CONNECTED IN SERIES WITH THE TUBE FILAMENT AND ONE SIDE OF THE "A" SUPPLY SO AS TO PROVIDE A VOLTAGE DROP OF 8 MINUS 5 OR 3 VOLTS. TO DETERMINE THE VALUE OF THIS RESISTOR, WE USE THE FORMULA $R = \frac{E}{I}$ AND "E" IN THIS CASE WILL BE 3 VOLTS WHILE "I" = 1 AMP. WE THEN HAVE $R = \frac{3}{1} = 3$ OHMS AS THE REQUIRED VALUE OF THE RESISTOR SO THAT ONLY 5 VOLTS WILL BE ACTUALLY APPLIED ACROSS THE TUBE FILAMENT EVEN THOUGH AN 8 VOLT "A" SUPPLY BE USED.

PARALLEL ELECTRICAL CIRCUITS

IN FIG. 14 YOU WILL SEE A TYPICAL EXAMPLE OF A PARALLEL ELECTRICAL CIRCUIT. NOTICE THAT IN THIS CASE THE THREE APPLIANCES, CONSISTING OF A BELL, LAMP, AND HEATER, ARE ALL CONNECTED SEPARATELY ACROSS THE TWO MAIN CIRCUIT WIRES FED BY THE BATTERY. WE CALL THESE SEPARATE BELL, LAMP AND HEATER CIRCUITS BRANCH CIRCUITS, AND IN A CIRCUIT SUCH AS THIS, EACH OF THE BRANCH CIRCUITS IS INDEPENDENT OF ALL THE OTHERS. THE VOLTAGE IMPRESSED ACROSS EACH BRANCH CIRCUIT OR PATH WILL BE PRACTICALLY THE SAME; THAT IS, 30 VOLTS IN THIS PARTICULAR EXAMPLE.

A PARALLEL ELECTRICAL CIRCUIT CAN BE COMPARED QUITE NICELY TO THE PARALLEL HYDRAULIC SYSTEM ILLUSTRATED IN FIG. 15. HERE YOU WILL OBSERVE THAT WE HAVE THREE PIPES WITH DIAMETERS OF 1", 2" AND 4", RESPECTIVELY, CONNECTED IN PARALLEL ACROSS THE TWO MAIN FEEDER PIPES WHICH SERVE TO DISTRIBUTE THE WATER THRU THE SYSTEM.

EACH OF THESE PARALLEL-CONNECTED PIPES HAS ITS INDIVIDUAL VALVE SO THAT THE FLOW OF WATER PASSING THROUGH IT CAN BE CONTROLLED. NOW, IT IS CLEAR THAT PRACTICALLY THE SAME PUMP PRESSURE IS EXERTED ACROSS EACH OF THESE PIPES, BUT IF THE VALVES OF THESE PIPES ARE ALL OPENED, THE CURRENT FLOW THRU THEM WILL BE UNEQUAL. THAT IS, EVEN THOUGH THE PRESSURE ON THE THREE PIPES IS THE SAME, THE RESISTANCE OF EACH PIPE WILL CONTROL THE QUANTITY OF WATER FLOWING THROUGH IT, AND SINCE THE DIAMETER OF THE

PIPES IN FIG. 15 DIFFER, THE PIPE OF LARGEST DIAMETER WILL HAVE THE LEAST RESISTANCE AND THE PIPE OF SMALLEST DIAMETER WILL OFFER THE GREATEST AMOUNT OF RESISTANCE. THEREFORE, THE LARGER PIPE WILL PERMIT THE GREATEST FLOW OF CURRENT, THE MEDIUM SIZED PIPE WILL PASS A LITTLE LESS WATER, AND THE SMALLEST PIPE WILL PASS THE LEAST.

THE SAME CONDITION EXISTS IN PARALLEL ELECTRICAL CIRCUITS, FOR HERE TOO, THE VOLTAGE OR ELECTROMOTIVE FORCE IS PRACTICALLY THE SAME ACROSS EACH OF THE PARALLEL BRANCHES OR PATHS AND THE CURRENT FLOW THRU ANY ONE OF THE PATHS WILL BE GOVERNED BY THE RESISTANCE OF THAT PARTICULAR PATH. THIS POINT CAN NO DOUBT BE MADE A LITTLE CLEARER BY CONSIDERING THE VOLTAGE AND CURRENT DISTRIBUTION IN THE CIRCUIT OF FIG. 14, WHICH FOR CONVENIENCE IS AGAIN SHOWN YOU IN FIG. 16, IN DIAGRAM FORM.

UPON STUDYING FIG. 16 VERY CAREFULLY, YOU WILL SEE THAT THE SAME E.M.F. (30 VOLTS) IS APPLIED ACROSS EACH OF THE PARALLEL PATHS OR RESISTANCES. THE CURRENT THROUGH EACH OF THESE RESISTANCES CAN BE CALCULATED BY USING OHM'S LAW IN THE FORM: I = E/R. FOR INSTANCE, TO DETERMINE THE CURRENT FLOW THRU THE RESISTANCE OF 30 OHMS, WE SUBSTITUTE THE VALUE OF 30 OHMS FOR "R" AND 30 VOLTS FOR "E". WE THEN HAVE $I = \frac{30}{30} = 1$ AMPERE AS THE CURRENT FLOWING THRU THE 30-OHM RESISTANCE.

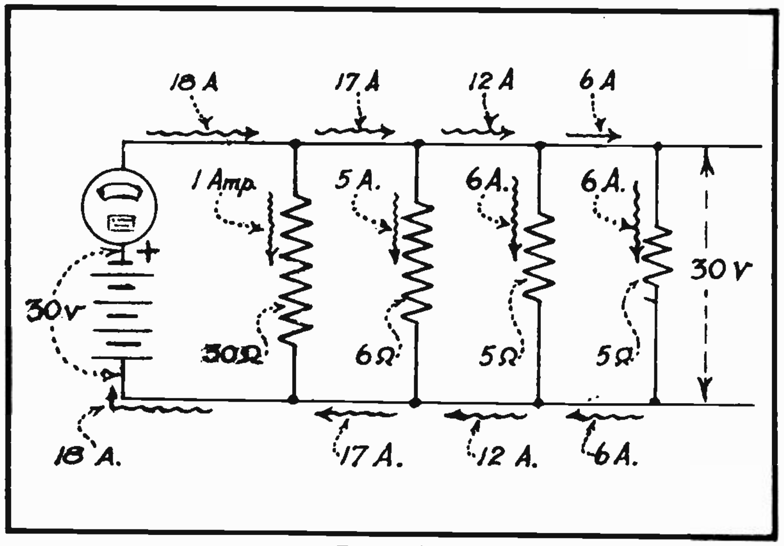


FIG. 17
ADDING ANOTHER PATH.

IN ORDER TO DETERMINE THE CURRENT FLOW THRU THE 6-OHM RESISTOR, WE USE THE SAME FORMULA, BUT "R" WILL NOW BE 6 OHMS AND "E" WILL BE 30 VOLTS. $I = \frac{30}{6} = 5$ AMPERES.

FINALLY, TO CALCULATE THE CURRENT THROUGH THE 5-OHM RESISTANCE, WE SUBSTITUTE THE VALUES OF 5 FOR "R" AND 30 FOR "E" AND THUS OBTAIN:

$$I = \frac{30}{5} = 6 \text{ AMPERES.}$$

THE TOTAL CURRENT, AS SUPPLIED BY THE BATTERY, WILL THEN BE EQUAL TO THE SUM OF THE CURRENTS FLOWING THRU EACH OF THE PARALLEL PATHS OR BRANCH CIRCUITS. THAT IS, THE TOTAL CURRENT IN THE CIRCUIT OF FIGS. 14 AND 16 WILL BE 1 + 5 + 6, OR 12 AMPS., AS INDICATED BY THE AMMETER WHICH IS LOCATED AT A POINT WHERE ALL OF THE CURRENT SUPPLIED TO THE ENTIRE CIRCUIT MUST FLOW THROUGH IT.

THE TOTAL RESISTANCE DECREASES AS MORE PARALLEL CIRCUITS ARE USED

IN FIG. 17, WE AGAIN HAVE OUR CIRCUIT OF FIG. 16, BUT IN ADDITION, another 5-ohm resistor has been connected in parallel with the first 3 resistors. By applying Ohm's Law again, with this additional 5-ohm resistance in circuit, we find that it will permit another 6 amperes of current to flow through it. ($I = \frac{E}{R} = \frac{30}{5} = 6$ amperes).

Since you have already found that the other three resistors draw a total current of 12 amperes from the battery, the additional parallel resistance shown in Fig. 17, will cause 6 amps. to be added so that the total current for the circuit in Fig. 17 will be 12 plus 6, or 18 amps. This shows you that the greater the number of resistors we connect in parallel, the LESS will be the total resistance of the circuit, and the total current flowing in the circuit will increase accordingly. The total resistance of this parallel circuit can also be calculated by applying Ohm's Law in the form: $R = \frac{E}{I}$, in which case "E" is the applied voltage across the entire circuit and "I" the total current flow. Hence $R = \frac{30}{18} = 1.66$ ohms.

Notice especially that the total resistance of a parallel circuit is even less than the smallest resistance value contained in any of the paths or branches.

A PARALLEL FILAMENT CIRCUIT

In receiver circuits where several tubes are employed, the filaments are generally, though not always, connected in parallel. In Fig. 18 you are shown three tube filaments connected in parallel and the combination is to be connected to a source of E.M.F. furnishing 9 volts. The filament of each of these tubes is designed to have an E.M.F. of 3 volts applied across it and will pass a current of 1 ampere under these conditions.

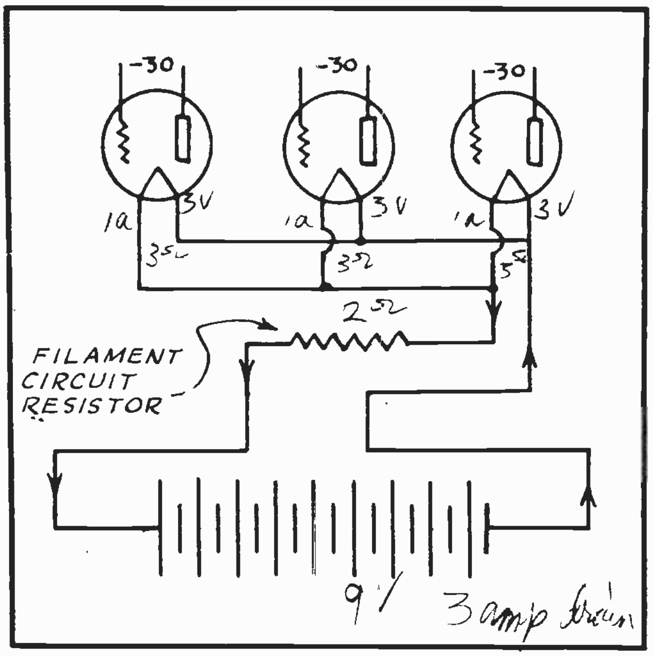


Fig. 18
A Parallel Filament Circuit.

Since a filament voltage of 3 is required at each tube and an E.M.F. of 9 volts is available, it is necessary to include a resistor in series with source of E.M.F. and the combination filament circuit, as shown in Fig. 18. The problem is to determine the correct value for the resistor which is to be used for this purpose.

The filament of each tube in Fig. 18 will draw 1 amp. but since the filaments of three of these tubes are connected in parallel, they will affect the circuit in the same manner as already shown you when resistors are connected in parallel because each tube filament is equiva

LENT TO A RESISTOR. BECAUSE OF THE FACT THAT THE RESISTANCE OF EACH OF THESE THREE FILAMENTS IS THE SAME, THEY WILL EACH DRAW 1 AMP. FROM THE "A" SUPPLY. THAT IS, THE TOTAL FILAMENT CURRENT IN THE CIRCUIT OF FIG. 18 WILL BE THREE TIMES 1 AMP. OR 3 AMPERES AND THIS TOTAL CURRENT WILL ALL BE REQUIRED TO FLOW THROUGH THE FILAMENT CIRCUIT RESISTOR.

SINCE THE "A" OR SUPPLY VOLTAGE IS 9 VOLTS AND ONLY 3 VOLTS ARE NEEDED AT THE TUBE FILAMENTS, THE VOLTAGE DROP WHICH IS REQUIRED ACROSS THE RESISTOR WILL BE EQUAL TO 9 VOLTS MINUS 3 VOLTS OR 6 VOLTS. THEREFORE, THE FILAMENT CIRCUIT RESISTOR MUST HAVE A VALUE OF $R = \frac{E}{I} = \frac{6}{3} = 2$ OHMS.

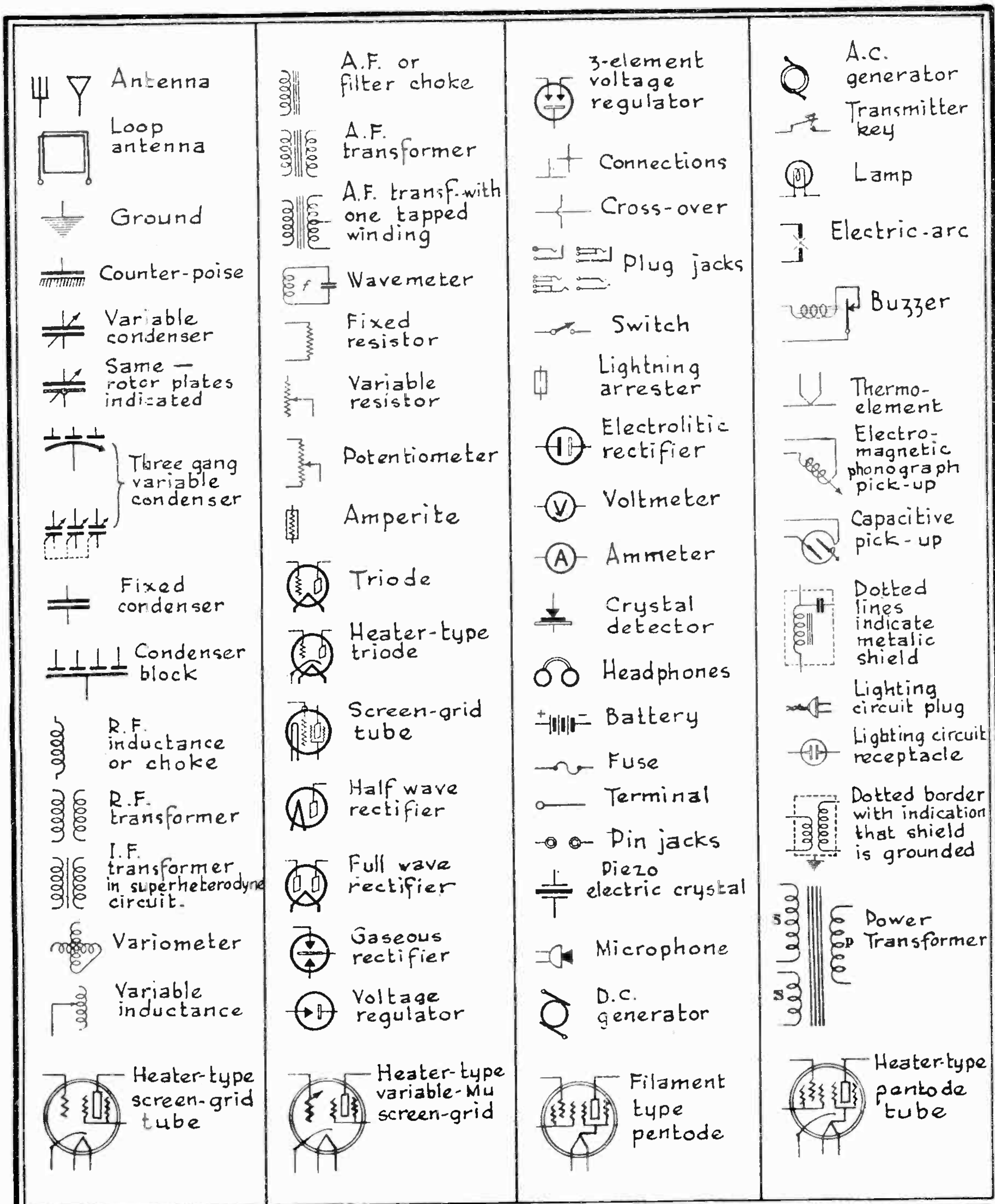
IF ONE OF THE PATHS OR BRANCH CIRCUITS IN A PARALLEL CIRCUIT SHOULD BECOME OPEN CIRCUITED, IT WILL NOT CAUSE THE OTHER PATHS TO BECOME INOPERATIVE. THAT IS, IF THE FILAMENT OF ONE OF THE TUBES IN THE CIRCUIT OF FIG. 18 SHOULD BURN OUT, THEN THIS CONDITION WILL NOT PREVENT ANY OF THE OTHER TUBES IN THE CIRCUIT FROM RECEIVING THE NECESSARY CURRENT TO CARRY ON THEIR NORMAL OPERATION. IN THE CASE OF FIG. 9 OF THIS LESSON, HOWEVER, WE HAVE A DIFFERENT STATE OF AFFAIRS FOR IN A SERIES CIRCUIT AS THIS, AN OPEN AT ANY POINT OF THE CIRCUIT WILL PREVENT THE ENTIRE SYSTEM FROM OPERATING.

SINCE IT IS THE AIM OF THIS INSTITUTION TO PROVIDE YOU WITH A MOST COMPLETE TRAINING, WE ARE COMBINING TECHNICAL INSTRUCTION WITH PRACTICAL INSTRUCTION AND THESE TWO FEATURES ARE WELL BALANCED THROUGHOUT THE WORK WHICH HAS BEEN CAREFULLY PLANNED FOR YOU. THIS MEANS THAT YOU WILL NOT BE DEPRIVED OF THE TECHNICAL KNOWLEDGE WHICH YOU ACTUALLY DO NEED IN ORDER TO BECOME A THOROUGHLY QUALIFIED TECHNICIAN.

IN ADDITION, SUCH TECHNICAL LESSONS ARE DISTRIBUTED AMONG THOSE LESSONS DEALING WITH THE MORE PRACTICAL SUBJECTS IN SUCH A WAY THAT YOUR STUDIES WILL AT ALL TIMES BE INTERESTING AND THERE WILL NEVER BE ANY OCCASION OF YOUR WORK HAVING A TENDENCY TO BECOME "DRY" OR TIRESOME.

IN THE NEXT LESSON, WE ARE GOING TO STUDY A SUBJECT WHICH IS GOING TO BE OF SPECIAL INTEREST TO YOU, NAMELY, RADIO TUNING. ALTHOUGH YOU HAVE ALREADY LEARNED SOMETHING ABOUT THIS IMPORTANT SUBJECT, YET WE ARE AT THIS TIME GOING TO CONSIDER IT IN GREATER DETAIL, SO THAT YOU WILL OBTAIN A PERFECT UNDERSTANDING OF WHAT TAKES PLACE IN TUNED CIRCUITS DURING THE RECEPTION OF A PROGRAM.

· RADIO SYMBOLS ·



To achieve what the world calls success a man must attend strictly to business and keep a little in advance of the time.

The man who reaches the top is the one who is not content with doing just what is required of him. He does more.

Every man should make up his mind that if he expects to succeed, he must give an honest return for the other man's dollar.

Grasp an idea and work it out to a successful conclusion.

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LESSON NO 8

Radio Tuning

In a previous lesson, you already learned about radio tuning in an elementary form but now we are going to study this subject in a more technical manner. The importance of tuning cannot be over emphasized since it has such a pronounced effect upon the performance of both transmitting and receiving equipment. Modern tuning circuits generally consist of a condenser used in conjuction with a winding of wire or coil but it will be advisable for us to first investigate how each of these two units will act in a circuit when used alone before considering their combined effects. We shall start with the coil.

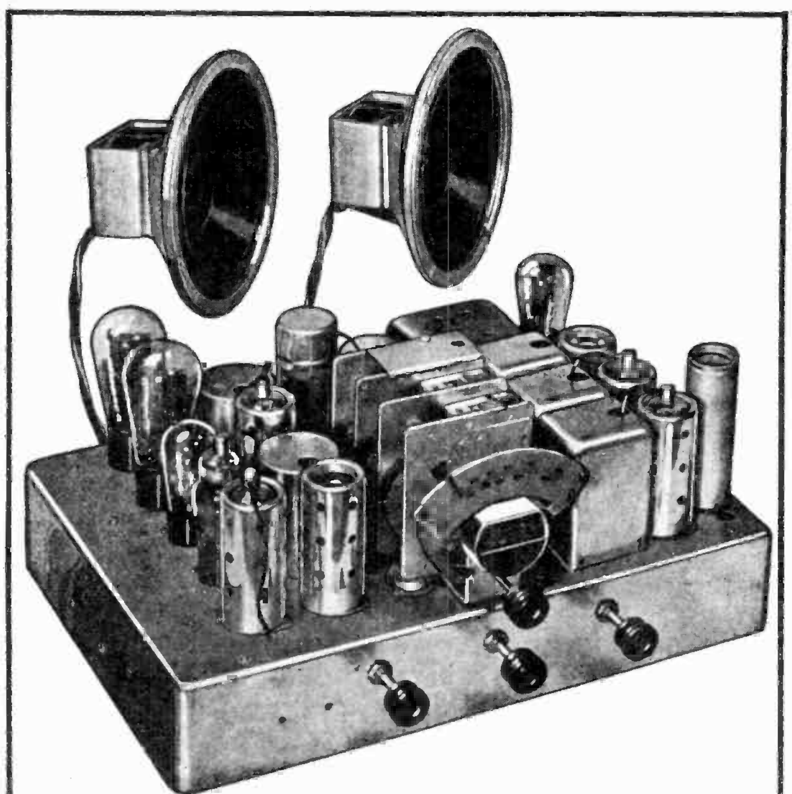

FIG. 1
Accurate Tuning Essential in Modern Receivers

MAGNETIC FIELD PRODUCED BY ALTERNATING CURRENT.

If the voltage across any circuit changes its intensity and polarity periodically, it is obvious that the current will do the same. Therefore, if a coil or winding of insulated wire is connected in an alternating current circuit, the result would be as illustrated in Fig. 2. In other words

WE WOULD START WITH NO CURRENT AT ALL AS INDICATED BY THE ZERO READING AT THE EXTREME LEFT OF FIG. 2. THEN AS THE CURRENT STARTS ITS FLOW IN THE DIRECTION AS INDICATED BY THE ARROWS IN THE NEXT ILLUSTRATION TOWARD THE RIGHT IN FIG. 2 AND INCREASES IN INTENSITY, A MAGNETIC FIELD OF THE POLARITY HERE DESIGNATED WILL BE ESTABLISHED.

AS THE CURRENT FLOW IN THIS DIRECTION STOPS AND REACHES A ZERO VALUE, THEN THE LINES OF FORCE AROUND THE COIL WILL COLLAPSE AND DISAPPEAR SO THAT AT THIS INSTANT, CONDITIONS WILL BE AS ILLUSTRATED IN THE CENTER OF FIG. 2. THIS DOES NOT LAST LONG, HOWEVER, FOR THE CURRENT WILL IMMEDIATELY COMMENCE ITS FLOW THROUGH THE COIL IN THE OPPOSITE DIRECTION AS INDICATED BY THE ARROWS IN THE NEXT ILLUSTRATION AND THE RESULTING MAGNETIC FIELD WHICH IS PRODUCED AROUND THE COIL AT THIS TIME WILL HAVE ITS POLARITY REVERSED ACCORDINGLY AS ALSO POINTED OUT HERE.

FINALLY, THE CURRENT WILL STOP FLOWING AND REACH A ZERO VALUE,

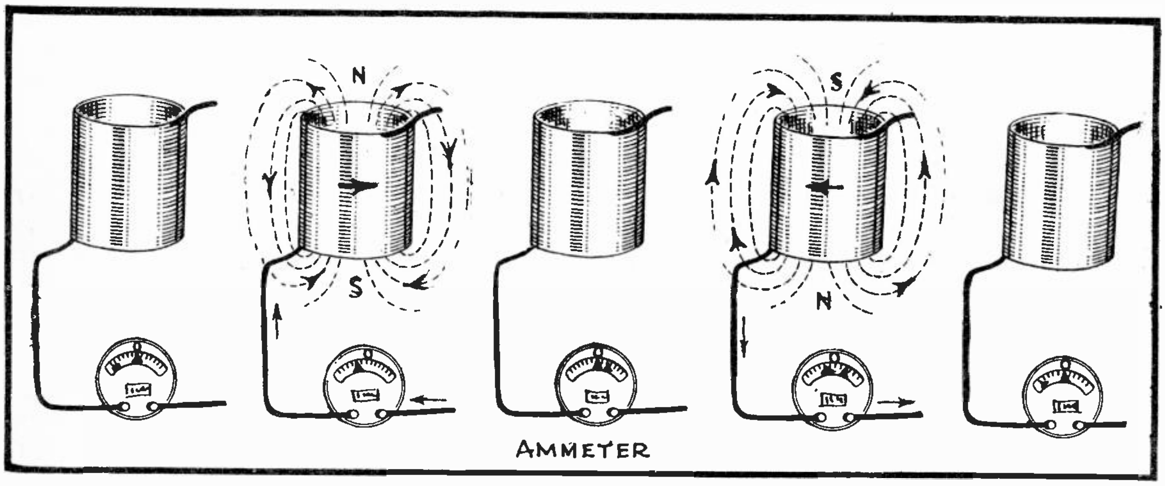

FIG. 2
The Effects of Current Variations Through A Coil.

THEREBY CAUSING THE MAGNETIC FIELD TO DISAPPEAR FROM AROUND THE COIL AGAIN AS PICTURED AT THE RIGHT OF FIG. 2. IN THIS WAY, THE MAGNETIC FIELD AROUND THE COIL WILL CONTINUALLY BUILD UP, COLLAPSE AND REVERSE ITS POLARITY IN STEP WITH THE VARIATION IN THE CURRENT WHICH IS FLOWING THROUGH IT.

COUNTER-ELECTROMOTIVE FORCE

BESIDE THE MAGNETIC FIELD REVERSAL OCCURRING AROUND THE COIL IN FIG. 2, ANOTHER IMPORTANT ACTION IS TAKING PLACE AND THAT IS THAT WHEN THE CURRENT FLOW THROUGH THE COIL INCREASES ITS INTENSITY IN ANY ONE DIRECTION, THE LINES OF FORCE AS THEY SPREAD OUTWARD OR BUILD UP, WILL CUT THE WINDING IN SUCH A DIRECTION SO THAT THEY WILL INDUCE A VOLTAGE IN THIS WINDING WHOSE POLARITY WILL BE OPPOSITE TO THAT OF THE APPLIED VOLTAGE AND BECAUSE OF ITS OPPOSING EFFECT, WE LOGICALLY CALL IT THE COUNTER-ELECTROMOTIVE FORCE.

FIG. 3 WILL AID TO ILLUSTRATE THIS POINT. IF A VOLTAGE, WHOSE VALUE IS INCREASING, SHOULD BE APPLIED ACROSS THE ENDS OF THIS WINDING SO AS TO CAUSE A CURRENT FLOW THROUGH THE COIL IN THE DIRECTION AS INDICA-

TED BY THE HEAVY ARROW, THEN THE COUNTER-ELECTROMOTIVE FORCE WILL TEND TO CAUSE A CURRENT TO FLOW THROUGH THE WINDING IN THE OPPOSITE DIRECTION OR AS INDICATED BY THE SMALLER ARROW IN THIS ILLUSTRATION. THIS OPPOSITION OF THE GENERATED COUNTER-ELECTROMOTIVE FORCE WILL REDUCE THE EFFECTS OF THE APPLIED E.M.F. SO THAT THE RESULTING E.M.F. OR ACTUAL EFFECTIVE E.M.F. WILL BE LESS THAN THE APPLIED E.M.F.

IN FIG. 4, FOR INSTANCE, WE HAVE AN APPLIED E.M.F. OF 7.5 VOLTS ACTING IN ONE DIRECTION AND A COUNTER-ELECTROMOTIVE FORCE OF 6 VOLTS ACTING IN THE OPPOSITE DIRECTION. THE STRONGER APPLIED E.M.F. WILL OF COURSE OVERCOME THE WEAKER COUNTER-E.M.F. AS HERE SHOWN BUT NEVERTHELESS ITS EFFECTIVE FORCE WILL BE GREATLY REDUCED AND THE RESULTING E.M.F. OF $1\frac{1}{2}$ VOLTS WILL ONLY BE CAPABLE OF FORCING ONE-FIFTH OF THE CURRENT THROUGH THE CIRCUIT THAN WOULD ORDINARILY BE POSSIBLE BY A STEADILY APPLIED E.M.F. OF 7.5 VOLTS.

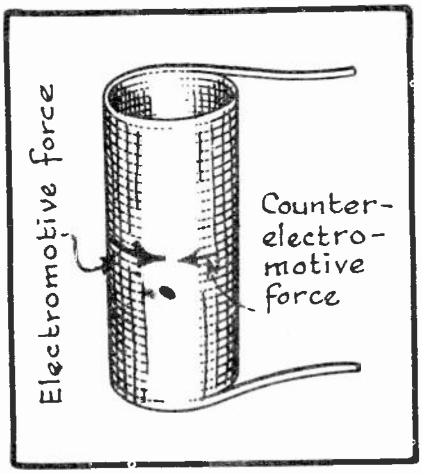

FIG. 3
Auto-Induction.

SO FAR, YOU HAVE SEEN HOW THE COUNTER-ELECTROMOTIVE FORCE OPPOSES AN APPLIED E.M.F. WHICH IS INCREASING IN VALUE. NOW, HOWEVER, LET US SEE WHAT HAPPENS AS THE APPLIED E.M.F. DECREASES FROM A MAXIMUM VALUE AND APPROACHES ZERO. AT THIS TIME, THE LINES OF FORCE WILL BE RECEDING OR COLLAPSING INWARD TOWARD THE CENTER OF THE WINDING AND THEREFORE CUTTING THE TURNS OF THE WINDING IN AN OPPOSITE DIRECTION THAN FORMERLY. HENCE INSTEAD OF OPPOSING THE APPLIED E.M.F., THE INDUCED VOLTAGE DURING THIS PERIOD WILL TEND TO KEEP THE CURRENT FLOWING THROUGH THE WINDING IN THE SAME DIRECTION AS IT WAS CAUSED TO FLOW ORIGINALLY BY THE APPLIED E.M.F.

SINCE THIS OPPOSING AND ASSISTING VOLTAGE ARE BROUGHT ABOUT BY ELECTROMAGNETIC INDUCTION, WE SAY THAT THESE EFFECTS ARE DUE TO THE INDUCTANCE OF THE WINDING. IN OTHER WORDS, WHENEVER AN ALTERNATING OR PULSATING CURRENT FLOWS THROUGH A WINDING, THE INDUCTANCE OF THE WINDING WILL OPPOSE ANY INCREASE IN CURRENT FLOW, WHEREAS IT WILL TEND TO KEEP THE CURRENT FLOWING THROUGH IT AS THE CURRENT PRODUCED BY THE APPLIED E.M.F. DECREASES IN VALUE. THIS IS A VERY IMPORTANT POINT TO REMEMBER REGARDING INDUCTANCE AND YOU ARE GOING TO USE THIS PRINCIPLE A GREAT DEAL THROUGHOUT YOUR RADIO WORK.

THE EFFECT OF A CORE UPON A WINDING'S INDUCTANCE

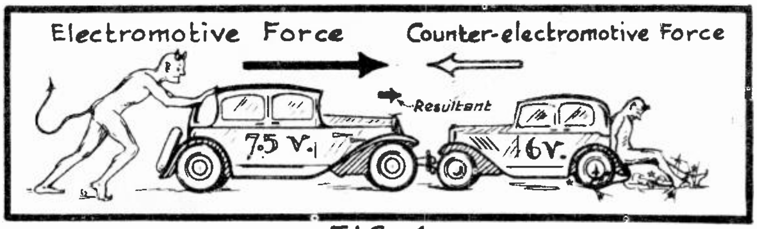

FIG. 4
The Effect of Opposing Voltages.

AT THE LEFT OF FIG. 5, WE HAVE A WINDING WITH NO METALLIC CORE. WE SPEAK OF A WINDING AS THIS AS HAVING AN AIR CORE, MEANING THEREBY THAT SIMPLY AIR WILL SERVE TO CONDUCT THE LINES OF FORCE WHICH ARE PRODUCED AROUND IT WHEN

A CURRENT IS FLOWING THROUGH THE WINDING. AT THE RIGHT OF FIG. 5, WE HAVE THE SAME WINDING, ONLY THAT A BUNCH OF SOFT SHEETS OR LAMINATIONS ARE INSERTED WITHIN IT SO AS TO FORM AN IRON CORE.

THE ADDITION OF THE IRON CORE INCREASES THE INDUCTANCE OF THE COIL TREMENDOUSLY AS SHOWN BY THE EXPERIMENT WHICH IS ILLUSTRATED FOR YOU IN FIGS. 6 & 7. IN FIG. 6, FOR EXAMPLE, A COIL WITH AN AIR CORE IS CONNECTED IN SERIES WITH A 110 VOLT ALTERNATING CURRENT LIGHTING CIRCUIT AND A 110 VOLT INCANDESCENT LAMP. ALTHOUGH THE BRILLIANCE OF THE LAMP WILL BE SLIGHTLY LESS THAN IF THE LAMP WERE CONNECTED DIRECTLY ACROSS THE LIGHTING CIRCUIT WITHOUT THE COIL BEING INCLUDED, YET THE DIFFERENCE IN BRILLIANCE UNDER THESE TWO CONDITIONS WILL BE HARDLY NOTICEABLE.

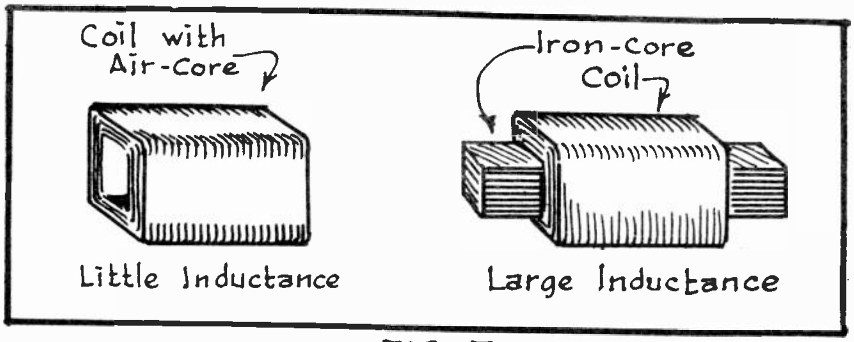

FIG. 5

An Iron-Core Increases the Inductance.

IF WE SHOULD NOW INSERT AN IRON CORE INTO THIS SAME WINDING AS SHOWN IN FIG. 7, THEN WE WOULD FIND THE BRILLIANCE OF THE LAMP TO BE REDUCED GREATLY AND IT WOULD ONLY EMIT A VERY DIM LIGHT.

IF WE SHOULD REPEAT THIS SAME EXPERIMENT BY CONNECTING THE TEST CIRCUIT ACROSS A 110 VOLT DIRECT CURRENT (D.C.) SUPPLY, THEN THE LAMP WOULD BURN AT FULL BRILLIANCE WHETHER AN IRON CORE BE INSERTED IN THE COIL OR NOT. THE BRILLIANCE OF THE LAMP WOULD ALSO NOW BE THE SAME WITH THE COIL INCLUDED IN THE CIRCUIT AS WITH THE COIL REMOVED FROM THE CIRCUIT.

THE ONLY STRIKING EFFECT WHICH WILL BE NOTICED UPON CONNECTING THE THE CIRCUIT WITH THE IRON-CORE COIL ACROSS THE D.C. LINE WILL BE THAT THE LAMP WILL BURN SOMEWHAT DIMLY WHEN THE VOLTAGE IS FIRST APPLIED ACROSS THE CIRCUIT BUT IT WILL THEN COME UP TO FULL BRILLIANCE AND REMAIN IN THIS STATE AS LONG AS THE VOLTAGE IS KEPT CONSTANT. IN OTHER WORDS, WHEN THE VOLTAGE IS FIRST APPLIED AND WHILE THE MAGNETIC FIELD IS ESTABLISHING ITSELF, A COUNTER-ELECTROMOTIVE FORCE WILL BE GENERATED AND OPPOSE THE APPLIED VOLTAGE MOMENTARILY BUT AFTER THIS FIELD IS ONCE COMPLETE, IT WILL REMAIN CONSTANT AND NO LONGER HAVE ANY EFFECT UPON THE COIL.

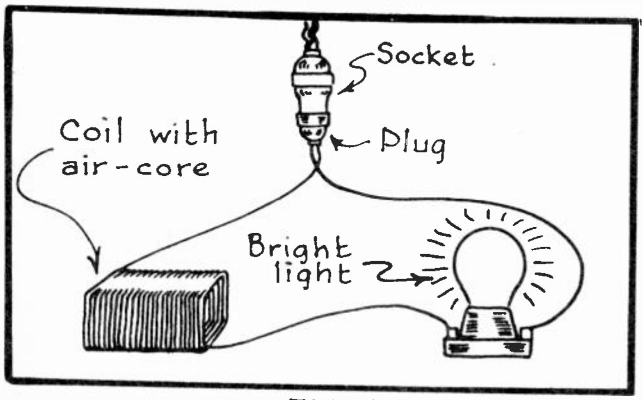

FIG. 6

The Air-Core Produces a slight Reduction In Current Flow.

THIS EXPERIMENT ILLUSTRATES TWO VERY IMPORTANT FACTS. FIRST, THAT AN IRON CORE INCREASES A COIL'S INDUCTANCE AND THE REASON FOR THIS IS THAT IRON SERVES AS A BETTER CONDUCTOR OF THE LINES OF FORCE THAN DOES AIR AND THEREFORE A MORE INTENSE MAGNETIC FIELD WILL BE ESTABLISHED AROUND THE COIL. WE SPEAK OF A substance's ability to conduct lines of force as being due to its permeability and thus iron has a greater permeability than air.

The second important fact which this experiment points out is that the inductance possessed by a coil has a tendency to prevent the flow of an alternating current, and the greater the inductance of the coil, the greater will be its opposition towards the flow of an alternating current.

THE RELATION BETWEEN THE SIZE OF A COIL AND ITS INDUCTANCE

Another factor which affects the inductance of a coil is the number of turns making up the winding. That is, the greater the number of turns employed for a winding, the greater will be the inductance of the finished coil.

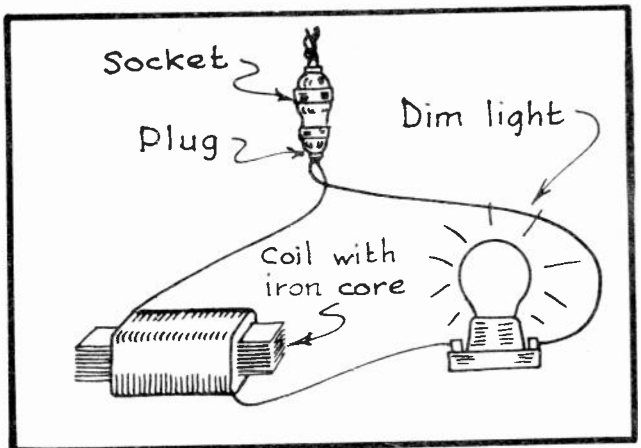

FIG. 7
The Iron-Core Produces a Great Reduction in Current Flow.

The relation between the length and diameter of the coil also has a pronounced effect upon the inductance of the coil.

All of this is illustrated in Fig. 8. At the top of Fig. 8 a winding is shown as consisting of 10 turns of wire. However, the coil at the left has a diameter of 1" while that at the right has a diameter of 2". The length or height of both these coils, nevertheless, is the same or 1". With conditions as here illustrated, the coil with the larger diameter will have the greater inductance.

At the center of Fig. 8, we have two coils with the same diameter of 1" but the coil at the right has 15 turns of wire while the one at the left has only 10 turns of wire. The coil with the greater number of turns will then have the greatest inductance.

Finally, at the bottom of Fig. 8, two coils are shown as having the same diameter and the same number of turns but a smaller wire size is used for the coil at the right so that the 10 turns can be crowded into a shorter winding length. The shorter coil will then have the greater inductance.

THE UNIT OF INDUCTANCE

Naturally, we must employ some suitable unit whereby the comparative inductance between different coils can be expressed and the unit of inductance which we use for this purpose is called the HENRY.

When a circuit or coil has sufficient inductance so that an electromotive force of one volt is generated when the current is changed at the rate of one ampere per second, then we say that the circuit or coil

HAS AN INDUCTANCE OF ONE HENRY.

QUITE OFTEN, WE DEAL WITH CIRCUITS HAVING VERY LITTLE INDUCTANCE AND FOR WHICH THE HENRY IS A RATHER LARGE UNIT TO EMPLOY. THEREFORE, WE ALSO HAVE THE ADDITIONAL INDUCTANCE UNITS THE MILLIHENRY AND THE MICROHENRY FOR EXPRESSING THE SMALLER INDUCTANCE VALUES. ONE MILLIHENRY IS EQUAL TO THE ONE-THOUSANDTH PART OF A HENRY AND ONE MICROHENRY IS EQUAL TO THE ONE --- MILLIONTH PART OF A HENRY. IT IS ALSO A COMMON PRACTICE IN RADIO TO USE THE LETTER "L" TO INDICATE INDUCTANCE.

THE RELATION BETWEEN THE A.C. FREQUENCY AND CURRENT FLOW THROUGH A COIL

IF WE SHOULD WIND A COIL WITH A CERTAIN NUMBER OF TURNS OF WIRE AND CONNECT IT ACROSS A 10 VOLT 60 CYCLE A.C. SUPPLY AS ILLUSTRATED IN THE UPPER PORTION OF FIG. 9, THEN A CURRENT OF DEFINITE INTENSITY WILL FLOW THROUGH THE WINDING. NOW IF WE SHOULD CONNECT THIS SAME COIL ACROSS A 10 VOLT CIRCUIT HAVING A FREQUENCY OF 180 CYCLES PER SECOND, THEN THE CURRENT FLOW THROUGH THE COIL WOULD BE MUCH LESS THAN THAT WHICH FLOWED THROUGH IT WHEN THE 60 CYCLE A.C. SUPPLY WAS APPLIED ACROSS IT.

IF THE FREQUENCY SHOULD BE INCREASED TO 10,000 CYCLES PER SECOND, THE OPPOSITION AS OFFERED BY THE COIL WOULD BECOME SO GREAT THAT VERY LITTLE CURRENT WOULD FLOW THROUGH IT. IN OTHER WORDS, THE HIGHER THE FREQUENCY OF ANY A.C. SUPPLY WHICH IS APPLIED ACROSS A COIL, THE GREATER WILL BE THE OPPOSITION OFFERED BY THE COIL TO THE FLOW OF CURRENT.

THE EXPLANATION OF THIS IS QUITE SIMPLE WHEN WE CONSIDER THE FACT THAT THE HIGHER THE FREQUENCY OF THE A.C. SUPPLY, THE MORE RAPID WILL BE THE VARIATION OF THE MAGNETIC FIELD. THEN SINCE THE EXTENT OF THE GENERATED COUNTER ELECTROMOTIVE FORCE INCREASES WITH THE SPEED WITH WHICH THE LINES OF FORCE CUT THROUGH THE WINDING, IT STANDS TO REASON THAT A GREATER COUNTER E.M.F. OF A HIGH FREQUENCY ORDER IS APPLIED ACROSS THE WINDING.

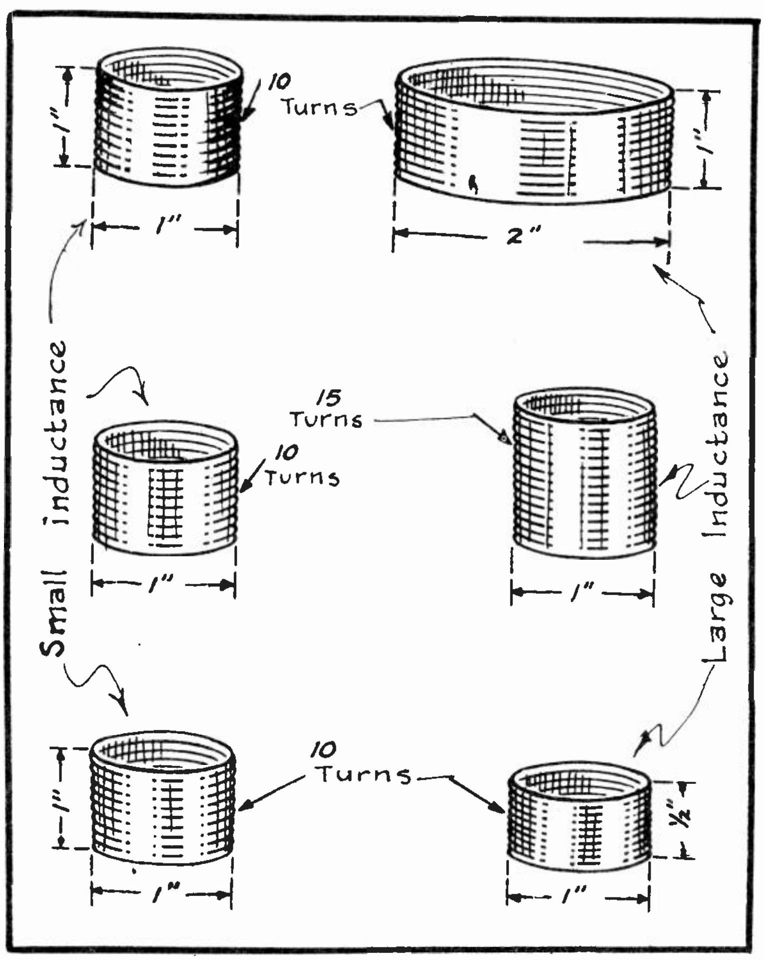

FIG. 8
The Inductance is Affected By the Size of the Coil.

SUMMING UP THE FACTS WHICH YOU HAVE SO FAR LEARNED IN THIS LESSON CONCERNING COILS, WE

HAVE:

(1) A COUNTER ELECTROMOTIVE FORCE IS GENERATED BY A WINDING WHENEVER A CURRENT FLOW THROUGH THE WINDING INCREASES IN VALUE.

(2) THE INDUCTANCE OF A WINDING TENDS TO KEEP THE CURRENT FLOWING THROUGH THE WINDING WHILE THE INITIAL CURRENT DECREASES IN VALUE.

(3) AN IRON CORE INCREASES THE INDUCTANCE OF A WINDING.

(4) INDUCTANCE OPPOSES THE FLOW OF ALTERNATING CURRENT.

(5) THE INDUCTANCE OF A WINDING INCREASES AS MORE TURNS OF WIRE ARE EMPLOYED, AS THE DIAMETER IS INCREASED, OR AS THE LENGTH IS REDUCED WITHOUT A REDUCTION IN TURNS.

(6) THE HENRY, MILLIHENRY AND MICROHENRY ARE USED AS THE UNITS OF INDUCTANCE.

(7) THE OPPOSITION WHICH A COIL OFFERS TOWARDS A FLOW OF ALTERNATING CURRENT INCREASES IF THE FREQUENCY OF THE CURRENT IS INCREASED.

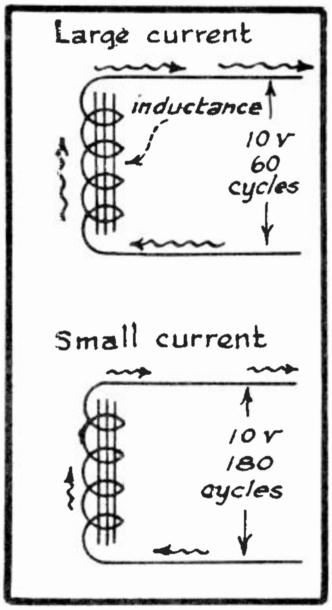

FIG. 9

The Current Decreases at Higher Frequencies.

WITH THESE IMPORTANT FACTS WELL IN MIND, LET US NOW TURN OUR ATTENTION TO CONDENSERS AND THEIR EFFECTS IN VARIOUS TYPES OF CIRCUITS.

THE EFFECT OF A CONDENSER IN D.C. CIRCUITS

AS YOU ALREADY KNOW, A CONDENSER CONSISTS OF TWO OR MORE METALLIC SURFACES WHICH ARE SEPARATED FROM EACHOTHER BY SOME GOOD INSULATIVE MATERIAL AND WE CALL SUCH AN INSULATOR A DIELECTRIC. WITH THIS IN MIND, LET US NOW SEE WHAT EFFECT A CONDENSER WILL HAVE IN A DIRECT CURRENT

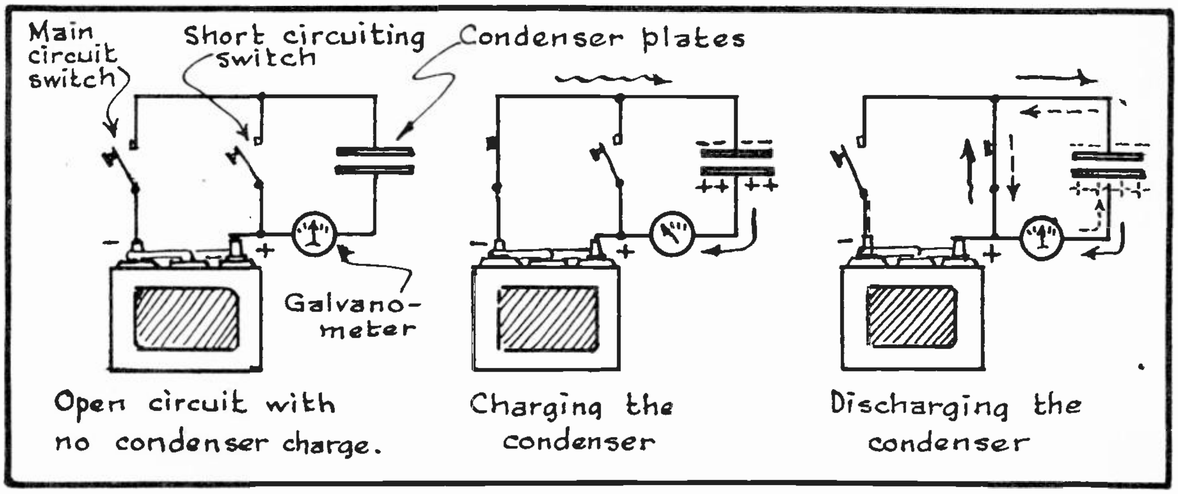

FIG. 10

A Condenser Used in a D.C. Circuit.

(D.C.) CIRCUIT. TO ILLUSTRATE THIS, WE SHALL USE FIG. 10, WHERE WE HAVE A CONDENSER CONNECTED IN A BATTERY CIRCUIT IN WHICH A GALVANOMETER AND SPECIAL SWITCH FASCILITIES ARE PROVIDED.

NOW THEN, AT THE LEFT OF FIG. 10, WE HAVE BOTH SWITCHES OPEN AND CONSEQUENTLY, THE CONDENSER PLATES ARE COMPLETELY DISCONNECTED FROM THE BATTERY. HOWEVER, THE FULL BATTERY VOLTAGE IS AVAILABLE DIRECTLY ACROSS THE BATTERY TERMINALS AND THE WIRING, CONDENSER PLATES, DIELECTRIC ETC. ARE LITERALLY FILLED WITH THE ELECTRONS WHICH CONSTITUTE THE MATTER OF THE VARIOUS MATERIALS WHICH ARE EMPLOYED IN THIS CIRCUIT.

THE NEXT STEP WILL BE TO CLOSE THE MAIN CIRCUIT SWITCH AS SHOWN IN THE CENTER ILLUSTRATION OF FIG. 10. UPON DOING SO, THE NEGATIVE POLE OF THE BATTERY WILL REPEL THE ELECTRONS CONTAINED IN THE SYSTEM AND THE POSITIVE POLE OF THE BATTERY WILL ATTRACT THE NEGATIVELY CHARGED ELECTRONS, WITH THE RESULT THAT WE HAVE A MOMENTARY FLOW OF ELECTRIC CURRENT THROUGH THE CIRCUIT IN THE DIRECTION AS INDICATED BY THE ARROWS.

ON ACCOUNT OF THE DIELECTRIC BETWEEN THE CONDENSER PLATES, THE ELECTRONS OR ELECTRIC CURRENT CANNOT FLOW DIRECTLY THROUGH THE CONDENSER AND THEREFORE THEY WILL HAVE A TENDENCY TO ACCUMULATE ON THE CONDENSER PLATE AT THE CENTER OF FIG. 10 WHICH IS MARKED WITH THE (-) SYMBOLS. THIS RESULTS IN A SURPLUS OF ELECTRONS AT THIS CONDENSER PLATE AND A DEFICIENCY OF ELECTRONS AT THE CONDENSER PLATE WHICH IS MARKED WITH THE (+) SYMBOLS. IN OTHER WORDS, THE ELECTRONS ARE BEING DRAWN AWAY FROM THE (+) SIDE OF THE CONDENSER AND FORCED OVER TO THE (-) SIDE OF THE CONDENSER.

FINALLY, A SUFFICIENT NUMBER OF ELECTRONS ARE DEPOSITED ON THE (-) PLATE OF THE CONDENSER SO THAT THIS PLATE BECOMES NEGATIVELY CHARGED TO SUCH AN EXTENT SO AS TO PREVENT ANY MORE ELECTRONS FROM COLLECTING ON IT. WE THEN SAY THAT THE CONDENSER IS CHARGED AND IF A VOLTMETER SHOULD BE CONNECTED ACROSS THE CONDENSER PLATES, IT WOULD INDICATE THE SAME VOLTAGE AS THAT SUPPLIED BY THE BATTERY. IN OTHER WORDS, THE VOLTAGE ACROSS THE CONDENSER PLATES WILL NOW OPPOSE THAT OF THE BATTERY AND SINCE THEY ARE OF EQUAL VALUE BUT OF OPPOSING POLARITY, ALL CURRENT FLOW THROUGH THE CIRCUIT WILL STOP. IT REQUIRES BUT AN INSTANT TO CHARGE A CONDENSER IN THIS MANNER AND THIS MOMENTARY FLOW OF CHARGING CURRENT WILL BE INDICATED BY AN ABRUPT DEFLECTION OF THE GALVANOMETER NEEDLE. THE NEEDLE OF THIS INSTRUMENT WILL THEN IMMEDIATELY RETURN TO ZERO AS SOON AS THE CONDENSER IS FULLY CHARGED.

IF THE MAIN CIRCUIT SWITCH IS NOW OPENED, THE CONDENSER HAS THE ABILITY TO HOLD OR STORE THIS ELECTRIC CHARGE OVER A CONSIDERABLE PERIOD OF TIME. NOW IF WE SHOULD CLOSE THE SHORT CIRCUITING SWITCH, WE WILL BE OFFERING A LOW RESISTANCE PATH BETWEEN THE TWO CONDENSER PLATES, THAT IS, WE WILL BE "SHORT CIRCUITING" THE CONDENSER PLATES.

WHEN THE PLATES OF A CHARGED CONDENSER ARE SHORT CIRCUITED IN THIS MANNER, THE SURPLUS OF ELECTRONS ON THE NEGATIVELY CHARGED CONDENSER PLATE WILL HAVE A NATURAL TENDENCY TO RETURN TO THE POSITIVE PLATE FROM WHENCE THEY CAME. IN THEIR RUSH TO REACH THEIR DESTINATION, MORE ELECTRONS REACH THE POSITIVE PLATE THAN CAN BE TOLERATED AT THIS POINT AND THEREFORE, SOME OF THEM WILL REMAIN HERE WHILE THE REST RUSH RIGHT BACK TO THE NEGATIVE PLATE AGAIN. ONCE MORE, THERE WILL BE TOO MANY ELECTRONS AT THE NEGATIVE PLATE SO THAT A CERTAIN NUMBER HASTILY FLOW BACK TO THE POSITIVE PLATE AGAIN AND THIS REVERSAL IN THE ELECTRON FLOW CONTINUES UNTIL THE ELECTRONS

AND PROTONS FINALLY NEUTRALIZE EACHOTHER SO THAT THE SYSTEM CAN RETURN TO ITS ORIGINAL STATE AND WITH NO DIFFERENCE OF POTENTIAL BETWEEN THE PLATES. THE CONDENSER WILL THEN BE SAID TO BE DISCHARGED.

THIS ALTERNATING FLOW OF ELECTRONS DURING THE DISCHARGE OF A CONDENSER OCCURS AT A TREMENDOUS SPEED, SO THAT THE CONDENSER WILL BE COMPLETELY DISCHARGED WITHIN A FRACTION OF A SECOND. SINCE THE ELECTRONS FLOW BACK AND FORTH BETWEEN THE CONDENSER PLATES WHILE DISCHARGING, WE SAY THAT THE CONDENSER UNDERGOES AN OSCILLATING DISCHARGE.

THE EFFECT OF A CONDENSER IN A.C. CIRCUITS

NOW LET US SEE WHAT EFFECT THAT A CONDENSER WILL HAVE IN AN ALTERNATING CURRENT (A.C.) CIRCUIT AND TO ILLUSTRATE THIS POINT, WE SHALL USE FIG. 11, WHERE AN A. C. GENERATOR IS SHOWN AS BEING CONNECTED ACROSS THE PLATES OF THE CONDENSER.

AT THE INSTANT PICTURED AT THE EXTREME LEFT OF FIG. 11, WE FIND THE POLARITY OF THE GENERATOR TO BE SUCH THAT THE ELECTRONS ARE CAUSED TO FLOW FROM THE (+) TO THE (-) CONDENSER PLATE, THEREBY CHARGING THE CON-

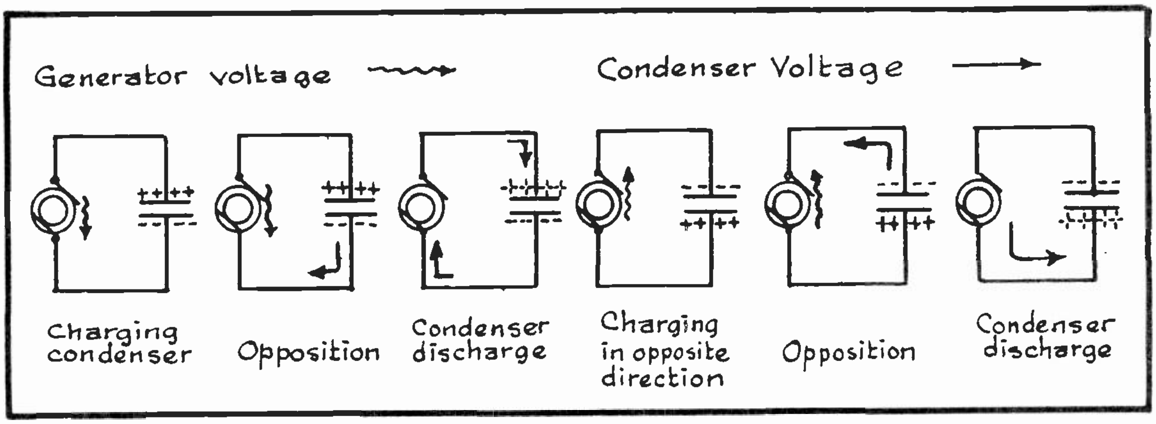

FIG. 11
A Condenser Used in an A.C. Circuit.

DENSER. WHEN THE VOLTAGE ACROSS THE CONDENSER PLATES BECOMES EQUAL TO THE GENERATORS VOLTAGE, THIS CHARGING CURRENT WILL STOP DUE TO THE OPPOSING EFFECT WHICH THE CONDENSER VOLTAGE OFFERS THE GENERATOR VOLTAGE.

THEN AS THE GENERATOR VOLTAGE DIMINISHES, THE CONDENSER WILL COMMENCE TO DISCHARGE THROUGH THE GENERATOR WINDINGS, THE INSTANT THAT THE GENERATOR VOLTAGE REACHES A ZERO VALUE, THE CONDENSER WILL DISCHARGE AT A RAPID RATE AS PICTURED BY THE THIRD ILLUSTRATION FROM THE LEFT IN FIG. 11.

THE GENERATOR WILL NOW COMMENCE TO BUILD UP A VOLTAGE OF OPPOSITE POLARITY THAN FORMERLY AND THEREBY CHARGE THE CONDENSER IN THE OPPOSITE DIRECTIONS WHEN THE CONDENSER IS FULLY CHARGED IN THIS DIRECTION, IT WILL AGAIN OPPOSE THE GENERATOR VOLTAGE AND WILL DISCHARGE THROUGH THE GENERATOR AS THE GENERATOR VOLTAGE ONCE MORE APPROACHES A VALUE OF ZERO. THUS THE CHARGING AND DISCHARGING OF THE CONDENSER DURING ONE A. C. CYCLE IS PICTORIALLY ILLUSTRATED IN FIG. 11. THIS SEQUENCE WILL THEN REPEAT ITSELF IN SUCCESSIVE ORDER AS LONG AS THE A. C. VOLTAGE RE-

MAINS APPLIED ACROSS THE CONDENSER PLATES.

IN THIS WAY, YOU CAN SEE THAT A CONDENSER PERMITS A MORE NEARLY CONSTANT FLOW OF ALTERNATING CURRENT BUT THAT THIS CURRENT DOES NOT ACTUALLY FLOW THROUGH THE DIELECTRIC OF THE CONDENSER. IN OTHER WORDS, THE ALTERNATING CURRENT SIMPLY FLOWS BACK AND FORTH THROUGH THE CIRCUIT FROM ONE CONDENSER PLATE TO THE OTHER AS THE CONDENSER UNDERGOES ITS CHARGE AND DISCHARGE WHEN SUBJECTED TO A.C. VOLTAGES. BECAUSE OF THE FACT THAT A FLOW OF ALTERNATING CURRENT IS NEARLY ALWAYS PRESENT THROUGH THE CIRCUIT IN WHICH THE CONDENSER IS CONNECTED, IT IS QUITE COMMON TO SAY THAT A CONDENSER PERMITS AN ALTERNATING CURRENT TO FLOW "THROUGH" IT. HOWEVER, WHAT WE REALLY MEAN IS THAT THE CONDENSER PERMITS A FLOW OF ALTERNATING CURRENT THROUGH THE CIRCUIT IN WHICH IT IS INSTALLED RATHER THAN THROUGH THE CONDENSER ITSELF.

CONDENSER CAPACITY

THE ABILITY OF A CONDENSER TO HOLD OR STORE AN ELECTRICAL CHARGE IS CALLED THE CAPACITY OR CAPACITANCE OF THE CONDENSER AND THE FARAD IS THE THE UNIT FOR MEASURING OR EXPRESSING THE CAPACITY OF A CONDENSER. IF THE VOLTAGE ACROSS A CONDENSER IS RAISED ONE VOLT BY A CHARGING CURRENT OF ONE AMPERE FLOWING INTO THE CAPACITY FOR ONE SECOND, THEN THE CONDENSER WILL HAVE A CAPACITY OF ONE FARAD. THE LETTER "C" IS QUITE OFTEN USED IN RADIO FORMULAS AND DIAGRAMS TO INDICATE CAPACITY. THIS IS SIMPLY DONE AS A MEANS OF CONVENIENCE.

FOR MOST RADIO PURPOSES, THE FARAD IS A RATHER LARGE UNIT TO EMPLOY AND THEREFORE, THE MICROFARAD IS EXTENSIVELY USED. ONE MICROFARAD IS EQUAL TO THE ONE-MILLIONTH PART OF A FARAD AND IT IS ABREVIATED AS "MFD."

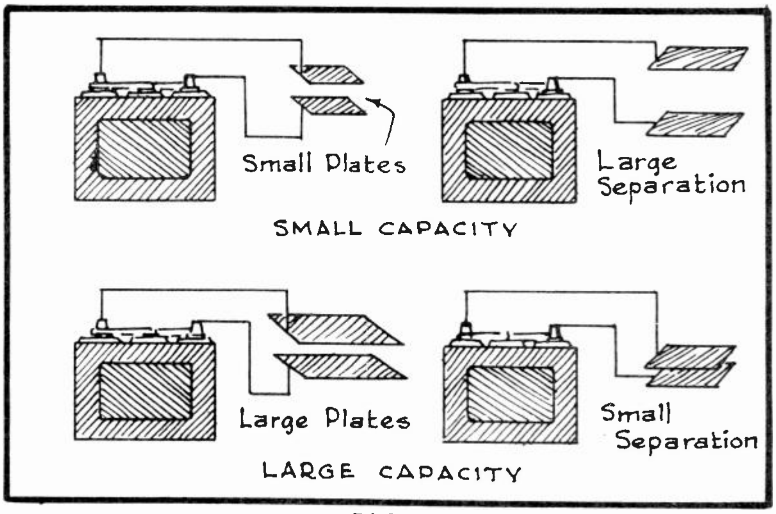

FIG. 12
Effect of Plate Area and Separation Upon Capacity.

SOME OF THE CONDENSERS WHICH ARE USED IN RADIO CIRCUITS HAVE SUCH A SMALL CAPACITY VALUE THAT EVEN THE MICROFARAD IS TOO LARGE A UNIT TO BE EMPLOYED CONVENIENTLY. THE CAPACITY OF THESE SMALL CONDENSERS ARE THEN EXPRESSED IN A STILL SMALLER UNIT THE MICRO-MICROFARAD. ONE MICRO-MICROFARAD IS EQUAL TO THE ONE-MILLIONTH PART OF A MICROFARAD AND IT IS ABREVIATED AS "MMFD."

THE CAPACITY OF A CONDENSER IS AFFECTED VERY MATERIALLY BY THE AREA OF THE PLATES USED, BY THE DISTANCE BETWEEN THE PLATES AND BY THE MATERIAL WHICH IS USED FOR THE DIELECTRIC BETWEEN THE PLATES.

FIG. 12 SHOWS YOU HOW THE AREA OF THE PLATES AND THE SEPARATION BETWEEN THEM AFFECTS THE CAPACITY OF THE CONDENSER. HERE YOU WILL OBSERVE

THAT THE CAPACITY OF THE CONDENSER IS INCREASED BY USING PLATES OF LARGER AREA AND ALSO BY DECREASING THE SEPARATION BETWEEN THE PLATES. THEN IN ADDITION TO THESE FACTORS, WE FIND THAT IF WE SHOULD COMPARE TWO CONDENSERS HAVING EXACTLY THE SAME PLATE AREA AND SEPARATION BETWEEN PLATES BUT ONE OF THEM HAVING A DIELECTRIC CONSISTING OF DRY AIR WHILE THE OTHER HAS A MICA DIELECTRIC, THE CONDENSER WITH THE MICA DIELECTRIC, WILL HAVE THE GREATER CAPACITY.

THE DIELECTRICS WHICH ARE MOST GENERALLY USED FOR RADIO CONDENSERS ARE DRY AIR, PARAFFINE PAPER, AND MICA. IF THE SAME PLATE AREA AND PLATE SEPARATION IS USED, THEN A CONDENSER WITH A DIELECTRIC CONSISTING OF PARAFFINE PAPER WILL HAVE ABOUT TWICE THE CAPACITY OF THE SAME CONDENSER WITH AN AIR DIELECTRIC. SHOULD A MICA DIELECTRIC BE EMPLOYED, THEN THE CAPACITY OF THE CONDENSER WILL BE FROM THREE TO SEVEN TIMES THAT WHICH IS AVAILABLE FROM THE SAME CONDENSER WITH AN AIR DIELECTRIC —THE INCREASE IN CAPACITY BEING DEPENDENT UPON THE GRADE OF MICA USED.

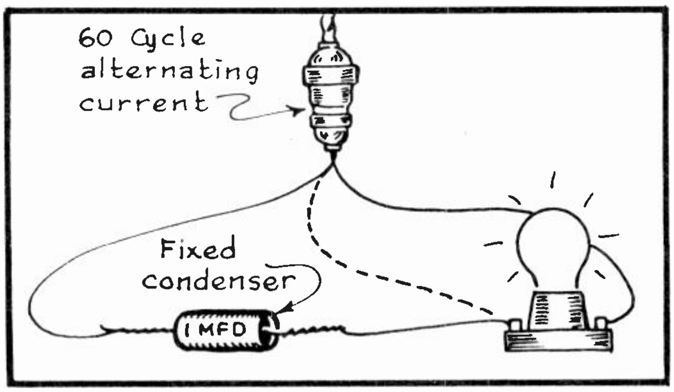

FIG. 13
A Condenser in the Circuit Permits the Lamp to Burn.

EFFECT OF CAPACITY UPON CURRENT

THE INTENSITY OF THE CURRENT FLOW THROUGH AN ALTERNATING CURRENT CIRCUIT IN WHICH A CONDENSER IS INCLUDED WILL INCREASE IF THE CAPACITY OF THE CONDENSER IS INCREASED. THIS CAN BE PROVED BY THE EXPERIMENTS WHICH ARE ILLUSTRATED IN FIGS. 13 AND 14.

IN FIG. 13 WE HAVE A CONDENSER WITH A CAPACITY RATING OF 1 MFD. CONNECTED IN SERIES WITH A 110 VOLT, 60 CYCLE LIGHTING CIRCUIT AND AN INCANDESCENT LAMP. THE FILAMENT OF THE LAMP WILL EMIT A DIM LIGHT, THUS DEMONSTRATING THE FACT THAT THE CONDENSER DOES NOT PREVENT THE FLOW OF ALTERNATING CURRENT ALTOGETHER BUT IT NEVERTHELESS DOES OFFER A DEFINITE OPPOSITION TO SUCH A CURRENT FLOW. SHOULD THE CONDENSER BE ELIMINATED FROM THE CIRCUIT AS WOULD BE THE CASE BY MAKING THE CONNECTION AS INDICATED BY THE DOTTED LINE, THEN THE LAMP WILL LIGHT AT FULL BRILLIANCE.

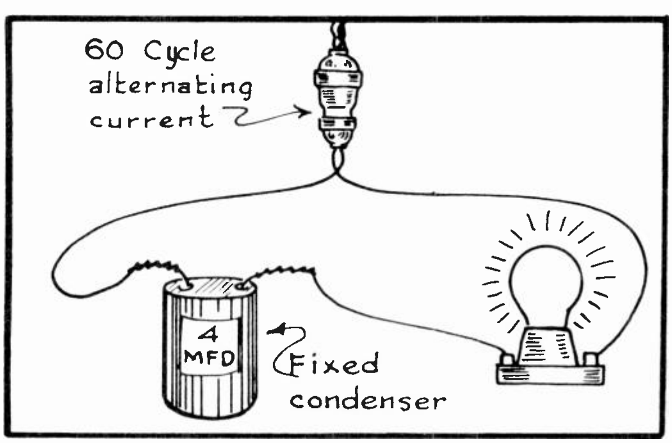

FIG. 14
The Current Increases With An Increase in Capacity.

NOW IF WE SHOULD REPLACE THIS CONDENSER WITH ONE HAVING A CAPACITY RATING OF 4 MFD., AS ILLUSTRATED IN FIG. 14, THEN THE BRILLANCE OF THE LAMP WILL INCREASE CONSIDERABLY AS COMPARED TO THE TEST WITH THE 1 MFD. CONDEN

SER. THEREFORE, WE CAN CONCLUDE THAT THE CONDENSER OF LARGER CAPACITY IN AN ALTERNATING CURRENT CIRCUIT OF GIVEN VOLTAGE AND FREQUENCY WILL PERMIT THE PASSAGE OF A CURRENT OF GREATER INTENSITY.

EFFECT OF FREQUENCY UPON CURRENT FLOW THROUGH A CIRCUIT CONTAINING A CONDENSER

IF WE SHOULD REPEAT THE PREVIOUS EXPERIMENT BY CONNECTING THE 4 MFD. CONDENSER IN SERIES WITH THE LAMP AND THEN CONNECT THIS TEST CIRCUIT TO A 110 VOLT LINE CARRYING A 120 CYCLE A.C. SUPPLY INSTEAD OF A 60 CYCLE CURRENT, THEN THE LAMP FILAMENT WILL EMIT A GREATER QUANTITY OF LIGHT THAN WHEN THE 60 CYCLE CURRENT WAS USED. THIS EXPERIMENT THEN SHOWS THAT FOR THE SAME APPLIED VOLTAGE, THE CURRENT THROUGH A CIRCUIT CONTAINING A CONDENSER INCREASES IF THE FREQUENCY OF THE CURRENT IS INCREASED.

IF THE FREQUENCY OF THE CURRENT SHOULD BE RAISED TO A VALUE OF 240 CYCLES PER SECOND, THE LAMP WOULD EMIT STILL MORE LIGHT, THERE--BY SHOWING THAT THE CURRENT FLOW HAS INCREASED ABOVE ITS PREVIOUS VALUE. IN OTHER WORDS, THE GREATER THE FREQUENCY OF THE APPLIED A.C. VOLTAGE, THE LESS WILL BE THE OPPOSITION OFFERED BY THE CONDENSER TOWARDS THE CURRENT FLOW AND CONSEQUENTLY THE CURRENT INCREASES ACCORDINGLY.

NOTICE CAREFULLY THAT A CONDENSER AFFECTS AN ALTERNATING CURRENT CIRCUIT IN JUST THE OPPOSITE MANNER THAN DOES A COIL. THAT IS, A COIL OFFERS A GREATER OPPOSITION TOWARDS A FLOW OF ALTERNATING CURRENT IF THE FREQUENCY OF THE ALTERNATING CURRENT OR THE INDUCTANCE RATING OF THE COIL IS INCREASED, WHEREAS A CONDENSER OFFERS LESS OPPOSITION TOWARDS A FLOW OF ALTERNATING CURRENT IF THE FREQUENCY OF THE ALTERNATING CURRENT OR THE CAPACITY RATING OF THE CONDENSER IS INCREASED.

THESE POINTS ARE OF EXCEPTIONAL IMPORTANCE AND THEY FORM THE BASIS OF ALL TUNED CIRCUITS USED IN RADIO, AS YOU SHALL SEE UPON READING A LITTLE FARTHER IN THIS LESSON. SO BY ALL MEANS, DO NOT FORGET THESE FACTS.

RADIO TUNING

SO FAR, WE HAVE CONSIDERED THE COIL AND CONDENSER SEPARATELY BUT NOW LET US SEE HOW THEIR COMBINED EFFECTS WILL REACT UPON EACHOTHER IN CIRCUITS CARRYING ALTERNATING CURRENTS OF VERY HIGH FREQUENCY VALUES. FIRST OF ALL, WE FIND THE INDUCTANCE OF A COIL TO OFFER A GREAT DEAL OF OPPOSITION TOWARDS SUCH A CURRENT FLOW AS ILLUSTRATED IN FIG. 15, WHERE AS THE CONDENSER OFFERS VERY LITTLE OPPOSITION AS PICTURED IN FIG. 16— THE TWO HAVING ENTIRELY OPPOSITE CHARACTERISTICS IN THIS RESPECT.

NOW LET US CONNECT THE ENDS OF THE COIL ACROSS THE PLATES OF A CONDENSER AS SHOWN IN FIG. 17 SO AS TO FORM A TUNED CIRCUIT. WE WILL ASSUME THAT AT A CERTAIN INSTANT, THE HIGH FREQUENCY SIGNAL VOLTAGE INDUCES A CURRENT INTO THE WINDING OR COIL OF THE TUNED CIRCUIT SO AS TO CAUSE A CURRENT OR FLOW OF ELECTRONS TO CIRCULATE THROUGH THE TUNED CIRCUIT IN THE DIRECTION INDICATED BY THE ARROW WHICH IS LABELED AS "HIGH FREQUENCY CURRENT"

THIS FLOW OF ELECTRONS WILL OF COURSE CHARGE THE CONDENSER BUT IN ADDITION, THIS SAME FLOW OF ELECTRONS MUST FLOW THROUGH THE COIL AND

In doing so, a magnetic field will build up and thereby generate a counter--electromotive force which will oppose or retard the flow of electrons. That is, the flow of electrons will be slowed up somewhat.

As the A.C. signal voltage drops from its maxinum voltage in this direction to a zero value, the magnetic field around the coil will collapse and tend to keep the condenser charged, while the condenser at the same time has a natural tendency to discharge through the coil. In other words, the condenser and inductance actions are opposing eachother and thereby regulate the speed with which the condenser will either accept a charge or discharge.

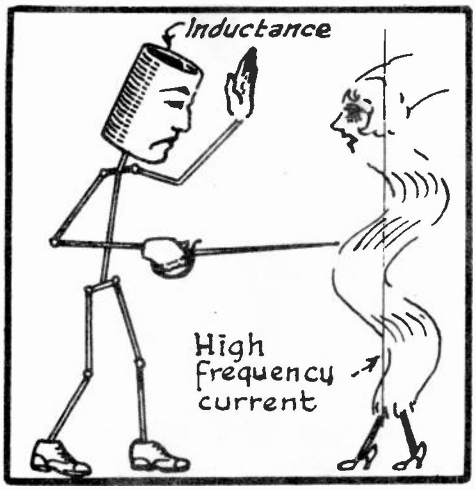

FIG.15

Inductance Opposes High Frequency Currents.

Then as the polarity of the signal voltage reverses, the induced current in the tuned circuit will reverse its direction of flow accordingly, while the condenser will discharge completely and immediately commence to accept a charge of opposite polarity. Again the coil will oppose an increasing flow of current in this direction and thereby slow up the condenser charging process. As the current flow decreases due to the applied signal voltage, the condenser commences to discharge but again this discharging action is retarded by the resulting counter-electromotive force created by the coil.

Altogether then, we have the signal voltage tending to produce a current flow of the signal frequency in the tuned circuit while the opposing effects between the condenser and the coil at the same time only permit the current to flow back and forth or alternate in this circuit at a rate fixed by them. In other words, the natural frequency to which the tuned circuit responds may be anything but the signal frequency. However, by choosing the correct capacity and inductance values, the characteristics of the tuned circuit can be made such that the natural frequency of the condenser charging and discharging currents will correspond to the signal frequency which is induced into the circuit. We then say that the circuit is "tuned" or in RESONANCE with the signal frequency.

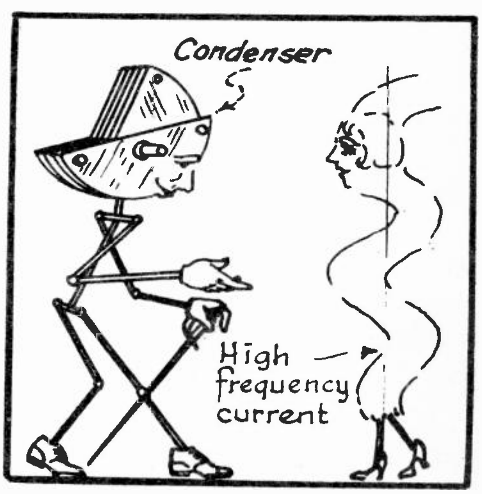

FIG. 16

Capacity Offers Little Opposition to High Frequency Currents.

Another way of visualizing the condition of a tuned circuit at resonance is that at the resonant frequency, the opposition offered by the condenser and coil are exactly equal to each other in value but in opposing directions so that these two forces neutralize each-

OTHER. THE ONLY OPPOSITION OFFERED A CURRENT AT THE RESONANT FREQUENCY THEN WILL BE THE PURE D.C. RESISTANCE OF THE CIRCUIT. THAT IS, THE RESISTANCE OF THE WIRE INCLUDED IN THE WINDINGS OF THE COIL AND IN THE CIRCUIT WIRING. FOR THIS REASON, THE MAXIMUM SIGNAL CURRENT WILL FLOW THROUGH THE TUNED CIRCUIT WHEN THIS CIRCUIT IS TUNED TO RESONANCE WITH THE SIGNAL FREQUENCY.

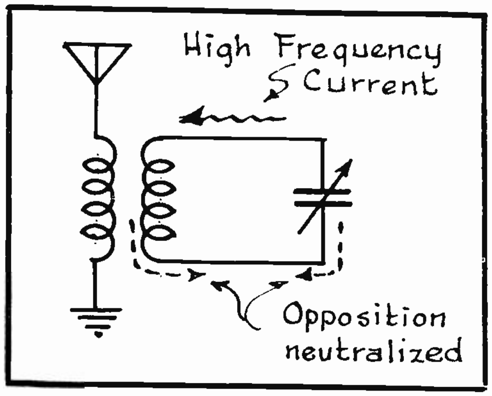

FIG. 17
The Tuned Circuit at Resonance.

THE CONDITIONSOF RESONANCE CAN BE PICTORIALLY ILLUSTRATED BY FIG. 18 WHERE WE HAVE THE OPPOSING FORCES OF CAPACITY AND INDUCTANCE FIGHTING IT OUT SO TO SPEAK, SO THAT NEITHER GETS THE BEST OF THE OTHER. IN THE MEAN TIME, THE HIGH FREQUENCY SIGNAL CURRENT PASSES RIGHT ON THROUGH PRACTICALLY UNMOLESTED.

BY CHANGING THE RELATIVE VALUES BETWEEN THE INDUCTANCE AND CAPACITY, THE TUNED CIRCUIT CAN BE MADE TO RESONATE AT ANY DESIRED FREQUENCY. FOR CONVENTIONAL RADIO TUNING, IT IS GENERALLY THE CUSTOM TO GIVE THE INDUCTANCE A FIXED VALUE BY WINDING THE TUNING COIL TO A CERTAIN SIZE AND A DEFINITE NUMBER OF TURNS. THE TUNING CONDENSER IS THEN BUILT, AS YOU HAVE ALREADY LEARNED, SO THAT ITS CAPACITY CAN BE VARIED AND IN THIS MANNER ALTER THE RELATION BETWEEN THE INDUCTANCE AND CAPACITIVE VALUES SO THE CIRCUIT CAN BE MADE TO RESONATE AT ANY FREQUENCY WITHIN A DEFINITE RANGE.

IF IT IS DESIRED TO RECEIVE A SIGNAL FREQUENCY OF 500Kc., THEN WE SIMPLY ADJUST THE CAPACITY OF THE TUNING CONDENSER SO THAT THE TUNED CIRCUIT WILL RESONATE AT A FREQUENCY OF 500 Kc. THE CIRCUIT WILL THEN OFFER LEAST OPPOSITION TO A FLOW OF SIGNAL CURRENT CORRESPONDING TO 500 Kc. THAN TO ANY OTHER FREQUENCY AND CONSEQUENTLY THIS WILL BE THE SIGNAL WHICH IS "PICKED UP".

THE OPPOSITION WHICH A CONDENSER OFFERS TOWARDS A FLOW OF ALTERNATING CURRENT IS CALLED CAPACITIVE REACTANCE AND IT IS MEASURED IN OHMS THE SAME AS ELECTRICAL RESISTANCE. THE OPPOSITION WHICH A COIL OFFERS TOWARDS A FLOW OF ALTERNATING CURRENT IS CALLED INDUCTIVE REACTANCE AND IT IS ALSO MEASURED IN OHMS.

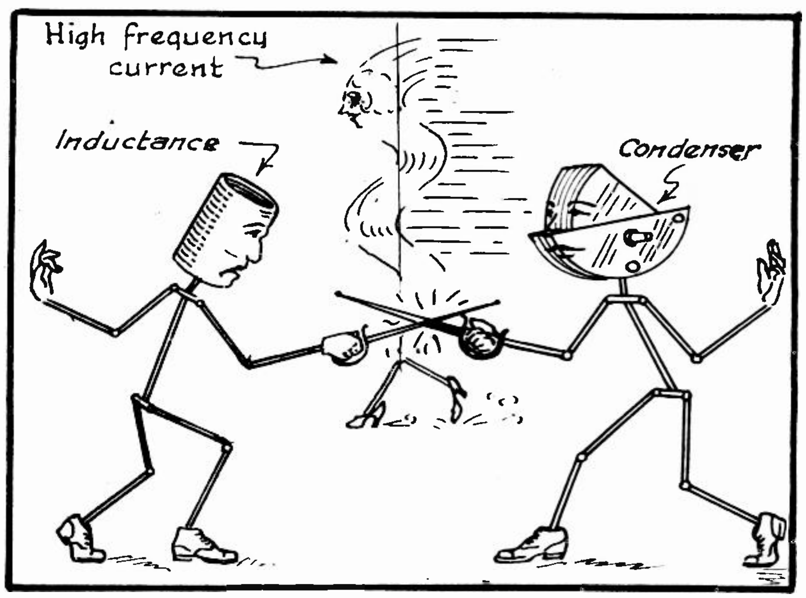

FIG. 18
At Resonance the Opposition of the Condenser is Equal and Opposite to that of the Inductance.

The subject of tuning is of tremendous importance in radio -- not only as applied to receivers but also as applied to transmitters, testing equipment, etc.

For the time being you have a sufficient understanding of tuning circuits so that we can continue with our study of fundamental circuits. However, later in the course you will receive detailed instruction for calculating inductive and capacitive reactance. You will also be shown at that time how to design tuned circuits for various purposes.

With this information of tuning now added to your increasing knowledge of radio, we will discuss the fundamental subject of detector circuits in the next lesson. As you progress with your study of detector circuits you will also realize what tremendous strides have been made in the development of this section of the receiver. Radical development and improvement of this nature makes radio such a highly interesting study.

TRAINING AND APPLICATION

All business as now conducted -- particularly those lines of business which embrace the so-called industries -- requires specialized training and technical education, in fact so much scientific knowledge that the distinctive line between "business" and "profession" is fast disappearing.

Any one who hopes to achieve success, even the average, must know more, or at least as much, about some one thing as anyother one, and not only know, but know how to do -- and how to utilize his experience and knowledge for the benefit of others.

The crying evil of the young man who enters the industrial world today is the lack of application, preparation, and thoroughness, with ambition but without the willingness to struggle to gain his desired end. Mental and physical strength comes only thru the exercise and working of mind and body.

There is too little idea of personal responsibility; too much of "the world owes me a living," forgetting that if the world does owe you a living, you yourself must be your own collector.

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LESSON NO. 9

DETECTOR CIRCUITS

Now that you are in a general way familiar with the simple receiver circuits, we are going to continue at this time by studying in detail the operation of grid leak and power type detector circuits. In order to keep this study as simple as possible, we are going to limit ourselves in this lesson to the detector circuit alone so that you will only have a single tube to think about. Then in the following lessons we shall enlarge the receiver by adding R.F. and A.F. stages to the detectors which are going to be explained in the present lesson.

So far, we have only considered the variable condenser as a means for tuning radio receivers, since this is the most popular system now being used. However, let us at this time look back a few years into the development of radio and check up on some of the different systems of receiver tuning which have been used in the past. In fact, the principles of some of these tuning systems are still being used to some extent in a modified form. The most modern detector systems are covered in a later lesson.

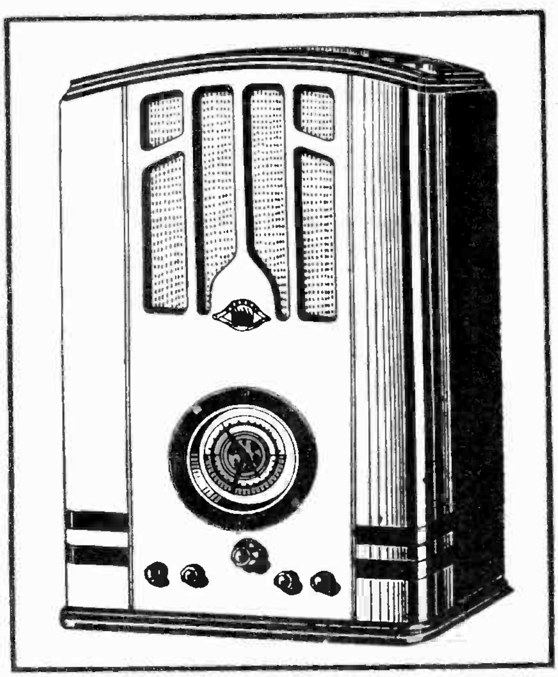

FIG. 1
A Table Model Receiver

The oldest tuning device is illustrated for you in Fig. 2. It is known as a SLIDE tuner and met with a great deal of popularity many years ago. As you will observe in Fig. 2, this unit consists of a coil of many turns of small size insulated wire wound on a section of tubing made of some such insulating material as varnished cardboard or bakelite. Enameled copper wire was often used for this purpose, that is, copper wire having a coating of baked enamel--the enamel serving as insulation for the copper conductor.

ONE END OF THIS WINDING OR COIL IS CONNECTED TO A TERMINAL WHICH IS MARKED "ANT". IN FIG. 2 WHILE ITS OTHER END IS SIMPLY FASTENED TO THE WINDING FORM SO AS TO PREVENT THE COIL FROM UNWINDING. THIS END, HOWEVER, IS NOT ELECTRICALLY CONNECTED TO ANYTHING BUT IS LEFT FREE AS SHOWN IN THE DIAGRAMATIC REPRESENTATION OF THE TUNER IN FIG. 3 AND IN WHICH CASE ITS CONNECTION TO THE CIRCUIT ARE ALSO POINTED OUT.

THE COIL IS SUPPORTED BETWEEN TWO INSULATIVE END PIECES SUCH AS WOOD OR BAKELITE AND A RAIL MADE OF A BRASS BAR OR ROD IS ALSO SUPPORTED BETWEEN THE END PIECES SLIGHTLY ABOVE THE COIL BUT PARALLEL TO IT.

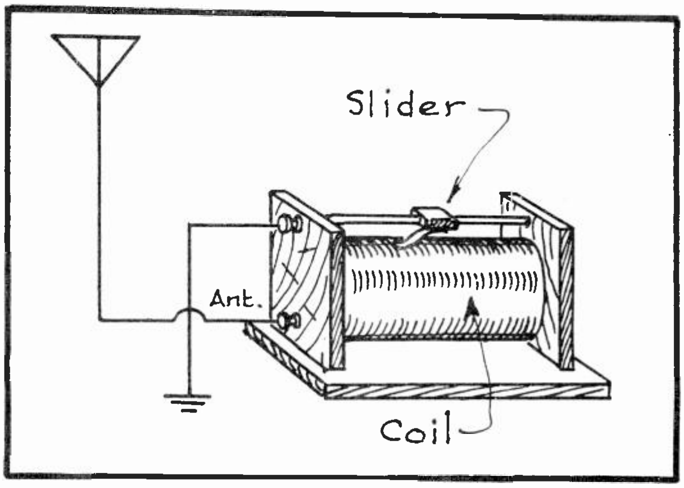

FIG. 2
The "Slide" Tuner

A SLIDING METAL CONTACT OR SLIDER IS MOUNTED ON THE BRASS RAIL AND THE ARRANGEMENT IS SUCH THAT THIS CONTACT CAN BE SLID FREELY ALONG THE ENTIRE LENGTH OF THE RAIL.

THE INSULATION IS REMOVED FROM THE WINDING DIRECTLY BELOW THE RAIL, SO THAT THE WIPING CONTACT OF THE SLIDER WILL CONTINUALLY BEAR AGAINST THE BARE COPPER WIRE OF THE WINDING AS IT IS SLID BACK AND FORTH ALONG THE RAIL. IN OTHER WORDS, A NON-INSULATED TRACK IS PROVIDED ALONG THE LENGTH OF THE WINDING, SO THAT THE SLIDER WILL ALWAYS BE IN DIRECT CONTACT WITH THE COPPER WIRE OF THE WINDING NO MATTER AT WHICH POINT OF THE RAIL IT MAY BE AT ANY PARTICULAR INSTANT. A TERMINAL IS FASTENED TO THIS RAIL AND THIS TERMINAL IS CONNECTED TO GROUND AS SHOWN BOTH IN FIGS. 2 AND 3. THE SLIDER CONTACT IS INDICATED IN FIG. 3 BY THE ARROW HEAD WHICH TOUCHES THE WINDING SYMBOL.

BY STUDYING FIG. 3 VERY CAREFULLY, YOU WILL OBSERVE THAT AS THE THE SLIDER IS MOVED FARTHER TOWARD THE RIGHT, MORE TURNS OF THE COIL WILL BE INCLUDED BETWEEN THE ANTENNA AND GROUND, THEREBY INCREASING THE INDUCTANCE WHICH IS INCLUDED IN THE ANTENNA CIRCUIT. AS THE SLIDER IS MOVED FARTHER TOWARDS THE LEFT IN FIG. 3, LESS TURNS OF THE WINDING WILL BE INCLUDED IN THE ANTENNA CIRCUIT AND THEREBY REDUCE THE EFFECTIVE INDUCTANCE OF THIS CIRCUIT.

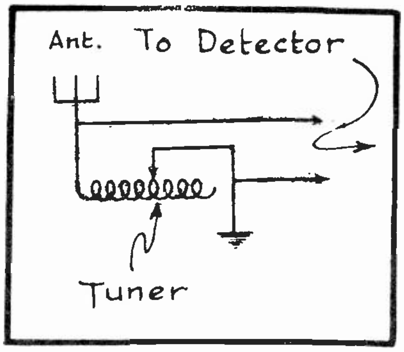

FIG. 3
Circuit for the slide Tuner

ANY ALTERATION IN THE INDUCTANCE OF THE CIRCUIT, WHICH IS BROUGHT ABOUT IN THIS MANNER, WILL VARY THE FREQUENCY CHARACTERISTIC OF THE CIRCUIT AND THEREBY OFFER TUNING FASCILITIES THE SAME AS WILL THE VARIATION OF CAPACITY IN THE CIRCUIT. IN FACT, IN THE SLIDER TUNER WE NOT ONLY HAVE INDUCTANCE TO WORK WITH, BUT A CERTAIN AMOUNT CAPACITY AS WELL.

THE CAPACITY WHICH IS AVAILABLE IN

This slide tuning circuit is made possible through the distributed capacity offered by the winding itself.

DISTRIBUTED CAPACITY OFFERED BY COILS

Fig. 4 shows you how a coil or winding can offer capacity in addition to inductance. A condenser, you will remember, consists of two metal conductors separated from eachother by some form of dielectric. In the case of a coil, any two adjacent turns of the wire also offer two metallic surfaces which are separated from eachother by either the insulation of the wire or by a slight air space between them and therefore each pair of adjacent turns serve or act as a condenser of very small capacity. This condition is illustrated by the smaller condensers which are indicated between each pair of adjacent turns in the drawing.

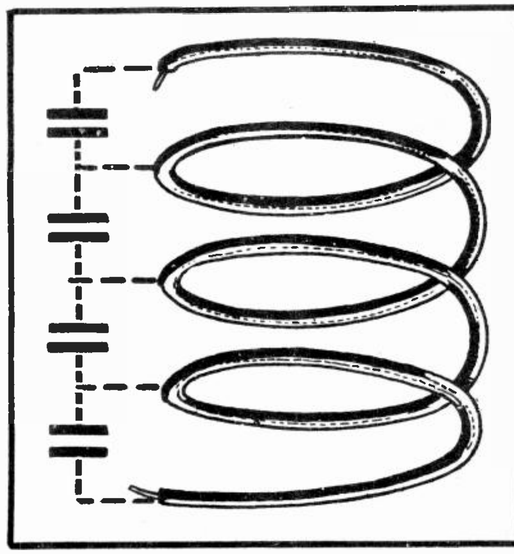

FIG. 4
Distributed Capacity.

Since the winding as a whole consists of a great many turns of wire, the capacity effect between each pair of adjacent turns will be accumulative, with the result that the complete winding will have an appreciable amount of capacity in addition to inductance. We call this the DISTRIBUTED CAPACITY of the coil or winding.

Besides the distributed capacity of the coil, we have still another source of capacity to deal with in this simple circuit of Fig. 3 and that is the capacity effect which is offered by the antenna system. The antenna installation, consisting of the elevated antenna wire and ground can also be considered as a condenser of small capacity. The elevated antenna wire in this case being considered as one plate of the condenser and ground as the other plate, while the air space between the antenna wire and ground serves as the dielectric. Hence we have in effect the antenna capacity included in the tuned circuit, that is, the winding of the tuner is connected across a condenser of which the antenna wire serves as one plate and ground as the other plate, thereby in itself constituting a tuned circuit.

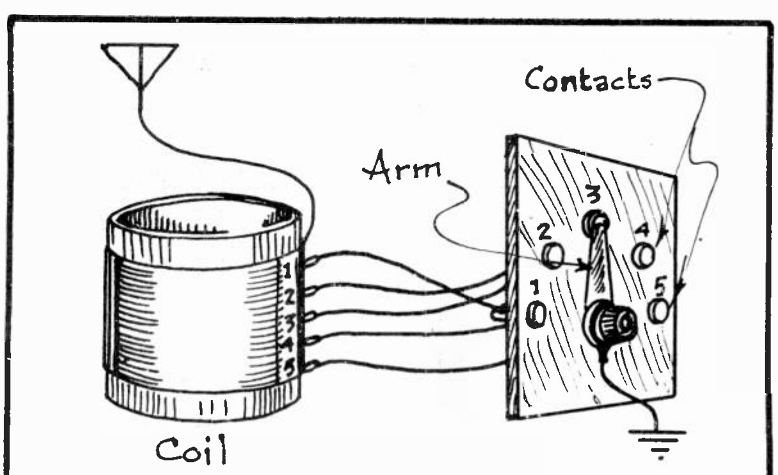

FIG. 5
The Tapped Inductance and Switch.

Altogether then, you can now see that by changing the position of the slider con

TACT OF OUR TUNER, WE WILL BE ALTERING BOTH THE CAPACITIVE AND INDUCTIVE VALUES OF THE CIRCUIT. IN THIS WAY, THE CIRCUIT CAN BE RESONATED TO MANY DIFFERENT FREQUENCIES AND ALTHOUGH NOT PROVIDING SUCH A HIGH DEGREE OF SELECTIVITY AS WE KNOW IT TODAY, IT NEVERTHELESS DOES PERMIT REASONABLY SATISFACTORY TUNING.

TUNING WITH A TAPPED INDUCTANCE

ANOTHER ELEMENTARY FORM OF TUNER IS ILLUSTRATED IN FIG. 5. HERE THE COIL IS ALSO WOUND ON A PIECE OF INSULATIVE TUBING BUT AFTER A CERTAIN NUMBER OF TURNS HAVE BEEN APPLIED, A CONNECTION IS BROUGHT OUT TO A CONTACT BUTTON. SUCH A LEAD WHICH IS BROUGHT OUT FROM A COIL IS CALLED A TAP AND THE COIL AS A WHOLE IS CALLED A TAPPED COIL OR TAPPED INDUCTANCE.

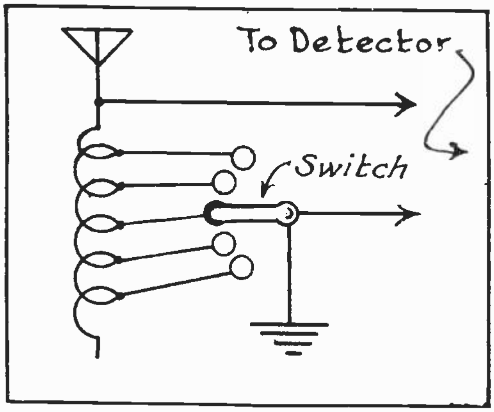

FIG. 6
Circuit for the tapped Inductance

THE CONTACT BUTTONS FOR THE VARIOUS COIL TAPS ARE MOUNTED ON A PANEL OF INSULATIVE MATERIAL AND IN SUCH A MANNER THAT A METAL ARM CAN BE REVOLVED ABOUT ITS CENTER SO AS TO ESTABLISH CONTACT WITH ANY ONE OF THE CONTACT BUTTONS DESIRED. THESE CONTACT BUTTONS, TOGETHER WITH THE CONTROL ARM CONSTITUTE AN INDUCTANCE SWITCH.

FIG. 6 SHOWS YOU HOW SUCH A TAPPED COIL IS USED FOR TUNING PURPOSES IN AN ELEMENTARY CIRCUIT. NOTICE THAT ONE END OF THE WINDING IS CONNECTED TO THE ANTENNA WHILE THE SUCCESSIVE TAPS ARE CONNECTED TO INDIVIDUAL CONTACT BUTTONS OF THE INDUCTANCE SWITCH. THE ARM OF THE SWITCH IS GROUNDED AND AT THE SAME TIME GOES TO ONE SIDE OF THE DETECTOR CIRCUIT AND THE ANTENNA END OF THE COIL GOES TO THE OTHER SIDE OF THE DETECTOR CIRCUIT.

BY CHANGING THE POSITION OF THE SWITCH ARM, THE NUMBER OF COIL TURNS INCLUDED IN THE CIRCUIT CAN BE VARIED. THEREFORE, THE INDUCTANCE AND DISTRIBUTED CAPACITY WILL BE VARIED ACCORDINGLY AND THUS MAKE TUNING POSSIBLE.

THE VARIOMETER

IN FIG. 7, YOU WILL SEE AN ENTIRELY DIFFERENT TUNING ARRANGEMENT. THIS UNIT IS KNOWN AS A VARIOMETER AND IT IS MADE UP OF TWO COILS WHICH ARE CONNECTED IN SERIES AND WOUND IN SUCH A MANNER SO THAT ONE OF THE COILS CAN BE ROTATED WITHIN THE OTHER. THE COIL WHICH IS WOUND WITHIN THE FRAME OF THE UNIT DOES NOT ALTER ITS POSITION AND IS THEREFORE CALLED THE STATIONARY WINDING. THE COIL WHICH IS WOUND ON THE SPECIAL ROTOR FORM IS CALLED THE ROTOR WINDING.

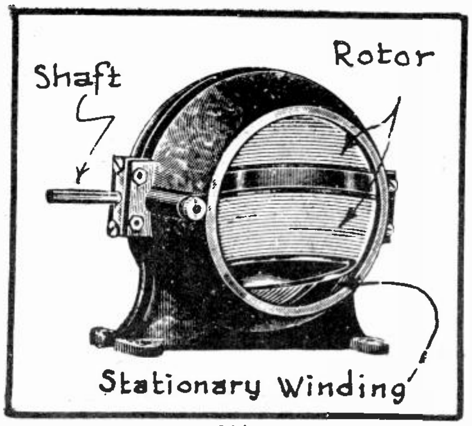

FIG. 7
The Variometer.

THE POSITION OF THE ROTOR AND ITS WINDING CAN BE REGULATED AT THE WILL OF THE OPERATOR THROUGH THE CONTROL SHAFT AND KNOB WHICH IS ATTACHED TO IT.

BY TURNING THE ROTOR TO A CERTAIN POSITION, THE COUNTER-ELECTROMOTIVE FORCE PRODUCEDIN ONE OF THE COILS BY THE SIGNAL VOLTAGE WILL OPPOSE THAT OF THE OTHER COIL, WITH THE RESULT THAT THE EFFECTIVE INDUCTANCE VALUE IS VERY SMALL. IF THE ROTOR IS SET TO THE POSITION DIRECTLY OPPOSITE, THEN THE TWO WINDINGS WILL NO LONGER OPPOSE EACHOTHER BUT INSTEAD, WILL ASSIST EACHOTHER TO INCREASE THE INDUCTANCE OF THE CIRCUIT.

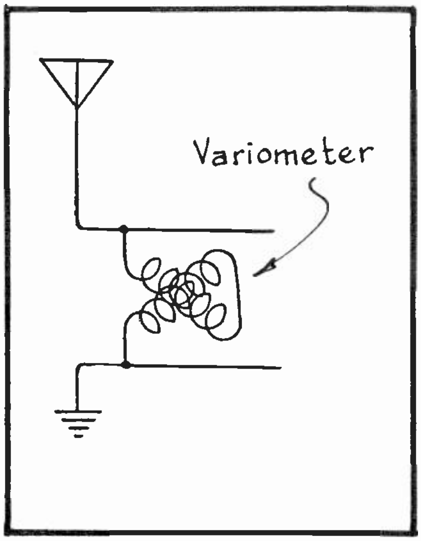

FIG.8
Application of the Variometer.

THUS, YOU CAN SEE THAT TUNING CAN BE ACCOMPLISHED BY ALTERING THE EFFECTIVE INDUCTANCE OF THE VARIOMETER CIRCUIT. FIG.8 ILLUSTRATES HOW THE VARIOMETER IS CONNECTED INTO THE CIRCUIT AND AS YOU WILL OBSERVE, ONE OF ITS COIL ENDS IS CONNECTED TO THE ANTENNA AND ONE SIDE OF THE DETECTOR CIRCUIT, WHILE ITS OTHER COIL END IS CONNECTED TO GROUND AND THE OTHER SIDE OF THE DETECTOR CIRCUIT. THE ANTENNA CAPACITY AND DISTRIBUTED CAPACITY OF THE VARIOMETER WINDINGS WILL OF COURSE REACT UPON THE CIRCUIT AS ALREADY EXPLAINED FOR THE OTHER TUNED CIRCUITS WHICH WERE SO FAR DESCRIBED.

THERE ARE ALSO OTHER ARRANGEMENTS ADAPTABLE TO SIMPLE TUNING CIRCUITS AS THIS BUT THE ONES WHICH WERE JUST SHOWN YOU ARE THE MOST SIMPLE ONES, AS WELL AS BEING THE MOST POPULAR DURING THE PROGRESS MADE IN RADIO RECEIVER CONSTRUCTION. FURTHERMORE, WITH A GOOD UNDERSTANDING OF THESE, YOU WILL BE ABLE TO UNDERSTAND ANY OTHER SIMILAR SYSTEM QUITE EASILY SINCE THEY WILL GENERALLY BE BASED UPON THESE SAME PRINCIPLES.

COUPLED CIRCUITS

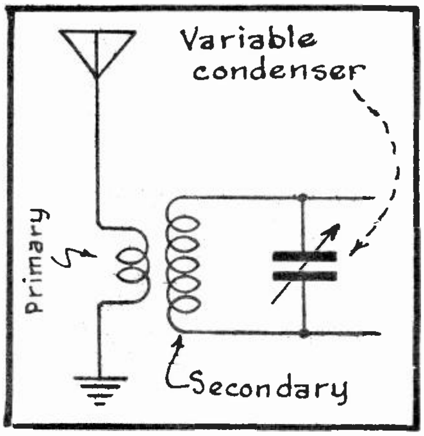

FIG.9
Inductively Coupled Circuits.

ALL OF THE RECEIVER INPUT CIRCUITS, WHICH WERE SHOWN YOU SO FAR IN THIS LESSON, ARE DIRECT COUPLED CIRCUITS. THAT IS, THE ANTENNA SYSTEM WAS CONNECTED DIRECTLY TO THE TUNING CIRCUIT AND THE TUNING CIRCUIT WAS AT THE SAME TIME DIRECTLY CONNECTED TO THE DETECTOR CIRCUIT.

NOW LET US TURN OUR ATTENTION TO FIG. 9. HERE WE HAVE THE MOST POPULAR FORM OF RECEIVER INPUT CIRCUIT AND WITH WHICH YOU ARE ALREADY FAMILIAR. IN THIS CASE, NO ADJUSTABLE TUNING PROVISIONS ARE MADE IN THE ANTENNA CIRCUIT, SO THAT ALL FREQUENCIES WILL HAVE ACCESS TO THIS CIRCUIT. THE SECONDARY WINDING OF THE R.F. TRANSFORMER, HOWEVER, HAS A VARIABLE CONDENSER CONNECTED ACROSS IT AND THEREFORE THE SECONDARY CIR-

CUIT ONLY IS TUNED.

SINCE THERE IS NO DIRECT CONNECTION BETWEEN THE ANTENNA AND TUNED CIRCUITS IN FIG. 9 AND THE SIGNAL ENERGY BEING TRANSFERRED FROM THE ANTENNA TO THE TUNED CIRCUIT BY ELECTROMAGNETIC INDUCTION IN THIS INSTANCE, WE CLASSIFY A CIRCUIT OF THIS TYPE AS AN INDUCTIVELY COUPLED CIRCUIT.

LOOSE AND CLOSE COUPLING

IF THE PRIMARY AND SECONDARY WINDINGS OF AN R.F. TRANSFORMER ARE SPACED AT CONSIDERABLE DISTANCE FROM EACHOTHER AS ILLUSTRATED AT THELEFT OF FIG. 10, THEN THERE WILL BE CONSIDERABLE MAGNETIC LEAKAGE. THAT IS, ONLY A RELATIVELY SMALL PORTION OF THE LINES OF FORCE PRODUCED AROUND THE PRIMARY WINDING WILL BE ABLE TO REACT UPON THE SECONDARY WINDING, WITH THE RESULT THAT THE VOLTAGE INDUCED INTO THE SECONDARY WINDING WILL RELATIVELY SMALL. WE THEN SAY THAT THE TWO WINDINGS AND THEIR RESPECTIVE CIRCUITS ARE LOOSELY COUPLED.

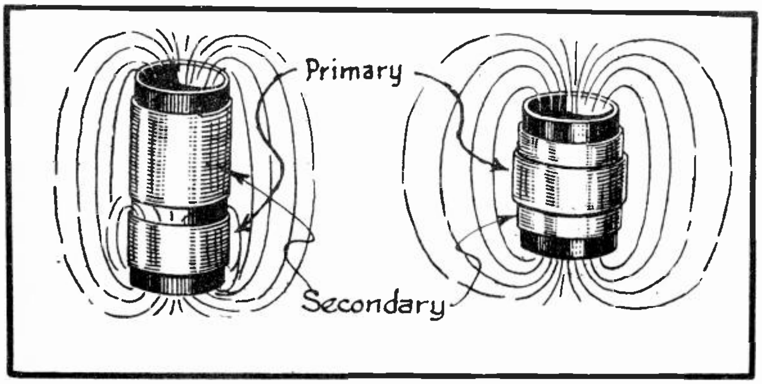

FIG. 10
Loose and Close Coupling.

ON THE OTHER HAND, IF THE PRIMARY WINDING IS PLACED CLOSER TO THE SECONDARY SO THAT A GREATER PORTION OFTHE PRIMARYWINDING'S LINES OF FORCE WILL ACT UPON THE SECONDARY WINDING, THEN WE SAY THAT THE WINDINGS ARE CLOSE COUPLED OR TIGHT COUPLED. AT THE RIGHT OF FIG. 10, FOR EXAMPLE, THE PRIMARY WINDING IS WOUND DIRECTLY OVER THE SECONDARY WINDING BUT INSULATED FROM IT, THEREFORE THESE TWO WINDINGS WILL BE CLOSELY COUPLED. IN OTHER WORDS, THE RELATION BETWEEN THE PRIMARY AND SECONDARY WINDINGS IS NOW SUCH THAT A LARGE PORTION OF THE PRIMARY WINDING'S LINES OF FORCE WILL BE AVAILABLE FOR INDUCING THE SIGNAL VOLTAGES INTO THE SECONDARY WINDING. THEREFORE, THERE WILL BE A CONSIDERABLE TRANSFER OF ENERGY BETWEEN THE TWO WINDINGS.

AN INTERESTING POINT CONCERNING THE DEGREE OF COUPLING BETWEEN THE ANTENNA CIRCUIT AND THE TUNED CIRCUIT OF THE SIMPLE RECEIVER IS THAT ALTHOUGH CLOSE COUPLING LEADS TOWARDS MAXIMUM ENERGY TRANSFER THROUGH THE R.F. TRANSFORMER, YET GREATER SELECTIVITY WILL BE OBTAINED THROUGH THE USE OF LOOSE COUPLING. THAT IS, WITH LOOSE COUPLING, IT WILL BE EASIER TO SEPARATE ONE STATION FROM ANOTHER WHILE TUNING THAN IS POSSIBLE WITH CLOSE COUPLING BUT THE VOLUME OF SIGNAL WILL OF COURSE BE DECREASED ACCORDINGLY.

VARIABLE COUPLING

NOT ONLY DOES THE DISTANCE BETWEEN TWO COILS AFFECT THE DEGREE OF COUPLING BETWEEN THEM BUT THE ANGULAR POSITION WHICH THESE TWO COILS BEAR TO EACHOTHER WILL ALSO DETERMINE THE EXTENT OF COUPLING BETWEEN THEM. THIS

IS ILLUSTRATED FOR YOU IN FIG. 11, WHERE WE HAVE EACH OF TWO COILS WOUND ON A SEPARATE FORM.

AT "A" OF FIG. 11, THE POSITION OF THE TWO COILS IS SUCH THAT A COMMON AXIS PASSES THROUGH THE CENTER OF BOTH. ASSUMING THE UPPER COIL TO BE THE PRIMARY WINDING, YOU CAN READILY SEE THAT THE RELATION BETWEEN THE TWO COILS AT THIS TIME PERMITS THE GREATER PORTION OF THE PRIMARY WINDING'S LINES OF FORCE TO ENCIRCLE THE SECONDARY WINDING AS WELL. CONSEQUENTLY, THERE WILL BE A MAXIMUM OF ENERGY TRANSFER FROM THE PRIMARY TO THE SECONDARY WINDING AT THIS TIME.

NOW AT "B" OF FIG. 11, THE ANGULAR POSITION OF THE PRIMARY WINDING HAS BEEN CHANGED SOMEWHAT, SO THAT THE CENTER LINE OF THE PRIMARY WINDING NO LONGER COINCIDES WITH THE CENTER LINE OF THE SECONDARY WINDING. IT IS OBVIOUS THAT UNDER THESE CONDITIONS, THE PRIMARY WINDINGS' LINES OF FORCE CANNOT ALL ENCIRCLE THE SECONDARY WINDING—IN FACT, ONLY A RELATIVELY SMALL PORTION OF THE PRIMARY'S LINES OF FORCE WILL HAVE THE OPPORTUNITY OF ACTING UPON THE SECONDARY WINDING. THIS NATURALLY RESULTS IN A MARKED DECREASE IN ENERGY TRANSFER BETWEEN THE TWO WINDINGS.

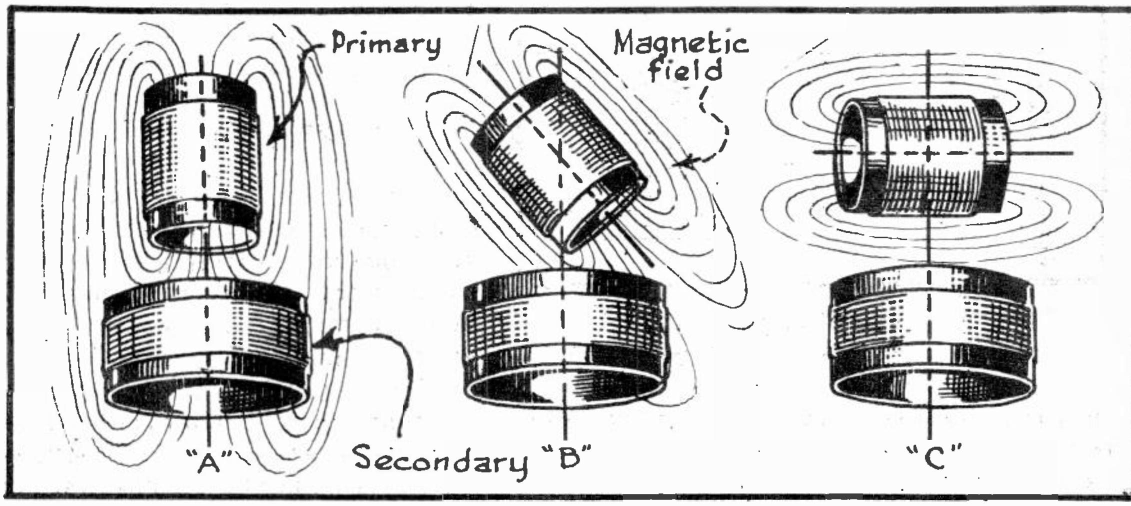

FIG. 11
Variable Coupling.

FINALLY, AT "C" OF FIG. 11 WE FIND THE AXIS OF THE PRIMARY WINDING TO BE AT RIGHT ANGLES TO THAT OF THE SECONDARY WINDING. THIS PERMITS PRACTICALLY NONE OF THE PRIMARY'S MAGNETIC FIELD TO ENCIRCLE THE SECONDARY WINDING AND THEREFORE THERE WILL BE NO APPRECIABLE AMOUNT OF ENERGY TRANSFER BETWEEN THEM.

REGARDLESS OF WHETHER THE PRIMARY OR SECONDARY WINDING SHOULD BE THE STATIONARY COIL WHILE THE ANGULAR POSITION OF THE OTHER IS VARIED, THE RESULTS WILL BE THE SAME.

A PRACTICAL APPLICATION OF THIS

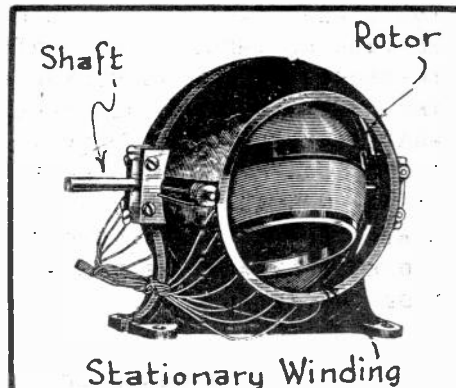

FIG. 12
The Vario-Coupler

PRINCIPLE IS ILLUSTRATED FOR YOU IN FIG. 12, IN THE FORM OF THE VARIO-COUPLER. BY STUDYING THIS UNIT, YOU WILL OBSERVE THAT IT CONSISTS OF A SHELL OF INSULATIVE MATERIAL, PROVIDED WITH A WINDING AROUND ITS INNER SURFACE. THIS PARTICULAR WINDING CORRESPONDS TO THE STATIONARY WINDING OF FIG. 11.

A ROTOR, WHICH IS ALSO MADE OF INSULATIVE MATERIAL, IS RIGIDLY MOUNTED ON A SHAFT AND SUPPORTED WITHIN THE SHELL. THE ROTOR IS PROVIDED WITH AN INDIVIDUAL WINDING. THE POSITION OF THE ROTOR WITHIN THE SHELL CAN THEN BE CONTROLLED AT THE WILL OF THE OPERATOR BY ACTUATING A CONTROL KNOB WHICH IS ATTACHED TO THE END OF THE ROTOR SHAFT AND IN THIS WAY, THE ANGULAR POSITION OF THE ROTOR WINDING IS CHANGED IN RESPECT TO THE STATIONARY WINDING. THEREFORE, THE DEGREE OF COUPLING BETWEEN THE TWO WINDINGS WILL BE ALTERED CORRESPONDINGLY AND THEREBY OFFER A MEANS FOR CONTROLLING THE AMOUNT OF ENERGY TRANSFER BETWEEN THE WINDINGS.

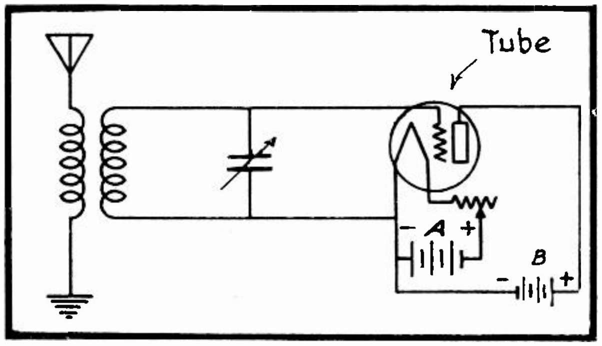

FIG. 13
The Amplifier Circuit.

AN AMPLIFIER CIRCUIT

NOW THAT YOU ARE A LITTLE MORE FAMILIAR WITH THE DIFFERENT TUNING SYSTEMS, COUPLING ETC., LET US NEXT CONNECT A TUNED CIRCUIT TO A VACUUM TUBE IN THE MANNER AS ILLUSTRATED IN FIG. 13. NOTICE ESPECIALLY IN THIS DIAGRAM THAT AN "A" BATTERY AND RHEOSTAT ARE CONNECTED ACROSS THE FILAMENT OF THE TUBE, THAT THE POSITIVE TERMINAL OF A "B" BATTERY IS CONNECTED TO THE PLATE OF THE TUBE, WHILE ITS NEGATIVE TERMINAL IS CONNECTED TO THE NEGATIVE TERMINAL OF THE "A" BATTERY AND THAT ONE SIDE OF THE TUNED CIRCUIT IS CONNECTED TO THE TUBE'S GRID AND ITS OTHER SIDE TO THE NEGATIVE SIDE OF THE TUBE FILAMENT.

OUR NEXT STEP WILL BE TO ANALYZE THE OPERATION OF THIS CIRCUIT. WE FIND FIRST THAT IF THE TUBE FILAMENT IS PERMITTED TO BE ADEQUATELY HEATED BY THE "A" SUPPLY, IT WILL EMIT ELECTRONS. THEN SINCE THE PLATE OF THE TUBE IS MAINTAINED AT A POSITIVE PLATE POTENTIAL BY THE "B" BATTERY, THE ELECTRONS WILL BE ATTRACTED TOWARDS THE PLATE AND THEREBY ALLOW "B" BATTERY CURRENT OR PLATE CURRENT TO FLOW THRU THE TUBE. IN OTHER WORDS, PLATE CURRENT WILL NOW BE FLOWING THROUGH THE PLATE CIRCUIT OF THE TUBE. WITH NO SIGNAL VOLTAGES BEING APPLIED TO THE TUBE'S GRID, THE PLATE CURRENT WILL REMAIN CONSTANT OR STEADY IN VALUE AND WE THEREFORE CALL IT THE NORMAL PLATE CURRENT. THIS NORMAL PLATE CURRENT IS REPRESENTED BY THE DOTTED HORIZONTAL LINE TO THE RIGHT OF THE TUBE IN FIG. 14.

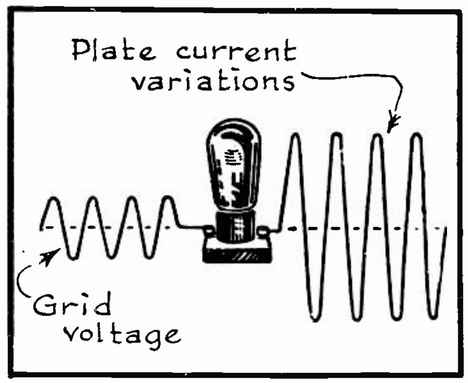

FIG. 14
The tube as an amplifier.

NOW IF WE SHOULD TUNE THE CIRCUIT SO THAT RADIO SIGNALS OF A DEFINITE FREQUENCY ARE RECEIVED, THEN ALTERNATING

VOLTAGES OF CORRESPONDING FREQUENCY WILL BE APPLIED ACROSS THE GRID CIRCUIT OF THE TUBE. THIS MEANS THAT THE POTENTIAL OF THE GRID WILL BE REVERSED PERIODICALLY IN RAPID SUCCESSION.

AT THE INSTANT THAT A POSITIVE VOLTAGE IS APPLIED TO THE GRID, THE PLATE CURRENT WILL INCREASE SOMEWHAT ABOVE ITS NORMAL VALUE. AS THE SIGNAL VOLTAGE DECREASES TO ZERO, THE PLATE CURRENT WILL RETURN TO ITS NORMAL VALUE BUT WHEN THE GRID POTENTIAL IS MADE MORE NEGATIVE BY THE INCOMING SIGNAL, THE PLATE CURRENT WILL REACH A POINT WHICH IS LESS THAN ITS NORMAL VALUE.

THUS IT FOLLOWS THAT AS THE SIGNAL VOLTAGES CHANGE THE POTENTIAL OF THE GRID, A SIMILAR OR CORRESPONDING CHANGE WILL OCCUR IN THE FLOW OF PLATE CURRENT, HOWEVER, THE PLATE CURRENT CHANGES WILL BE GREATER IN MAGNITUDE THAN THE CORRESPONDING CHANGES OF GRID POTENTIALS. THIS CONDITION CAN THEN BE ILLUSTRATED AS IN FIG. 14.

THE CURVE TO THE LEFT OF THE TUBE IN FIG. 14 ILLUSTRATES THE ALTERNATING SIGNAL VOLTAGE AS APPLIED TO THE TUBE'S GRID, WHEREAS THE CURVE TO RIGHT OF THE TUBE REPRESENTS THE CORRESPONDING INCREASES AND DECREASES IN PLATE CURRENT IN RESPECT TO THE NORMAL PLATE CURRENT.

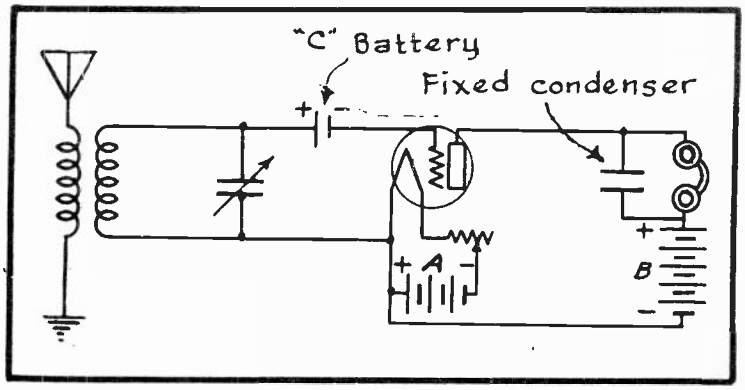

FIG. 15

Power Detector Circuit.

BY STUDYING THIS ILLUSTRATION VERY CAREFULLY, YOU WILL NOTE THAT THE INCREASES IN PLATE CURRENT ARE EXACTLY EQUAL IN VALUE TO THE DECREASES IN PLATE CURRENT, ONLY IN OPPOSITE DIRECTION. FOR THIS REASON, VARIATIONS IN PLATE CURRENT WILL OCCUR AT RADIO FREQUENCIES THE SAME AS THE SIGNAL VOLTAGES WHICH ARE APPLIED TO THE GRID AND WOULD THEREFORE BE INAUDIBLE. IN OTHER WORDS, IF A PAIR OF HEADPHONES WERE INCLUDED IN THE PLATE CIRCUIT, NO SIGNAL SOUNDS WOULD BE HEARD.

WHAT WE REALLY HAVE IN FIG. 13 IS AN AMPLIFIER CIRCUIT AND SINCE THE PLATE CURRENT VARIATIONS OCCUR AT RADIO FREQUENCIES, THIS PARTICULAR AMPLIFIER CIRCUIT IS LOGICALLY CLASSIFIED AS A RADIO FREQUENCY AMPLIFIER OR SIMPLY R.F. AMPLIFIER.

POWER DETECTION

NOW LET US MAKE SOME MINOR CHANGES IN THE CIRCUIT OF FIG. 13 SO THAT IT WILL BE CONVERTED TO A DETECTOR. THE REVISED CIRCUIT WILL THEN APPEAR AS ILLUSTRATED IN FIG. 15. OBSERVE THAT A SET OF HEADPHONES HAVE NOW BEEN INCLUDED IN THE PLATE CIRCUIT, WITH A FIXED CONDENSER CONNECTED ACROSS THEM. IN ADDITION, AN EXTRA BATTERY, WHICH WE CALL THE "C" BATTERY, HAS BEEN PLACED IN THE GRID CIRCUIT OF THE TUBE.

THE IMPORTANT THING TO REMEMBER ABOUT THIS "C" BATTERY IS THAT ITS NEGATIVE TERMINAL IS CONNECTED TO THE GRID OF THE TUBE, THEREBY MAINTAIN-

ING THE GRID AT A SLIGHTLY NEGATIVE POTENTIAL AT ALL TIMES. WE THEN SAY THAT THE TUBE IS BEING OPERATED WITH A NEGATIVE BIAS. SHOULD THE "C" BATTERY IN QUESTION PROVIDE A VOLTAGE OF 3 VOLTS, THEN THE TUBE IN THIS CASE WOULD BE CONSIDERED AS BEING OPERATED WITH A BIAS VOLTAGE OF -3 VOLTS.

RETURNING TO OUR CIRCUIT OF FIG. 15 AGAIN, WE FIND THAT IF R.F. SIGNAL VOLTAGES ARE NOW APPLIED TO THE GRID OF THE TUBE, CORRESPONDING VARIATIONS IN PLATE CURRENT WILL AGAIN OCCUR BUT SINCE THE "C" BATTERY KEEPS THE GRID SLIGHTLY NEGATIVE IN SPITE OF THE POSITIVE SIGNAL VOLTAGES WHICH ARE APPLIED TO IT, THE INCREASES IN PLATE CURRENT WILL BE CONSIDERABLY GREATER THAN THE DECREASES IN PLATE CURRENT WITH RESPECT TO THE NORMAL PLATE CURRENT VALUE. THEREFORE, WE OBTAIN A FORM OF RECTIFICATION, WHICH IS ONE OF THE REQUIREMENTS FOR DETECTION, AS YOU WILL REMEMBER FROM YOUR PREVIOUS STUDIES. THIS IS AGAIN ILLUSTRATED FOR YOUR CONVENIENCE IN FIG. 16, WHERE THE GRID OR SIGNAL VOLTAGE VARIATIONS ARE REPRESENTED BY THE CURVE TO THE LEFT OF THE TUBE AND THE CORRESPONDING PLATE CURRENT VARIATIONS TO THE RIGHT OF THE TUBE. THE INCREASES IN PLATE CURRENT, YOU WILL OBSERVE, ARE MUCH GREATER THAN THE DECREASES.

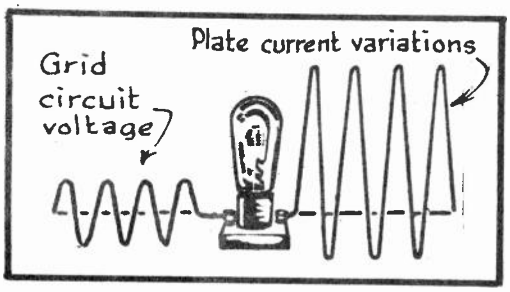

FIG.16

The tube as a detector.

QUITE OFTEN, YOU WILL HEAR OF THIS TYPE OF SIGNAL RECTIFICATION SPOKEN OF AS PLATE CIRCUIT RECTIFICATION BUT IT IS STILL MORE COMMON TO SPEAK OF IT AS POWER DETECTION.

FIG. 17 WILL AID YOU IN VISUALIZING MORE CLEARLY WHY THE SIGNAL IS AUDIBLE AFTER RECTIFICATION IN THIS MANNER. THIS ILLUSTRATION SHOWS YOU HOW A MODULATED WAVE FORM PRODUCES AN AVERAGE CHANGE IN THE PLATE CIRCUIT OF THE DETECTOR TUBE AND IT IS THESE AVERAGE CHANGES IN THE PLATE CURRENT FLOWING THROUGH THE WINDINGS OF THE HEADPHONES WHICH MAKE THE SIGNALS OR RADIO SOUNDS AUDIBLE. THE "PEAKS" OF THE PLATE CURRENT VARIATIONS WHICH ARE ALSO SHOWN IN FIG. 17 OCCUR AT RADIO FREQUENCIES AND THEIR FREQUENCY VALUE IS THEREFORE TOO HIGH TO BE RECOGNIZED AS SOUND, AND FURTHERMORE, THE HEADPHONE DIAPHRAGMS WILL NOT RESPOND TO SUCH HIGH FREQUENCIES.

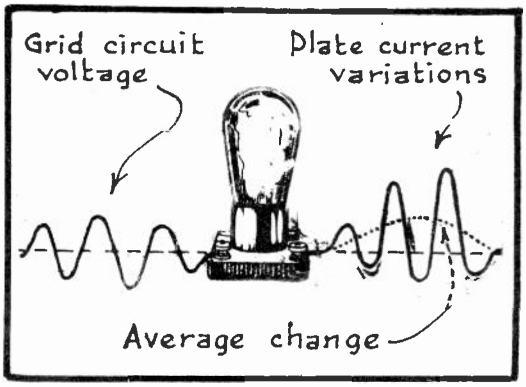

FIG.17

The Audible Component

ALTHOUGH IT IS TRUE THAT SIGNAL RECTIFICATION OR DETECTION CAN ALSO BE BROUGHT ABOUT BY REVERSING THE "C" BATTERY CONNECTIONS SO THAT THE GRID OF THE TUBE IS MAINTAINED AT A POSITIVE POTENTIAL, YET SUCH A SYSTEM IS NOT SATISFACTORY FOR GOOD PERFORMANCE. THE REASON FOR THIS IS THAT A POSITIVELY CHARGED GRID WILL HAVE A NATURAL TENDENCY TO ATTRACT

ELECTRONS AND THIS WOULD RESULT IN AN ACCUMULATION OF ELECTRONS UPON THE GRID AND A FLOW OF ELECTRONS THROUGH THE GRID CIRCUIT. SUCH A CONDITION WILL DESTROY THE TONE QUALITY OF THE RECEIVED SIGNALS, THEREBY OFFERING DISTORTED RECEPTION. THIS IS NOT THE CASE WHEN OPERATING THE TUBE WITH A NEGATIVE GRID BIAS VOLTAGE.

OBJECT OF THE PHONE CONDENSER

AS WAS ALREADY MENTIONED, THE REMAINING PEAKS OF THE RECTIFIED SIGNAL AS PICTURED IN FIG. 17 ARE OF A RADIO-FREQUENCY ORDER AND OF NO PARTICULAR VALUE AFTER DETECTION HAS TAKEN PLACE. THEREFORE, IN ORDER TO PREVENT THEIR TRYING TO FORCE THEMSELVES THROUGH THE COMPARATIVELY HIGH INDUCTANCE OFFERED BY THE HEADPHONE WINDINGS, A FIXED CONDENSER IS CONNECTED ACROSS THE HEADPHONES.

A CONDENSER, YOU WILL RECALL, OFFERS LESS OPPOSITION TO CURRENT VARIATIONS AS THE FREQUENCY INCREASES, WHEREAS THE EFFECT PRODUCED BY AN INDUCTANCE IS JUST THE OPPOSITE. THEREFORE, IT STANDS TO REASON THAT INSTEAD OF THE HIGH FREQUENCY COMPONENT OF THE RECTIFIED SIGNAL ATTEMPTING TO FLOW THROUGH THE DIFFICULT PATH OFFERED BY THE INDUCTANCE OF THE HEADPHONE WINDINGS, THEY WILL UTILIZE THE PATH OFFERED BY THE PHONE CONDENSER INSTEAD. AS A RESULT, THE HIGH FREQUENCY COMPONENT IS ELIMINATED FROM THE HEADPHONE WINDINGS ALTOGETHER AND ONLY THE AVERAGE PLATE CURRENT VARIATIONS WHICH OCCUR AT AUDIO FREQUENCIES REMAIN TO ACTUATE THE HEADPHONE DIAPHRAGMS TO PRODUCE THE SOUNDS.

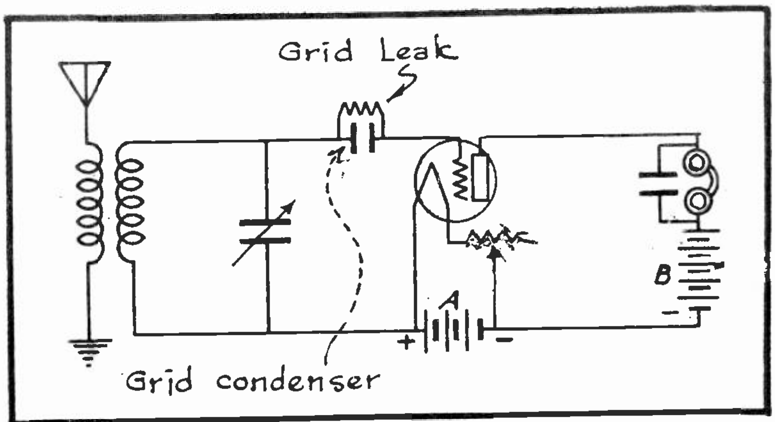

FIG. 18
A Detector Circuit with Grid Condenser and Leak.

THE CAPACITIVE VALUE OF THIS CONDENSER MUST OF COURSE BE SUCH THAT IT WILL BE LARGE ENOUGH TO PERMIT THE FLOW OF RADIO FREQUENCY CURRENTS BUT NOT LARGE ENOUGH TO PASS AUDIO FREQUENCY CURRENTS. THE A.F. CURRENTS MUST BE CONFINED TO THE CIRCUIT OFFERED BY THE WINDINGS OF THE HEADPHONES.

DETECTION WITH A GRID CONDENSER AND LEAK RESISTOR

NOW LET US STUDY IN GREATER DETAIL THE OPERATION OF A DETECTOR CIRCUIT WHICH WAS ALREADY INTRODUCED TO YOU IN AN EARLIER LESSON. THIS CIRCUIT IS ILLUSTRATED IN FIG. 18 AND NO DOUBT, YOU WILL IMMEDIATELY NOTICE THE FACT THAT A GRID CONDENSER AND LEAK RESISTOR ARE EMPLOYED IN THE GRID CIRCUIT OF THE TUBE.

FIRST, LET US CONSIDER WHAT OCCURS IN THE CIRCUIT OF FIG. 18 IF THE LEAK RESISTOR WERE ENTIRELY ELIMINATED. THIS BEING THE CASE, WE

FIND THAT IF A SIGNAL WERE "TUNED-IN", THE HIGH FREQUENCY SIGNAL VOLTAGES WOULD STILL BE IMPRESSED UPON THE GRID OF THE TUBE FOR THE SIMPLE REASON THAT THE CONDENSER OFFERS COMPARATIVELY LITTLE OPPOSITION TO SUCH HIGH FREQUENCIES. HOWEVER, AS FAR AS ALL DIRECT CURRENT OR D.C. VOLTAGES ARE CONCERNED, THE TUBE'S GRID IS COMPLETELY ISOLATED FROM THE REST OF THE CIRCUIT BECAUSE THE GRID CONDENSER PREVENTS D.C. ENERGY FROM PASSING THROUGH A CIRCUIT IN WHICH IT IS INCLUDED.

NOW THEN, WHENEVER A POSITIVE SIGNAL POTENTIAL IS APPLIED TO THE GRID OF THE TUBE, A CERTAIN NUMBER OF THE ELECTRONS, WHICH ARE EMITTED BY THE FILAMENT, WILL BE ATTRACTED BY THE POSITIVELY CHARGED GRID AND SOME OF THESE ELECTRONS WILL ACTUALLY BE DEPOSITED UPON THE GRID AT THIS TIME.

EACH TIME THAT THE GRID GOES POSITIVE, MORE ELECTRONS WILL BE DEPOSITED UPON IT. SINCE THESE ELECTRONS ARE IN REALLITY NEGATIVE ELECTRICAL CHARGES, THEIR ACCUMULATION UPON THE GRID WILL HAVE A NATURAL TENDENCY TO MAKE THE GRID ASSUME A NEGATIVE POTENTIAL. EVENTUALLY, SUCH A LARGE QUANTITY OF ELECTRONS WILL HAVE ACCUMULATED UPON THE GRID, SO THAT THE GRID WILL BECOME NEGATIVELY CHARGED TO SUCH AN EXTENT AS TO STOP THE FLOW OF PLATE CURRENT ALTOGETHER. WE THEN SAY THAT THE TUBE IS "BLOCKED" AND ITS FUNCTION AS A TUBE WOULD CEASE.

TO PREVENT THIS BLOCKING OF THE TUBE, WE CONNECT A RESISTOR OF RATHER HIGH OHMIC VALUE ACROSS THE PLATES OF THE GRID CONDENSER. THIS RESISTOR WILL THEN OFFER A SUITABLE PATH WHEREBY THE ELECTRONS WHICH HAVE ACCUMULATED UPON THE GRID MAY "DRAIN" OFF THE GRID AND BY FLOWING THROUGH THE SECONDARY WINDING OF THE R.F. TRANSFORMER, RETURN TO THE FILAMENT OF THE TUBE FROM WHENCE THEY ORIGINALLY CAME. IN OTHERWORDS, THIS RESISTOR OFFERS A D.C. COMMUNICATION BETWEEN THE GRID OF THE TUBE AND THE REST OF THE CIRCUIT AND SINCE IT LITERALLY PERMITS THE ELECTRONS TO LEAK OFF THE GRID, IT IS LOGICALLY CALLED A "GRID LEAK RESISTOR" OR SIMPLY "LEAK RESISTOR".

DUE TO THE HIGH RESISTANCE VALUE OF THE RESISTOR USED FOR THIS PURPOSE, THE HIGH FREQUENCY SIGNAL VOLTAGES WILL STILL BE APPLIED TO THE GRID THROUGH THE GRID CONDENSER. THE VALUE OF THIS RESISTOR IS ALSO SUFFICIENTLY GREAT SO THAT IT SOMEWHAT RETARDS THE LEAKAGE FLOW OF ELECTRONS OFF THE GRID, CAUSING THIS DRAINAGE TO OCCUR AT A RATHER SLOW RATE.

THE "TRICK" OF THIS CIRCUIT IS TO CHOOSE THE GRID CONDENSER AND LEAK RESISTOR VALUES SO THAT THERE WILL BE A DEFINITE ACCUMULATION OF ELECTRONS UPON THE GRID DURING ONE-HALF OF AN AUDIO CYCLE CONTAINED IN A RECEIVED WAVE TRAIN AND THAT THESE ELECTRONS WILL ALSO HAVE THE OPPORTUNITY OF DRAINING OFF THE GRID BEFORE THE NEXT WAVE TRAIN COMES IN. A "WAVE TRAIN" CONSISTS OF ALL THE R.F. VARIATIONS IN SIGNAL VOLTAGE WHICH OCCUR DURING THE TIME ONE CYCLE OF AUDIO OR SOUND CURRENT MODULATION TAKES PLACE.

SINCE THE BUILDING UP OF THE NEGATIVE POTENTIAL UPON THE GRID, AS WELL AS THE REDUCTION OF THIS NEGATIVE POTENTIAL BY THE ELECTRON DRAINAGE OCCUR DURING EACH AUDIO CYCLE OF THE RECEIVED WAVE FORM, THE AVERAGE CHANGE IN THE FLOW OF PLATE CURRENT WILL VARY CORRESPONDINGLY, THAT IS, AT AUDIO FREQUENCIES. THIS AVERAGE CHANGE IN THE PLATE CURRENT WILL

THEN ACTUATE THE HEADPHONE DIAPHRAGMS TO PRODUCE THE SOUNDS, WHILE ANY REMAINING R.F. RIPPLE IN THE PLATE CURRENT WILL BE BY-PASSED AROUND THE HEADPHONE WINDINGS THROUGH THE PHONE CONDENSER, AS ALREADY EXPLAINED TO YOU.

IN VIEW OF THE FACT THAT THE AVERAGE GRID POTENTIAL IS VARIED AT AUDIO FREQUENCIES RATHER THAN AT THE R.F. FREQUENCIES OF THE RECEIVED SIGNAL, WE ACTUALLY HAVE A FORM OF SIGNAL RECTIFICATION IN THE GRID CIRCUIT. FOR THIS REASON, THIS TYPE OF DETECTION IS OFTEN SPOKEN OF AS GRID CIRCUIT RECTIFICATION.

AS A GENERAL RULE, A GRID CONDENSER HAVING A CAPACITY RATING OF .00025 MFD., USED IN CONJUNCTION WITH A GRID LEAK RESISTOR OF 2 MEGOHMS WILL BRING ABOUT SATISFACTORY DETECTOR OPERATION. HOWEVER, BESIDES THESE TWO SPECIFIED VALUES, THERE ARE ALSO OTHER SUITABLE CONDENSER AND LEAK RESISTOR VALUE COMBINATIONS WHICH WILL SERVE FOR THIS PURPOSE AND THEY WILL BE BROUGHT TO YOUR ATTENTION AS YOU PROGRESS WITH YOUR STUDIES.

ANOTHER IMPORTANT POINT WHICH YOU SHOULD REMEMBER ABOUT GRID CONDENSER AND LEAK DETECTION IS THAT IN ORDER TO OBTAIN THE BEST PERFORMANCE, THE GRID RETURN CIRCUIT SHOULD BE CONNECTED TO THE POSITIVE SIDE OF THE "A" SUPPLY. THIS YOU WILL FIND TO BE THE CASE IN FIG. 18. BY MAKING THE CIRCUIT CONNECTION IN THIS MANNER, A SLIGHT INITIAL POSITIVE POTENTIAL WILL BE IMPRESSED UPON THE TUBE'S GRID BY THE "A" BATTERY THRU THE GRID LEAK RESISTOR. THIS THEN, WILL CAUSE THE ELECTRONS TO MORE READILY COMMENCE THEIR ACCUMULATION UPON THE GRID TO START THE DETECTOR ACTION.

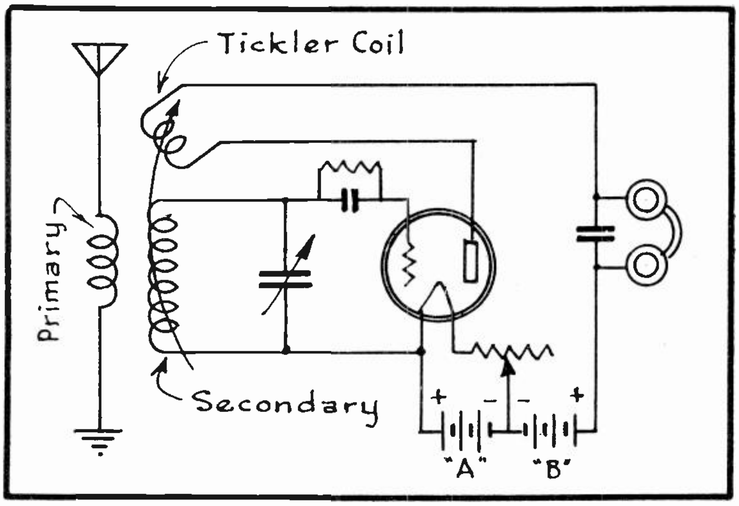

FIG. 19

The Regenerative Detector

REGENERATION

SINCE THE SINGLE TUBE RECEIVER DOES NOT OFFER A GREAT DEAL OF SIGNAL VOLUME, VARIOUS METHODS HAVE BEEN TRIED TO INCREASE THE SIGNAL STRENGTH IN RECEIVERS OF THIS TYPE. THE MOST POPULAR AND SATISFACTORY METHOD SO FAR DISCOVERED TO ACCOMPLISH THIS PURPOSE IS KNOWN AS REGENERATION.

A SIMPLE FORM OF REGENERATIVE DETECTOR IS ILLUSTRATED FOR YOU IN THE CIRCUIT DIAGRAM OF FIG. 19. AS YOU WILL OBSERVE, THE CIRCUIT AS A WHOLE IS QUITE SIMILAR TO THE ONE TUBE RECEIVERS WHICH WERE ALREADY BROUGHT TO YOUR ATTENTION. HOWEVER, AN IMPORTANT ADDITION EXISTS IN THE FORM OF AN EXTRA WINDING WHICH IS INCLUDED BETWEEN THE PLATE OF THE TUBE AND THE HEADPHONES. THIS WINDING CONSISTS OF ONLY A RELATIVELY FEW TURNS OF WIRE AND IT IS PLACED IN AN INDUCTIVE RELATIONSHIP WTTH THE SECONDARY OR TUNED WINDING. WE GENERALLY REFER TO THIS SMALL

WINDING AS THE REGENERATION WINDING OR TICKLER COIL.

IT IS A COMMON OCCURRENCE TO FIND THIS TICKLER COIL WOUND ON A ROTOR SIMILAR TO THAT OF THE VARIOMETER OR VARIO-COUPLER WHICH ARE ILLUSTRATED IN THIS LESSON. IN THIS CASE, THE PRIMARY AND SECONDARY WINDINGS WILL BE STATIONARY AND INDUCTIVELY COUPLED, WHILE THE DEGREE OF COUPLING BETWEEN THE TICKLER COIL AND SECONDARY WINDING IS ALTERED BY CHANGING THE ANGULAR POSITION OF THE TICKLER COIL. A UNIT AS THIS IS CALLED A THREE-CIRCUIT TUNER AND THE DIAGONAL ARROW WHICH IS DRAWN THROUGH ITS SYMBOL, AS ILLUSTRATED IN FIG. 19, POINTS OUT THE FACT THAT THE DEGREE OF COUPLING BETWEEN THE TICKLER COIL AND THE OTHER WINDINGS IS VARIABLE OR ADJUSTABLE.

NOW LET US INVESTIGATE THE OPERATION OF THIS REGENERATIVE DETECTOR OF FIG. 19. FIRST, WE FIND THAT THE SIGNAL VOLTAGES ARE APPLIED TO THE GRID OF THE TUBE IN THE NORMAL MANNER AND WE THEREFORE OBTAIN AN AUDIO FREQUENCY VARIATION OR COMPONENT, TOGETHER WITH A CERTAIN AMOUNT OF RADIO FREQUENCY RIPPLES IN THE PLATE CIRCUIT OF THE TUBE. ALL OF THESE PLATE CURRENT VARIATIONS MUST FLOW THROUGH THE TICKLER COIL.

THIS CURRENT VARIATION THROUGH THE TICKLER COIL WILL CAUSE CORRESPONDING MAGNETIC FIELD FLUCTUATIONS AND BY COUPLING THE TICKLER COIL QUITE CLOSE TO THE TUNED WINDING, THESE MAGNETIC FIELD VARIATIONS WILL REACT UPON THE TUNED WINDING AND INDUCE CORRESPONDING VOLTAGE CHANGES IN IT. SINCE THESE VOLTAGE VARIATIONS ALREADY CORRESPOND TO THE SIGNAL VOLTAGES BEING RECEIVED AND WHICH ARE ALREADY PRESENT IN THE TUNED CIRCUIT, WE OBTAIN AN ACCUMULATIVE ACTION WHICH TENDS TO INTENSIFY THE OSCILLATIONS IN THE TUNED CIRCUIT, WITH THE RESULT THAT THE SIGNAL VOLTAGES WHICH ARE APPLIED TO THE GRID ARE OF GREATER INTENSITY THAN ORDINARILY AND THEREBY CAUSE GREATER CURRENT VARIATIONS IN THE PLATE CIRCUIT. THIS, OF COURSE MEANS, MORE ENERGY TO ACTUATE THE HEADPHONE DIAPHRAGMS AND THUS BRINGS ABOUT AN AUDIBLE SIGNAL OF GREATER INTENSITY.

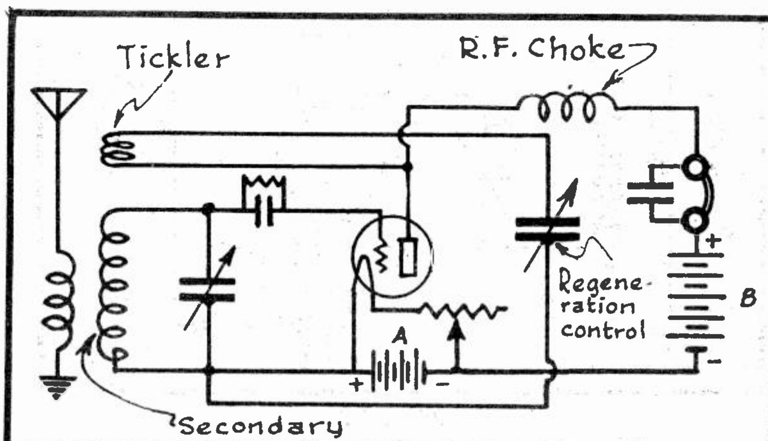

FIG. 20
Condenser Control of Regeneration.

WHAT WE ARE REALLY DOING IN THIS REGENERATIVE CIRCUIT IS TO USE THE RADIO-FREQUENCY CHANGES WHICH ARE STILL PRESENT IN THE PLATE CIRCUIT AND RETURN THEM TO THE GRID CIRCUIT, SO THAT THE TUBE CAN AMPLIFY THEM AGAIN. BY VARYING THE POSITION OF THE ROTOR AND COUPLING BETWEEN THE TICKLER AND SECONDARY WINDINGS, WE ARE ABLE TO CONTROL THE AMOUNT OF REGENERATION AND AMPLIFICATION.

THERE IS A LIMIT TO THE THE AMOUNT OF REGENERATION WHICH CAN BE USED, FOR IF EXCESSIVE REGENERATION EXISTS, A CRITICAL POINT IS REACHED AT WHICH THE CIRCUIT COMMENCES TO OSCILLATE AND PRODUCE SQUEALING NOIS

ES IN THE HEADPHONES.

CONTROLLING REGENERATION WITH A CONDENSER

IN FIG. 20, YOU WILL SEE ANOTHER METHOD WHEREBY REGENERATION MAY BE CONTROLLED. IN THIS CASE, A TICKLER COIL IS ALSO USED BUT ITS POSITION IN RELATION TO THE TUNED WINDING IS FIXED AND CANNOT BE ALTERED. THAT IS, THE PRIMARY, SECONDARY AND TICKLER WINDINGS ARE ALL WOUND ON THE SAME PIECE OF TUBING AND INDUCTIVELY COUPLED.

ONE END OF THIS TICKLER COIL IS CONNECTED TO THE PLATE OF THE TUBE WHILE ITS OTHER EXTREMITY IS CONNECTED TO ONE SIDE OF A VARIABLE CONDENSER. THE OTHER SIDE OF THIS CONDENSER IS CONNECTED TO THE GRID RETURN CIRCUIT OR A+. ANOTHER WINDING, WHICH IS CALLED AN R.F. CHOKE, IS CONNECTED BETWEEN THE PLATE OF THE TUBE AND THE HEADPHONES.

THE RADIO FREQUENCY VARIATIONS IN THE PLATE CIRCUIT OF THIS TUBE FIND IT VERY DIFFICULT TO PASS THROUGH THE R.F. CHOKE BECAUSE THE INDUCTANCE OF THIS UNIT OFFERS A GREAT DEAL OF OPPOSITION TOWARDS HIGH FREQUENCY CURRENTS BUT IT PERMITS THE AUDIO FREQUENCY VARIATIONS TO PASS THROUGH IT WITH EASE.

THE TICKLER COIL CONSISTS OF ONLY A FEW TURNS OF WIRE AND THEREFORE PROVIDES VERY LITTLE INDUCTANCE SO THAT THE HIGH FREQUENCY VARIATIONS CAN PASS THROUGH IT SATISFACTORILY. THE VARIABLE CONDENSER, WHICH IS CONNECTED TO THE TICKLER COIL, ALSO PERMITS THE HIGH FREQUENCY CURRENT VARIATIONS TO PASS THROUGH IT WITH EASE.

WITH CONDITIONS AS DESCRIBED, THE OPPOSING EFFECT OF THE R.F. CHOKE WILL FORCE THE HIGH FREQUENCY VARIATIONS TO PASS THROUGH THE TICKLER WINDING AND REGENERATION CONTROL CONDENSER. AS THIS CONDENSER IS ADJUSTED TO PROVIDE GREATER CAPACITY, MORE OF THIS R.F. ENERGY WILL FLOW THROUGH IT AND THE TICKLER WINDING, THEREBY INCREASING REGENERATION AND AMPLIFICATION OF THE SIGNAL. AS THE CAPACITY OF THIS CONDENSER IS REDUCED BY TURNING ITS ROTOR PLATES FARTHER OUT OF MESH, LESS R.F. ENERGY WILL PASS THROUGH THE TICKLER COIL AND THE REGENERATIVE ACTION WILL THEREFORE DECREASE.

IN FIG. 21 YOU WILL SEE A DETAILED DRAWING OF HOW THE VARIOUS PARTS OF THE CIRCUIT ILLUSTRATED IN FIG. 20 ARE ARRANGED AND CONNECTED TOGETHER ON THE ACTUAL RECEIVER. THE VALUES OF ALL PARTS ARE ALSO SPECIFIED FOR YOUR INFORMATION. THE CIRCUIT AS HERE ILLUSTRATED, IS INTENDED TO EMPLOY A TYPE -01 A TUBE, AND A 6 VOLT STORAGE BATTERY FOR THE "A" SUPPLY. THE R.F. CHOKE CAN BE OF THE REGULAR COMMERCIAL BROADCAST TYPE HAVING AN INDUCTANCE RATING OF 85 MILLIHENRIES OR CAN BE CONSTRUCTED BY WINDING 300 TURNS OF #30 SINGLE COTTON COVERED WIRE IN BUNCH FASHION ON AN INSULATIVE FORM HAVING A DIAMETER OF ABOUT ¼".

THIS SAME CIRCUIT CAN ALSO BE ADAPTED TO THE USE OF A TYPE -30 TUBE BY USING TWO SERIES CONNECTED #6 DRY CELLS FOR THE "A" SUPPLY AND A RHEOSTAT HAVING A RATED VALUE OF 20 OHMS. THIS RHEOSTAT SHOULD THEN BE ADJUSTED SO THAT A VOLTAGE OF TWO VOLTS IS AVAILABLE ACROSS THE FILAMENT TERMINALS OF THE TUBE SOCKET.

THE VARIABLE CONDENSERS AND RHEOSTAT CAN BE MOUNTED ON A CONTROL PANEL WITH THEIR RESPECTIVE DIALS AND CONTROL KNOB, WHILE ALL OTHER parts can be mounted on a base-board. When wiring the circuit, special precaution should be taken so that the grid circuit wiring does not run parallel to the plate circuit wiring, as this will cause coupling between these two circuits and produce oscillation with resulting whistling and squealing sounds in the headphones.

If the connections at the ends of the tickler coil should be reversed, no regeneration would be obtained. In fact, reversed connections at this point would cause the magnetic energy of the tickler coil to buck signal energy in the tuned circuit rather than to help build it up. Therefore, if upon constructing a receiver of this type and no control of regeneration is apparent upon testing its performance, then the connections at the ends of the tickler coil should be reversed or exchanged.

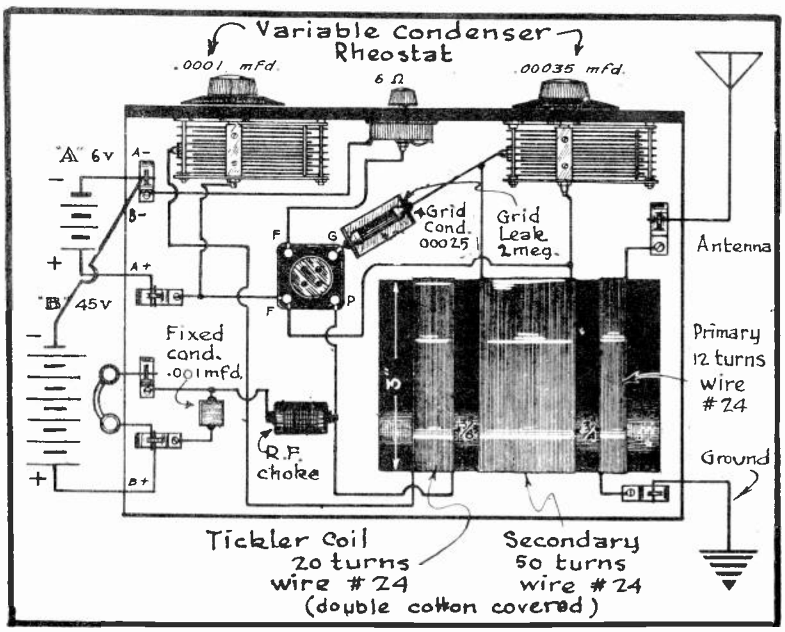

FIG. 21

The Complete Regenerative Detector.

TUBE CAPACITIES

A still different method is available for obtaining regeneration and this is made possible by using the inter element capacity of the vacuum tube as the means for passing the R.F. energy from the plate circuit back to the grid circuit.

By inspecting Fig. 22 very carefully, you will see a very interesting and important condition which is pointed out here. At the left of this illustration, we have an ordinary three-element tube or triode. Now when this tube is in operation, there is a different potential impressed upon each of its elements and since in addition all of these elements are separated from eachother by a definite space, we have in effect three individual capacities or condensers within this tube as pointed out at the right of Fig. 22.

That is, we have capacity between the plate and the filament, between the plate and the grid and between the grid and filament. Of these three capacities, the one between the plate and grid is the most effective and we can use this same capacity in order to obtain regeneration as shown in Fig. 23.

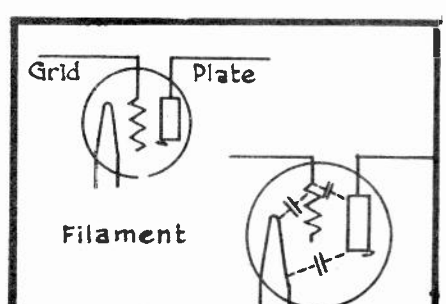

FIG. 22

Tube Capacity.

As you will notice in Fig. 23, no tickler coil is employed and the detector circuit is conventional in every respect with the exception that a variometer is connected between the plate of the tube and

THE HEADPHONES. THE VARIOMETER, YOU WILL REMEMBER, IS CONSTRUCTED IN SUCH A MANNER SO THAT ITS INDUCTANCE CAN BE VARIED BY CONTROLLING THE POSITION OF ITS ROTOR.

IF THE VARIOMETER IN FIG. 23 IS SO ADJUSTED THAT ITS INDUCTANCE VALUE BECOMES QUITE HIGH, THEN IT WILL OFFER A MAXIMUM OPPOSITION TOWARDS ANY RADIO FREQUENCY ENERGY IN THE PLATE CIRCUIT AND WILL FORCE THIS ENERGY THROUGH THE CAPACITY WHICH EXISTS BETWEEN THE PLATE AND GRID OF THE TUBE AND IN THIS WAY RETURN IT TO THE GRID CIRCUIT. IN OTHER WORDS, THIS IS JUST ANOTHER INSTANCE WHERE CAPACITY OFFERS MUCH LESS OPPOSITION TOWARDS HIGH FREQUENCY ENERGY THAN DOES INDUCTANCE.

THE R.F. ENERGY WHICH IS THUS RETURNED TO THE GRID CIRCUIT IS ADDED TO THE ENERGY OF THE INCOMING SIGNAL AND THEREBY PRODUCES REGENERATION AND GREATER SIGNAL STRENGTH. BY ADJUSTING THE VARIOMETER SO THAT IT WILL SUPPLY LESS INDUCTANCE, THERE WILL BE LESS R.F. ENERGY FORCED FROM THE PLATE TO THE GRID OF THE TUBE AND REGENERATION WILL THEREFORE DECREASE ACCORDINGLY.

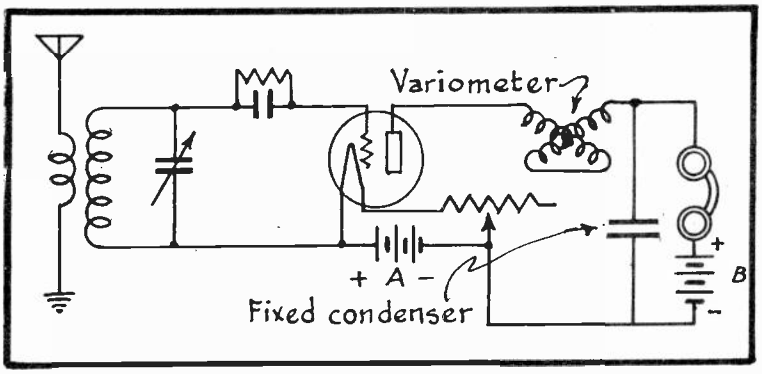

FIG. 23
Controlling Regeneration With a Variometer.

OPERATION SUGGESTIONS

WHEN OPERATING ANY RECEIVER WITH A REGENERATION CONTROL, BEST RESULTS WILL BE OBTAINED BY FIRST TUNING IN THE SIGNAL WITH THE REGENERATION CONTROL SET SO AS TO PROVIDE AS LITTLE REGENERATION AS POSSIBLE WITHOUT LOOSING THE SIGNAL ALTOGETHER. THEN AFTER THE SIGNAL HAS ONCE BEEN BROUGHT IN, GRADUALLY INCREASE REGENERATION UNTIL THE SIGNAL STRENGTH IS AS DESIRED FOR COMFORTABLE RECEPTION. AT THE TIME MAXIMUM REGENERATION IS OBTAINED, THE RECEIVER WILL HAVE A TENDENCY TO "HISS" SOMEWHAT, WHILE EXCESSIVE REGENERATION CAUSES OSCILLATION AND SQUEALING.

BESIDES THE REGENERATIVE SYSTEMS SHOWN YOU IN THIS LESSON, THERE ARE STILL OTHERS AND THEY WILL ALL BE BROUGHT TO YOUR ATTENTION AS YOU PROGRESS WITH YOUR STUDIES.

WIRE SIZES

SO FAR IN YOUR STUDIES, WIRE SIZES WERE MENTIONED TO YOU SEVERAL DIFFERENT TIMES BUT AT SUCH TIMES THEY WERE ONLY GIVEN YOU IN THE FORM OF SPECIFICATIONS. AS YOU WILL RECALL, THESE SIZES WERE ALL EXPRESSED IN NUMBER SIZES, WITH THE LETTERS B&S FOLLOWING THEM, SUCH AS A #12B&S WIRE OR A #26 B&S WIRE ETC. SINCE YOU WILL DEAL EXTENSIVELY WITH THE DIFFERENT WIRE SIZES DURING YOUR WORK IN THE RADIO INDUSTRY, IT WILL BE TIME WELL SPENT TO BECOME THOROUGHLY FAMILIAR WITH THESE SIZES. SO NOW, LET US SEE JUST EXACTLY HOW LARGE A WIRE THAT THESE DIFFERENT NUMERICAL SIZES ACTUALLY REPRESENT.

THE MOST COMMONLY USED SYSTEM FOR MEASURING WIRE SIZES HERE IN THE UNITED STATES IS BASED UPON A SYSTEM WHICH IS KNOWN AS THE BROWN& SHARPE WIRE GAUGE AND GENERALLY ABREVIATED SIMPLY AS THE B&S GAUGE. IT IS ALSO SOMETIMES REFERRED TO AS THE AMERICAN WIRE GAUGE.

WITH THIS SYSTEM OF MEASUREMENT, THE WIRE SIZE IS EXPRESSED NUMERICALLY FROM 0000 UPWARDS, AS SHOWN YOU IN THE LEFT HAND COLUMN OF TABLE I. THIS PARTICULAR TABLE HERE SHOWN LISTS ALL SIZES FROM A #0000 B&S SIZE UP TO A #40 B&S SIZE.

THE SECOND COLUMN FROM THE LEFT IN TABLE I. TELLS YOU THE EXACT DIAMETER EXPRESSED IN MILS FOR EACH OF THE B&S SIZES HERE LISTED. FOR EXAMPLE, A #18 B&S WIRE HAS A DIAMETER OF 40.30 MILS AT A TEMPERATURE OF OF 20° C.(CENTIGRADE) OR 68° F. (FAHRENHEIT). THE CROSS-SECTIONAL AREA OF THIS SAME WIRE WOULD BE 1,624 CIRCULAR MILS AS LISTED IN THE THIRD COLUMN, OR 0.00127 AS SPECIFIED IN THE FOURTH COLUMN.

THE FIFTH COLUMN OF THIS TABLE TELLS YOU THE WEIGHT PER THOUSAND FEET OF LENGTH OF EACH OF THE WIRE SIZES, WHILE THE SIXTH COLUMN SPECIFIES THE FEET OF WIRE PER POUND OF EACH SIZE WIRE. FINALLY, IN THE LAST THREE COLUMNS AT THE RIGHT OF THE TABLE, YOU ARE INFORMED OF THE RESISTANCE IN OHMS PER 1000 FT. LENGTHS OF EACH OF THE WIRE SIZES AT TEMPERATURES OF 20° C. OR 68° F., AT 25°C. OR 77°F. AND 75° C. OR 167°F. NOTICE THAT THE HIGHER THE TEMPERATURE, THE GREATER WILL BE THE RESISTANCE OF ANY ONE GIVEN SIZE OF WIRE AND THE LARGER THE NUMBER SIZE OF THE WIRE, THE SMALLER WILL BE ITS ACTUAL DIAMETER.

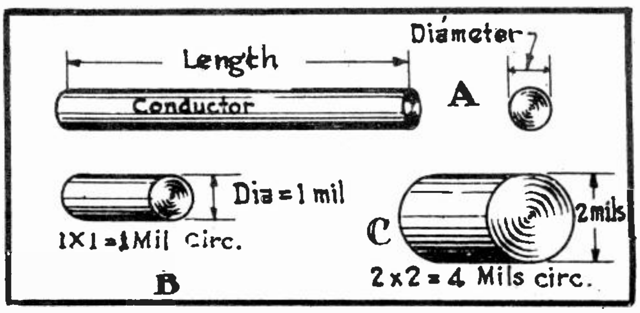

FIG. 24
Wire Dimensions.

FIG. 24 WILL ENABLE YOU TO CLEARLY VISUALIZE THE DIMENSIONS AS GENERALLY APPLIED TO WIRES. FOR INSTANCE, THE LENGTH AND DIAMETER OF THE CONDUCTOR OR WIRE WOULD BE MEASURED AS ILLUSTRATED AT "A" OF FIG. 24.

NOW FOR THE EXPRESSION "MIL" AS USED IN THE WIRE TABLE—ONE MIL IS EQUIVALENT TO THE ONE THOUSANDTH PART OF AN INCH. THAT IS, IF A CERTAIN CONDUCTOR HAS A DIAMETER OF 1/1000 INCH, THEN THIS WILL BE EQUIVALENT TO A DIAMETER OF 1 MIL, AS POINTED OUT AT "B" OF FIG. 24.

THE CIRCULAR MIL AREA OF A WIRE IS EQUAL TO ITS MIL-DIAMETER SQUARED. THAT IS, IF THE DIAMETER OF THE WIRE IS 1 MIL, THEN ITS CIRCULAR MIL AREA WILL BE 1 TIMES 1 OR 1 CIRCULAR MIL AS AT "B" OF FIG. 24. SHOULD THE DIAMETER OF THE WIRE IN QUESTION BE 2 MILS AS AT "C" OF FIG. 24, THEN ITS CIRCULAR MIL AREA WOULD BE EQUAL TO 2 TIMES 2 OR 4 CIRCULAR MILS ETC.

WE SINCERELY HOPE THAT YOU ARE FINDING YOUR RADIO STUDIES INCREASINGLY INTERESTING AS YOU ADVANCE WITH YOUR WORK. REMEMBER, THAT EACH LESSON WHICH YOU STUDY SERVES AS A STEPPING STONE TOWARDS A MORE COMPLETE UNDERSTANDING OF THIS GREAT SCIENCE, RADIO.

TABLE I

DIMENSION, WEIGHT AND RESISTANCE OF BARE SOLID COPPER WIRE								
AMERICAN (BROWN AND SHARPE) GAUGE								
B&S wire size	Diameter in mils. at 20° c.	Cross-Sectional Area		Weight lbs. per 1,000 feet	Feet per lb.	Resistance Ohms per 1000 feet		
		Circular mils.	Square Inches			At 20°C 68°F	At 25°C 77°F	At 75°C 167°F
0000	460.0	211,600.	0.1662	640.5	1.561	0.04901	0.04998	.05961
000	409.6	167,800.	0.1318	507.9	1.968	0.06180	0.06302	0.07516
00	364.8	133,100.	0.1045	402.8	2.482	0.07793	0.07947	0.09478
0	324.9	105,500.	0.08289	319.5	3.130	0.09827	0.10020	0.11950
1	289.3	83,640.	0.06573	253.3	3.947	0.12390	0.12640	0.15070
2	257.6	66,370.	0.05213	200.9	4.977	0.15630	0.15930	0.19000
3	229.4	52,640.	0.04134	159.3	6.276	0.19700	0.20090	0.23560
4	204.3	41,740.	0.03278	126.4	7.914	0.24850	0.25330	0.30229
5	181.9	33,100.	0.02600	100.2	9.980	0.31330	0.31950	0.38100
6	162.0	26,250.	0.02062	79.46	12.58	0.39510	0.40280	0.48050
7	144.3	20,820.	0.01635	63.02	15.87	0.49820	0.50800	0.60590
8	128.5	16,510.	0.01297	49.98	20.01	0.62820	0.64050	0.76400
9	114.4	13,090.	0.01028	39.63	25.23	0.79210	0.80770	0.96330
10	101.9	10,380.	0.00815	31.43	31.82	0.99890	1.018	1.2150
11	90.74	8,234.	0.00646	24.92	40.12	1.260	1.284	1.5320
12	80.81	6,530.	0.00512	19.77	50.59	1.588	1.619	1.9310
13	71.96	5,178.	0.00406	15.68	63.80	2.003	2.042	2.4360
14	64.08	4,107.	0.00322	12.43	80.44	2.525	2.575	3.0710
15	57.07	3,205.	0.00255	9.858	101.4	3.184	3.247	3.8730
16	50.82	2,583.	0.00202	7.818	127.9	4.016	4.094	4.8840
17	45.26	2,048.	0.00160	6.200	161.3	5.064	5.163	6.1580
18	40.30	1,624.	0.00127	4.917	203.4	6.385	6.510	7.7650
19	35.89	1,288	0.00101	3.899	256.5	8.051	8.210	9.7920
20	31.96	1,022.	0.00080	3.092	323.4	10.15	10.35	12.350
21	28.46	810.10	0.00063	2.452	407.8	12.80	13.05	15.570
22	25.35	642.40	0.00050	1.945	514.2	16.14	16.46	19.630
23	22.57	509.50	0.00040	1.542	648.4	20.34	20.76	24.760
24	20.10	404.00	0.00031	1.223	817.4	25.67	26.17	31.220
25	17.90	320.40	0.00025	0.9699	1031.0	32.37	33.00	39.360
26	15.94	254.10	0.00019	0.7692	1300.0	40.81	41.62	49.640
27	14.20	201.50	0.00015	0.6100	1639.0	51.47	52.48	62.590
28	12.64	159.80	0.00012	0.4837	2067.0	64.90	66.17	78.930
29	11.26	126.70	0.00009	0.3836	2607.0	81.83	83.44	99.520
30	10.03	100.50	0.00007	0.3042	3287.0	103.2	105.2	125.50
31	8.928	79.70	0.00006	0.2413	4145.0	130.1	132.7	158.20
32	7.950	63.21	0.00004	0.1913	5227.0	164.1	167.3	199.50
33	7.080	50.13	0.000039	0.1517	6591.0	206.9	211.0	251.60
34	6.305	39.75	0.000031	0.1203	8310.0	260.9	266.0	317.30
35	5.615	31.52	0.000024	0.0954	10480.	329.0	335.5	400.10
36	5.000	25.00	0.000019	0.0756	13210.	414.8	423.0	504.50
37	4.453	19.83	0.000015	0.0600	16660.	523.1	533.4	636.20
38	3.965	15.72	0.000012	0.0475	21010.	659.6	672.6	802.20
39	3.531	12.47	0.000009	0.0377	26500.	831.8	848.1	1012.0
40	3.145	9.88	0.000007	0.0299	33410.	1049	1069	1276.0

Success Secrets

The man who thinks he has no chance destroys his chances by acknowledgment of self-defeat.

The world is filled with good brains which have missed the opportunity of training.

You say that you deserve success—then prove it.

Present your facts—show results, but don't rest your case with words.

Dishonesty doubles the journey to success.

A crooked path must always be longer than a straight one.

There's only one way that's right, and all the other ways are wrong.

Good ideas are only seeds. They must be planted and tilled before they can produce.

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LESSON NO. 10

AUDIO FREQUENCY AMPLIFICATION

It is necessary to intensify or increase the loudness of the received signals after the detector has separated the audible frequencies from the carrier wave. Since this process involves the audible frequencies, it is logically called AUDIO FREQUENCY AMPLIFICATION. Fig. 2 of this lesson shows the relation between the four main elements included in the system which you are about to study; they are the antenna, the detector, the audio frequency or A.F. amplifier, and the speaker.

This lesson will not further discuss detection, but will consider what happens to the audio frequencies after they leave the detector circuit. The problem then becomes, how can we couple the detector circuit to the A.F. amplifier?

THE AUDIO TRANSFORMER

The most simple method of transferring audio frequency energy from the detector circuit to the audio frequency amplifier is by means of a transformer of the type called audio frequency transformer, or simply A.F. transformer. The external appearance of a totally enclosed type is shown in Fig. 3, the open type and its component parts in Fig. 4. Although there are many sizes and shapes

Fig. 1
A Class In Receiver Construction

OF THESE TRANSFORMERS, IN THEIR GENERAL CONSTRUCTION THEY ARE ALL MUCH THE SAME. TO BE ABLE TO TRANSFER MUCH ENERGY THRU AUDIO TRANSFORMERS IT IS NECESSARY THAT THE WINDINGS ENCIRCLE AN IRON CORE. THE FORM WOUND COIL IS SHOWN AT THE LEFT OF FIG. 4.

YOU WILL OBSERVE THAT THE SECONDARY WINDING IS WOUND OVER THE PRIMARY, BUT THE WINDINGS ARE INSULATED FROM EACH OTHER AND FROM THE CORE SHOWN IN THE CENTER OF FIG. 4, WHICH IS BUILT OF LAYERS OF HIGH GRADE SHEET SILICON STEEL STAMPINGS TO FORM WHAT IS KNOWN AS A LAMINATED CORE. THE COILS ARE MOUNTED ON THE CENTER LEG OF THE CORE, FORMING A COMPACT UNIT. BOLTS, RIVETS, OR OTHER SUITABLE DEVICES PREVENT THE LAMINATIONS FROM COMING APART.

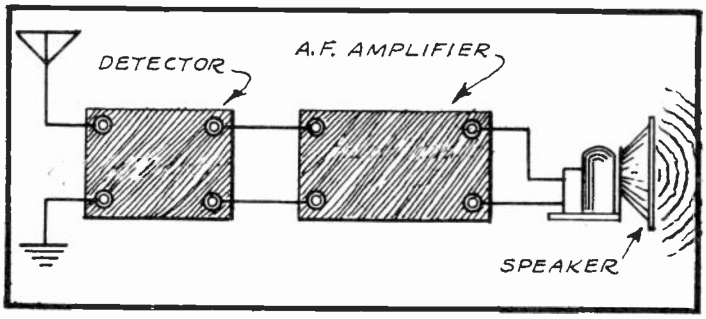

Fig. 2
Location Of The Audio Amplifier
In The Receiver

A.F. TRANSFORMERS FOR THIS PARTICULAR PURPOSE ARE GENERALLY EQUIPPED WITH FOUR TERMINALS, SOMETIMES PROVIDED WITH MARKINGS SUCH AS "P", "G", "B" AND "F-". TO INSTALL AN AUDIO TRANSFORMER SUCH AS THIS,TO COUPLE THE DETECTOR CIRCUIT TO THE AUDIO AMPLIFIER,THE "P" TERMINAL OF THE TRANSFORMER IS CONNECTED TO THE PLATE TERMINAL OF THE DETECTOR TUBE SOCKET, THE "B" TERMINAL TO THE POSITIVE "B" BATTERY TERMINAL, THE "G" TERMINAL TO THE GRID TERMINAL OF THE AUDIO AMPLIFYING TUBE'S SOCKET,AND THE "F-" TERMINAL TO THE NEGATIVE "A" BATTERY TERMINAL. THIS RESULTS IN THE CIRCUIT CONNECTIONS SHOWN IN FIG.5. NOTICE THAT THE PRIMARY WINDING OF THE TRANSFORMER IS CONNECTED IN SERIES WITH THE PLATE CIRCUIT OF THE DETECTOR TUBE, AND THAT THE SECONDARY WINDING IS CONNECTED ACROSS THE GRID AND FILAMENT OF THE AUDIO AMPLIFYING TUBE.

A.F. AMPLIFICATION

WITH THE CONNECTIONS AS SHOWN IN FIG. 5, YOU CAN READILY SEE THAT VARIATIONS IN THE PLATE CURRENT OF THE DETECTOR TUBE WILL CAUSE A VARYING MAGNETIC FIELD TO BE PRODUCED AROUND THE PRIMARY WINDING OF THE AUDIO TRANSFORMER. THIS FIELD WILL IN TURN INDUCE CORRESPONDING VOLTAGE CHANGES IN THE SECONDARY WINDING. REMEMBER, THAT THE VOLTAGE CHANGES WHICH WE ARE NOW CONSIDERING ARE AT AUDIO FREQUENCY, NOT RADIO FREQUENCY.

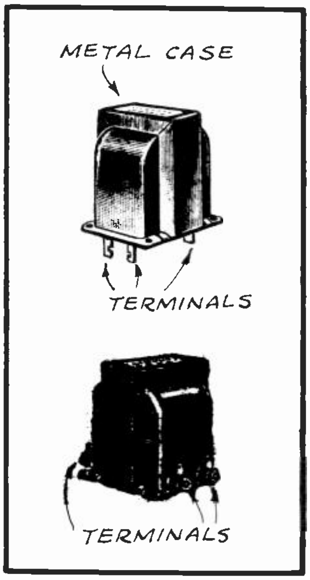

Fig. 3
Audio Transformer

THE INDUCED AUDIO FREQUENCY VOLTAGES IN THE SECONDARY WINDING OF THE TRANSFORMER WILL BE IMPRESSED UPON THE GRID OF THE AUDIO AMPLIFYING TUBE, AND WILL CONTROL THE PLATE CURRENT OF THAT TUBE. THE AVERAGE CHANGE IN THE PLATE CURRENT MUST ALSO OCCUR AT AUDIO FREQUENCIES,AND AS THE HEAD-PHONES ARE INSERTED IN THE PLATE CIRCUIT OF THIS LAST TUBE, THE

PLATE CURRENT VARIATIONS WILL CAUSE THE DIAPHRAGMS OF THE PHONES TO VIBRATE AT LIKE FREQUENCIES, THEREBY REPRODUCING THE SOUND OF THE BROADCAST.

THUS FAR, WE HAVE TRANSFERRED AUDIO FREQUENCIES FROM THE DETECTOR CIRCUIT TO AND THRU ONE STAGE OF AUDIO FREQUENCY AMPLIFICATION, AND INTO THE HEADPHONES. NO DOUBT YOU NOW WONDER JUST WHERE AMPLIFICATION ENTERS INTO THIS PROCESS, AND WHY THE SOUNDS IN THE PHONES SHOULD BE LOUDER THAN IF THE PHONES WERE CONNECTED DIRECTLY INTO THE PLATE CIRCUIT OF THE DETECTOR TUBE.

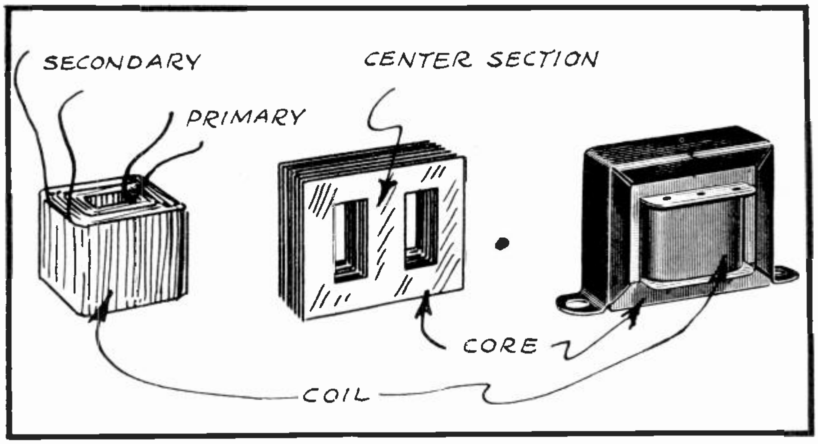

Fig. 4
Construction Of The Audio Transformer

THE AMPLIFICATION IS DUE TO TWO SEPARATE PROCESSES. FIRST, THE TRANSFORMER PROVIDED A STEP-UP IN VOLTAGE BECAUSE THERE ARE MORE TURNS OF WIRE IN ITS SECONDARY WINDING THAN IN ITS PRIMARY. IN FACT, IN MANY CASES THE SECONDARY WINDING CONTAINS THREE TIMES AS MANY TURNS OF WIRE AS ARE IN THE PRIMARY. THIS MEANS THAT THE VOLTAGE DEVELOPED ACROSS THE SECONDARY WINDING WILL BE APPROXIMATELY THREE TIMES THAT FED INTO THE PRIMARY. THE RELATION OF PRIMARY TURNS TO SECONDARY TURNS IS CALLED THE WINDING RATIO OR TURNS RATIO OF THE TRANSFORMER. THAT IS, IF THE SECONDARY WINDING CONTAINS THREE TIMES AS MANY TURNS OF WIRE AS ARE IN THE PRIMARY WINDING, THE TRANSFORMER IS SAID TO HAVE A RATIO OF 3 TO 1.

SINCE THE VOLTAGE CHANGES ACROSS THE ENDS OF THE SECONDARY OF THE TRANSFORMER ARE GREATER THAN THOSE ACROSS ITS PRIMARY, GREATER VOLTAGE CHANGES ARE IMPRESSED UPON THE GRID OF THE AMPLIFYING TUBE THAN WERE USED TO OPERATE THE GRID OF THE DETECTOR TUBE. THEREFORE, STILL GREATER CURRENT CHANGES WILL BE PRODUCED IN THE PLATE CIRCUIT OF THE AUDIO AMPLIFYING TUBE, WITH WHICH TO OPERATE THE DIAPHRAGMS OF THE HEADPHONES. FOR THIS REASON, THE DIAPHRAGMS WILL BE OPERATED WITH MORE FORCE THAN WOULD BE POSSIBLE BY THE PLATE CURRENTS OF THE DETECTOR TUBE, AND THE SOUNDS PRODUCED THEREBY WILL BE MUCH LOUDER. THUS, NOT ONLY DOES THE AUDIO TRANSFORMER INCREASE THE LOUDNESS OF THE SOUNDS, BUT THE

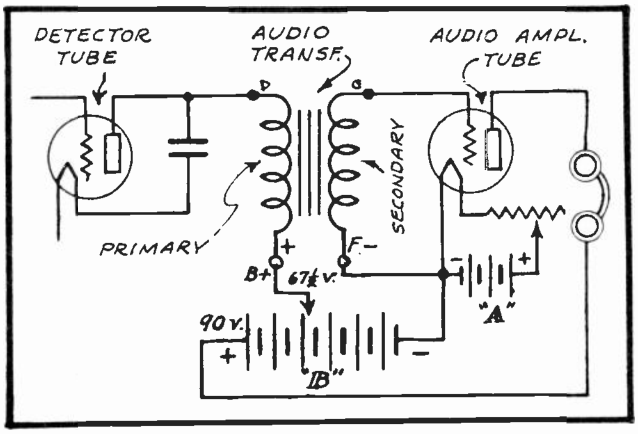

Fig. 5
Transformer Coupling

AMPLIFICATION FACTOR OF THE AUDIO AMPLIFYING TUBE ALSO ADDS A GREAT DEAL TO THE STRENGTH OF SOUND.

AN AUDIO TRANSFORMER AND ITS ACCOMPANYING AMPLIFYING TUBE AND THEIR INTERCONNECTIONS CONSTITUTE ONE "STAGE" OF AUDIO FREQUENCY AMPLIFICATION, BUT USUALLY A SINGLE STAGE IS NOT SUFFICIENT TO PROVIDE PROPER LOUD SPEAKER PERFORMANCE, THEREFORE, YOU WILL USUALLY FIND MORE THAN A SINGLE STAGE OF AUDIO FREQUENCY AMPLIFICATION IN MODERN RECEIVERS.

A FUNDAMENTAL CIRCUIT CONSISTING OF THE DETECTOR, TWO STAGES OF AUDIO FREQUENCY AMPLIFICATION, AND A LOUD SPEAKER IS SHOWN IN FIG.6, WITH TWO AUDIO TRANSFORMERS AND TWO AMPLIFYING TUBES, FOLLOWING THE DETECTOR CIRCUIT. EACH OF THE AMPLIFYING STAGES IS INDUCTIVELY COUPLED.

WITH THIS ARRANGEMENT, THE OUTPUT OF THE DETECTOR ACTS UPON THE INPUT OF THE FIRST AUDIO AMPLIFYING TUBE, AND THE OUTPUT OF THIS TUBE ACTS UPON THE INPUT OF THE LAST AMPLIFYING TUBE. THE PLATE CURRENT CHANGES THRU THIS LAST TUBE ARE MUCH GREATER THAN THOSE IN ANY OF THE PRECEDING PLATE CIRCUITS, AND WILL OPERATE THE SPEAKER UNIT QUITE VIGOROUSLY.

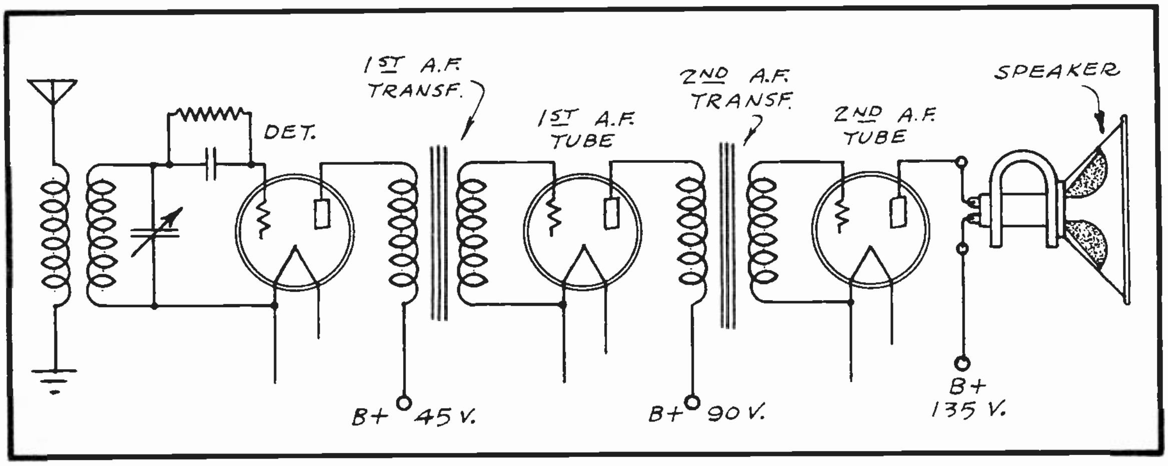

Fig. 6
Fundamental Circuit Of Three-Tube Receiver

IT IS POSSIBLE TO USE THE SAME TYPE OF TUBE FOR THE DETECTOR AND THE TWO STAGES OF AUDIO FREQUENCY AMPLIFICATION, BUT BETTER PERFORMANCE WILL BE OBTAINED BY USING A SPECIAL TYPE CALLED "POWER TUBE" IN THE LAST AMPLIFYING STAGE.

ANALYSIS OF AMPLIFICATION

FIG. 7 HAS BEEN PREPARED FURTHER TO ILLUSTRATE HOW THE SIGNAL VOLTAGE IS BUILT-UP DURING THE PROCESS OF AMPLIFICATION. A TYPE 30 DETECTOR TUBE IS SHOWN, FEEDING INTO AN AUDIO TRANSFORMER WHICH HAS A 3 TO 1 RATIO. ANOTHER 3 TO 1 TRANSFORMER IS BETWEEN THE FIRST AMPLIFIER TUBE AND THE 31 POWER TUBE.

IF THE DETECTOR IN THIS CIRCUIT IMPRESSES A WORKING VOLTAGE OF 1 VOLT ACROSS THE PRIMARY OF THE FIRST AUDIO TRANSFORMER, THE 3-TO-1 TRANSFORMER RATIO WILL DELIVER 3 VOLTS ACROSS ITS SECONDARY, WITH WHICH TO OPERATE THE GRID OF THE FIRST AUDIO AMPLIFIER TUBE. THIS TUBE, WITH AN

AMPLIFICATION FACTOR OR "MU" OF 9.3, WILL DELIVER 3 TIMES 9.3, OR 27.9 VOLTS ACROSS THE PRIMARY OF THE SECOND AUDIO TRANSFORMER, WHICH PROVIDES ANOTHER 3-TO-1 STEP-UP, SO THAT 27.9 TIMES 3, OR 83.7 VOLTS WILL BE IMPRESSED UPON THE GRID OF THE POWER TUBE.

BEAR IT IN MIND THAT THE GREATER THE VOLTAGE-CHANGES ON THE GRID OF A TUBE, THE GREATER WILL BE THE VARIATION OF THE PLATE CURRENT OF THIS TUBE, SO THAT A MORE VIGOROUS DIAPHRAGM MOVEMENT WILL BE OBTAINED IN THE SPEAKER. THE TYPE 31 POWER TUBE HAS AN AMPLIFICATION FACTOR OF 3.8, AND WILL DELIVER A WORKING VOLTAGE OF 83.7 TIMES 3.8, OR 318 VOLTS. THESE VOLTAGE GAINS ARE ALL INDICATED AT THE BOTTOM OF FIG. 7, BELOW THE POINTS WHERE THEY ARE DEVELOPED. THE FIGURES THERE GIVEN ARE CHOSEN ARBITRARILY SIMPLY TO GIVE YOU AN IDEA OF HOW WE ARE ABLE TO AMPLIFY BY MEANS OF THIS SYSTEM.

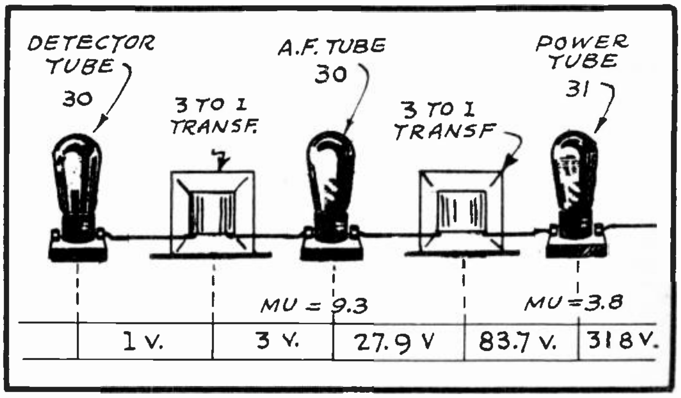

Fig. 7
Obtaining The Amplification

WHEN A SERIES OF AMPLIFYING STAGES IS USED, WE USUALLY SAY THAT WE HAVE A CASCADE CIRCUIT, IN WHICH EACH STAGE ADDS AMPLIFICATION TO THAT OF THE ONE PRECEDING IT.

YOU WILL ALSO FREQUENTLY FIND CASES WHERE THE TURNS RATIO OF THE FIRST AUDIO TRANSFORMER IS NOT THE SAME AS THAT OF ONE OF THE FOLLOWING AUDIO TRANSFORMERS. SOMETIMES A 4-TO-1 TRANSFORMER IS USED BETWEEN THE DETECTOR AND FIRST AMPLIFYING TUBE, AND A 3-TO-1 OR 3.5-TO-1 RATIO IN THE SECOND STAGE.

IMPORTANCE OF OPERATING VOLTAGES

TO OBTAIN AS PURE AMPLIFICATION AS POSSIBLE, WITHOUT CHANGING THE AUDIO WAVE-FORM AND THEREBY BRINGING ABOUT DISTORTION WITH ITS ACCOMPANYING FALSE SOUNDS, IT IS NECESSARY TO OPERATE ALL TUBES AT THEIR CORRECT VOLTAGES. FIG. 8 ILLUSTRATES THIS. ALL THREE TUBES HAVE DIFFERENT PLATE OR "B" BATTERY VOLTAGES, THE DETECTOR USING 45 VOLTS, THE FIRST

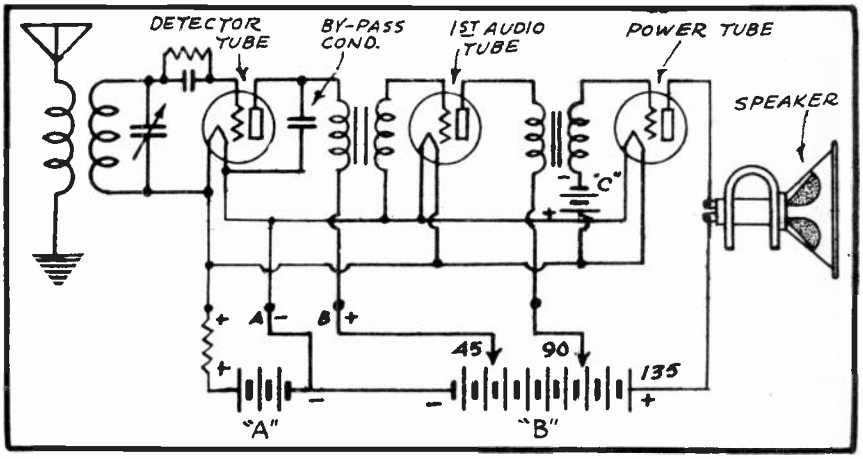

Fig. 8
A Complete 3 Tube Receiver

AUDIO 90 VOLTS, AND THE POWER TUBE 135 VOLTS. ALSO, DO NOT OVERLOOK THE FACT THAT THERE IS A BYPASS CONDENSER INSTALLED IN THE DETECTOR TUBE'S OUTPUT, TO KEEP THE RADIO FREQUENCIES OUT OF THE AUDIO AMPLIFYING STAGES, THEREBY FULFILLING THE SAME PURPOSE AS THE PHONE CONDENSER USED IN THE ONE-TUBE CIRCUITS. THE RESISTOR IS INCLUDED IN THE FILAMENT CIRCUIT TO REDUCE THE "A" BATTERY VOLTAGE TO THAT FOR WHICH THE TUBE FILAMENTS ARE DESIGNED.

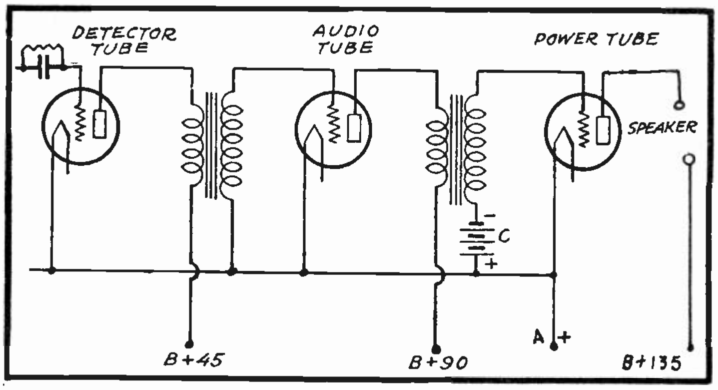

Fig. 9
Use Of The "C" Battery

IN ONE OF THE PREVIOUS LESSONS ON RADIO TUBES YOU WERE TOLD THE PURPOSES FOR WHICH CERTAIN TUBES MAY BE USED, AND WHAT THE VOLTAGE VALUES SHOULD BE, SO THAT THE TUBES WILL OPERATE PROPERLY. THERE IS USUALLY A PRINTED SLIP ENCLOSED IN THE TUBE PACKAGE WHICH TELLS YOU HOW THAT PARTICULAR TUBE SHOULD BE USED. FURTHER TO ASSIST YOU IN THIS MATTER, A COMPLETE HANDY REFERENCE CHART OF TUBE CHARACTERISTICS IS INCLUDED WITH THE JOB SHEETS WHICH WE SUPPLY YOU.

ALSO OBSERVE IN FIG. 8 THAT A "C" BATTERY HAS BEEN ADDED TO THE GRID CIRCUIT OF THE LAST TUBE. ITS CONNECTION IN THE CIRCUIT, AND THE "B" VOLTAGE VALUES, ARE SHOWN IN MORE DETAILED FORM IN FIG. 9. NOTICE THAT THE NEGATIVE TERMINAL OF THE "C" BATTERY IS CONNECTED TO THE POWER TUBE'S GRID, AND THE POSITIVE TERMINAL IS CONNECTED TO THE FILAMENT CIRCUIT. USING THE TUBE AS SHOWN, ABOUT 22½ VOLTS OF "C" NEGATIVE BIAS WILL BE REQUIRED. THE BIAS VOLTAGE REQUIRED BY THE VARIOUS TUBES IS SPECIFIED BY THE TUBE MANUFACTURER, AND DEPENDS PRINCIPALLY UPON THE PLATE VOLTAGE AT WHICH THE TUBE IS OPERATED, AND ALSO UPON THE SIGNAL VOLTAGE APPLIED TO THE GRID OF THIS TUBE.

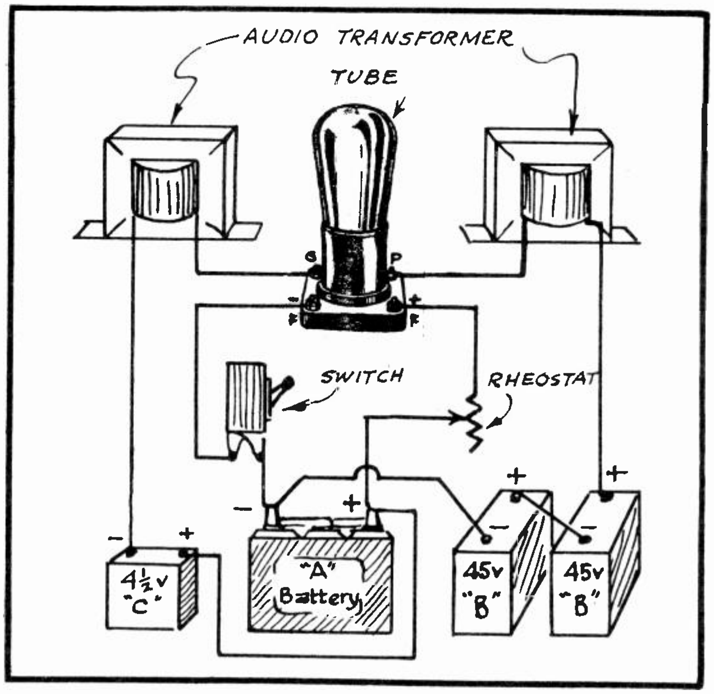

Fig. 10
The Battery Connections

BY SUFFICIENTLY BIASING THE GRID OF THE POWER TUBE (NEGATIVELY) SO THAT IT NEVER BECOMES POSITIVE, EVEN THOUGH A POSITIVE SIGNAL VOLTAGE BE IMPRESSED

UPON IT, THE GRID WILL NEVER ACCUMULATE ELECTRONS; HENCE NO RESULTING CURRENT WILL FLOW THRU THE GRID CIRCUIT, AND DISTORTION WILL BE KEPT AT A MINIMUM.

FIG. 10 IS A PICTORIAL DIAGRAM SHOWING CLEARLY THE EXACT MANNER OF CONNECTING THE A, B, AND C BATTERIES IN AN A.F. AMPLIFIER STAGE. IN THIS PARTICULAR CASE, A "B" VOLTAGE OF 90 VOLTS AND A "C" BIAS OF $-4\frac{1}{2}$ VOLTS IS BEING APPLIED TO THE TUBE.

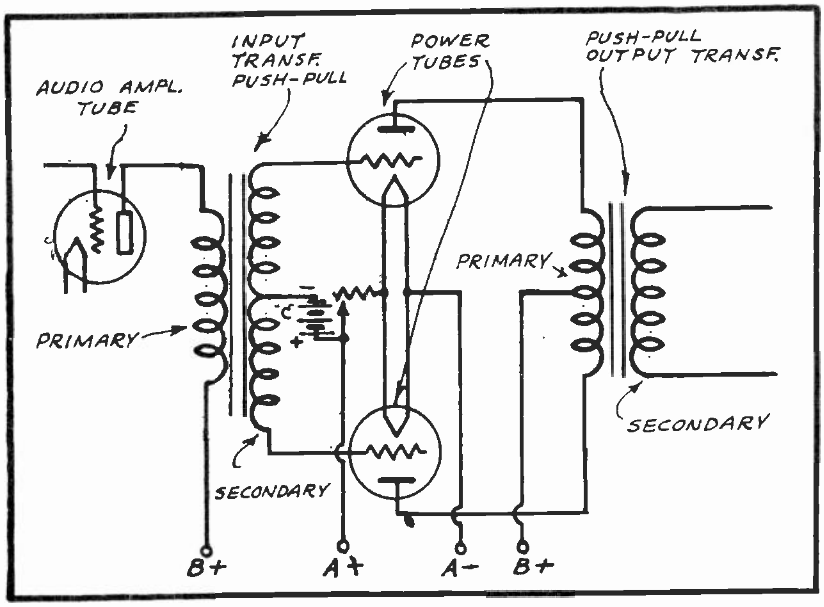

Fig. 11
A Stage Of Push-Pull Amplification

PERFORMANCE

A GREAT BURDEN IS PLACED UPON THE AUDIO FREQUENCY AMPLIFIER, BECAUSE IT IS EXPECTED TO HANDLE ALL OF THE AUDIBLE FREQUENCIES IN THE WIDE RANGE BETWEEN 30 AND 10,000 CYCLES PER SECOND. AS YET, NO SYSTEM HAS BEEN DEVISED WHICH WILL AMPLIFY ALL OF THESE GREQUENCIES EQUALLY, WITHOUT FAVORING CERTAIN ONES, GROUPS OR "BANDS". TRANSFORMER-COUPLED CIRCUITS -- FOR INSTANCE -- WILL NOT AMPLIFY THE LOW NOTES (SOUNDS OF LOW FREQUENCIES) NEARLY AS WELL AS THE HIGHER NOTES, AND AS A RESULT, MUSIC REPRODUCED BY THE LOUD SPEAKER WILL APPEAR SOMEWHAT HIGH PITCHED, WITH MANY OF THE LOWER NOTES MISSING. IF A COMPLETE SYMPHONY ORCHESTRA IS PLAYING A SELECTION, THE BACKGROUND PRODUCED BY SUCH LOW-PITCHED INSTRUMENTS AS THE BASS-VIOL, DOUBLE-BASS HORN, ETC., WILL BE QUITE WEAK, WHEREAS THE SOUNDS OF THE VIOLINS AND OTHER HIGH PITCHED INSTRUMENTS WILL BE TOO PRONOUNCED.

ANOTHER SHORT-COMING OF THE AUDIO TRANSFORMER IS THAT THE INDUCTANCE OF ITS WINDINGS, REACTING WITH ITS DISTRIBUTED CAPACITY, WILL TUNE THE TRANSFORMER SO THAT IT WILL BECOME RESONANT TO SOME ONE FREQUENCY, GENERALLY AROUND 5,000 CYCLES. THE RESULT WILL BE THAT THE 5000-CYCLE TONE WILL ALWAYS BE OVER-EMPHASIZED IN THE SPEAKER.

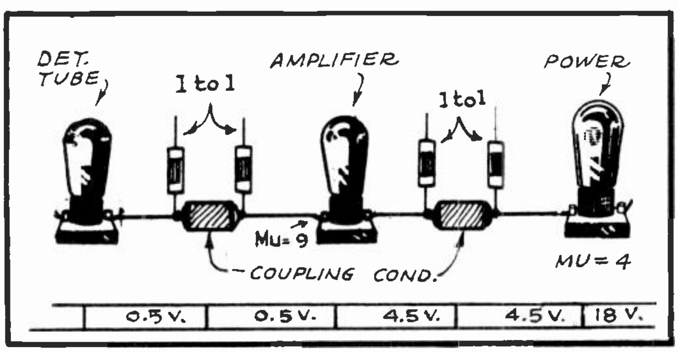

Fig. 12
Resistance-Capacity Coupling

PUSH-PULL AMPLIFICATION

IT HAS BEEN FOUND THAT TWO POWER TUBES CAN BE ARRANGED

IN WHAT IS KNOWN AS A PUSH-PULL CIRCUIT, AND THEREBY BECOMES CAPABLE OF SUPPLYING THE SPEAKER WITH MORE POWER, WITHOUT PRODUCING SO MUCH UNDESIRABLE NOISE CAUSED BY DISTORTION. TO ACCOMPLISH THIS, THE PRIMARY WINDING OF A SPECIAL INPUT PUSH-PULL TRANSFORMER IS CONNECTED IN THE PLATE CIRCUIT OF THE LAST AUDIO AMPLIFYING TUBE, AS SHOWN IN FIG. 11. THE FILAMENTS OF THE TWO POWER TUBES ARE CONNECTED IN PARALLEL, AS ILLUSTRATED, AND THE ENDS OF THE SECONDARY WINDING OF THIS TRANSFORMER ARE CONNECTED TO THE GRIDS OF THE TWO POWER TUBES, AS ALSO SHOWN.

THIS SECONDARY WINDING IS TAPPED AT ITS CENTER, AND THIS POINT IS CONNECTED TO THE NEGATIVE TERMINAL OF THE "C" BATTERY. THE PLATES OF THE POWER TUBES ARE EACH CONNECTED TO AN END OF THE PRIMARY WINDING OF A SPECIAL PUSH-PULL OUTPUT-TRANSFORMER; THIS WINDING IS ALSO TAPPED AT ITS CENTER AND CONNECTED TO THE POSITIVE END OF THE "B" SUPPLY.

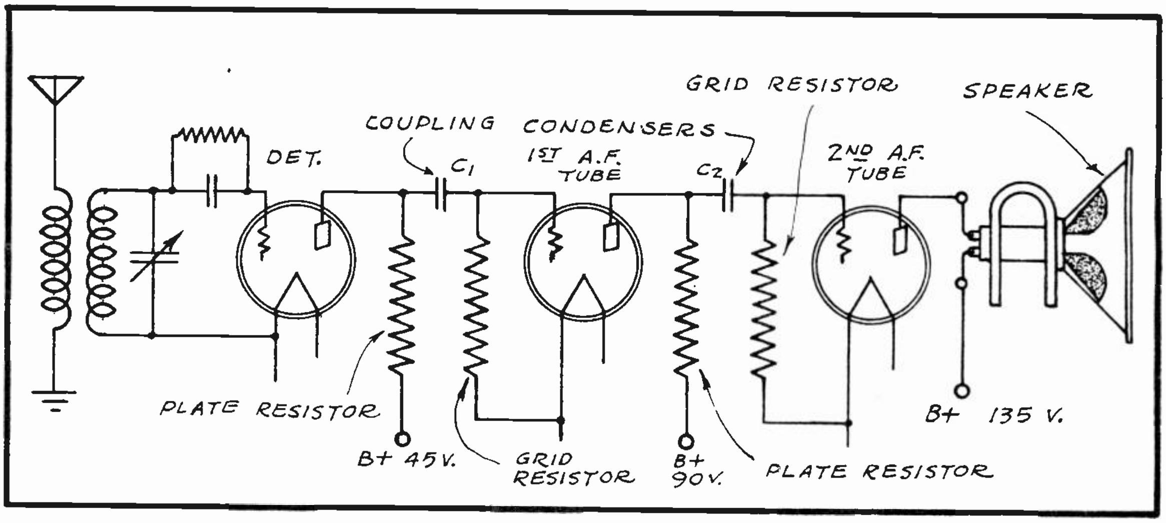

Fig. 13
Basic Diagram Of Resistance-Coupled Amplifier

BY HAVING TWO TUBES CONNECTED AND OPERATING IN THIS ARRANGEMENT, THE TWO POWER TUBES WILL TOGETHER BE ABLE TO DELIVER SOMEWHAT MORE THAN TWICE AS MUCH POWER TO THE SPEAKER, WITHOUT RUNNING THE RISK OF OVERLOADING EITHER TUBE. AS A RESULT, VERY LOUD SOUNDS CAN BE PRODUCED WITH GOOD TONE QUALITY.

INPUT PUSH-PULL TRANSFORMERS USUALLY HAVE A RATIO OF ABOUT 1 TO 1 OR 1.8 TO 1, SO THAT LITTLE OR NO VOLTAGE STEP-UP IS OBTAINED FROM THEM. SOME OF THE PUBLIC ADDRESS AMPLIFIERS USE INPUT TRANSFORMERS WITH 3-TO-1 RATIO, BECAUSE THE TYPE OF POWER TUBE USED FOR SUCH PURPOSES CAN GENERALLY HANDLE LARGE GRID VOLTAGE CHANGES WITHOUT PRODUCING SOUND DISTORTION. FOR THE PRESENT, WE ARE CONCERNED ONLY WITH THE APPLICATION OF THE PUSH-PULL PRINCIPLE -- A DETAILED ANALYSIS OF THE OPERATING PRINCIPLES WILL BE GIVEN LATER.

RESISTANCE-CAPACITY COUPLED AMPLIFIER

ALTHOUGH SOME OF THE MORE EXPENSIVE AUDIO TRANSFORMERS WILL HANDLE THE REQUIRED RANGE OF AUDIO FREQUENCIES REMARKABLE WELL, THERE ARE SEVERAL OTHER TYPES OF INTER-STAGE COUPLING NOW SUCCESSFULLY USED IN A.F.

AMPLIFIERS. AMONG THESE IS THE RESISTANCE-CAPACITY COUPLED CIRCUIT ILLUSTRATED IN FIG. 12, IN WHICH THE INTER-STAGE COUPLING IS OBTAINED BY THE USE OF FIXED CONDENSERS AND RESISTORS. A BASIC DIAGRAM OF SUCH AN AMPLIFIER IS SHOWN IN FIG. 13. NOTICE THAT THE PLATE OF THE DETECTOR TUBE IS CONNECTED TO THE GRID OF THE FIRST AUDIO TUBE THRU A CONDENSER C_1. THE PLATE OF THE FIRST AUDIO TUBE AND THE GRID OF THE SECOND AUDIO TUBE ARE CONNECTED THRU CONDENSER C_2. WHEN CONDENSERS ARE USED IN THIS MANNER, THEY ARE GENERALLY CALLED COUPLING CONDENSERS.

A RESISTANCE UNIT (FIXED RESISTOR) IS CONNECTED IN THE PLATE CIRCUIT OF EACH TUBE, AS SHOWN IN FIG. 13, SO THAT THE PLATE CURRENT THRU EACH TUBE MUST ALSO FLOW THRU THE CORRESPONDING PLATE RESISTOR. THESE RESISTORS THUS ACT AS LOADS IN THE PLATE CIRCUITS, AND TEND TO FORCE THE SIGNAL THRU THE COUPLING CONDENSERS.

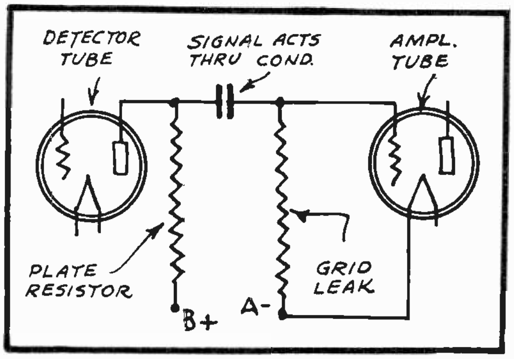

Fig. 14
The Resistance Coupling

IN FIG. 14 IS SHOWN A DETAILED PICTURE OF THIS RESISTANCE-CAPACITY COUPLING BETWEEN THE DETECTOR AND FIRST AUDIO TUBE. NOTICE THAT THE COUPLING CONDENSER PREVENTS THE HIGH-VOLTAGE PLATE CURRENT OF THE DETECTOR TUBE FROM REACHING THE GRID OF THE AUDIO TUBE AND MAKING IT STRONGLY POSITIVE. THE FLUCTUATING SIGNAL VOLTAGES, HOWEVER, CAN REACT THRU THIS SMALL CONDENSER, AND THUS BE IMPRESSED UPON THE GRID OF THE AUDIO TUBE.

THE PURPOSE OF THE GRID LEAK IN THE AUDIO TUBE'S GRID CIRCUIT IS TO PERMIT EXCESS ELECTRONS TO DRAIN FROM THE AUDIO TUBE'S GRID TO ITS FILAMENT. THE INCOMING SIGNALS CAUSE ELECTRONS TO ACCUMULATE ON THIS GRID, AS IN THE GRID LEAK-AND-CONDENSER TYPE OF DETECTOR CIRCUIT, AND THE LEAK RESISTOR PERMITS THEIR REMOVAL.

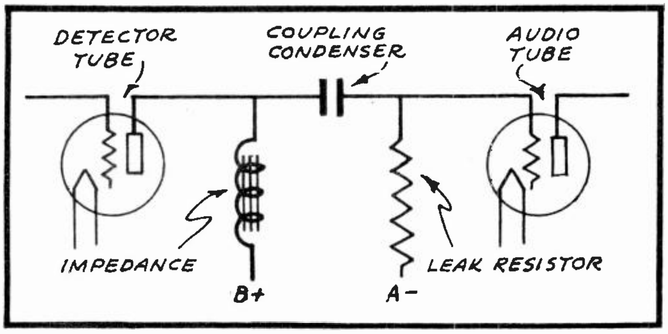

Fig. 15
Impedance Coupling

TO OBTAIN THE MOST SATISFACTORY RESULTS FROM SUCH A RESISTANCE-COUPLED CIRCUIT, IT IS ESSENTIAL TO CHOOSE RESISTORS AND COUPLING CONDENSERS OF THE PROPER VALUES. THE CONDENSER MAY HAVE A CAPACITY VALUE FROM .006 MFD. TO 0.1 MFD. THE GREATER THE RESISTANCE OF THE GRID LEAK, THE GREATER WILL BE THE POSSIBLE AMPLIFICATION, BUT ON THE OTHER HAND, A LEAK WITH TOO MUCH RESISTANCE WILL ACT TO "BLOCK" THE TUBE. THAT IS, WHEN POSITIVE SIGNAL POTENTIALS ARE IMPRESSED UPON THE TUBE'S GRID, ELECTRONS WILL ACCUMULATE ON IT, AND IF THE LEAK RESISTANCE IS TOO GREAT, SUCH ELECTRONS WILL HAVE NO FREE WAY TO RETURN TO THE FILAMENT, AND THE TUBE WILL BECOME "BLOCKED" OR INOPERATIVE. LATER IN THIS COURSE YOU WILL BE INSTRUCTED IN THE METHOD OF CALCULATING THE

PROPER RESISTOR AND CONDENSER VALUES WHEN DESIGNING RESISTANCE-CAPACITY COUPLED AMPLIFIERS. IT IS COMMON PRACTICE AMONG RADIO MEN TO REFER TO THESE RESISTANCE-CAPACITY COUPLED CIRCUITS SIMPLY AS "RESISTANCE-COUPLED" CIRCUITS.

PERFORMANCE OF RESISTANCE-CAPACITY COUPLING

RESISTANCE-COUPLING IN ITSELF PROVIDES NO VOLTAGE STEP-UP; THAT IS, RESISTANCE-COUPLING OFFERS ONLY A 1 TO 1 RATIO, AND ALL AMPLIFICATION IS LIMITED TO THAT OFFERED BY THE AMPLIFICATION OF THE TUBES. IN FACT, NOT EVEN THE FULL AMPLIFICATION FACTOR OF THE TUBES WILL BE REALIZED IN PRACTICE, AND CONSEQUENTLY MORE STAGES OF RESISTANCE COUPLIED CIRCUITS MUST BE USED TO OBTAIN A GIVEN AMOUNT OF AMPLIFICATION THAN WOULD BE NECESSARY IF TRANSFORMER-COUPLED CIRCUITS WERE EMPLOYED.

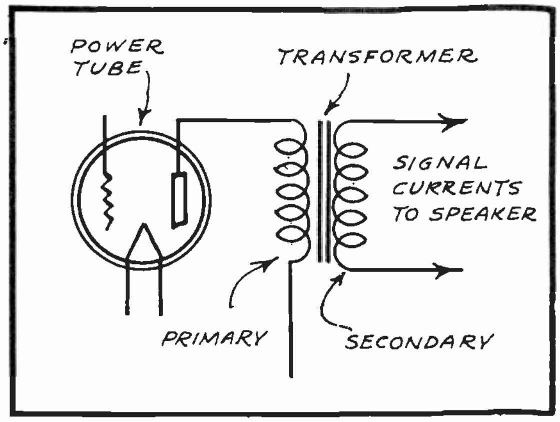

Fig. 16
Transformer Speaker Coupling

LOOKING BACK AT FIG. 12, YOU WILL SEE THAT WITH 100% EFFICIENCY IN THE AMPLIFIER CIRCUIT (WHICH IS NOT POSSIBLE IN PRACTICE) WE WILL HAVE VOLTAGE STEP-UPS AS INDICATED AT THE BOTTOM OF THE ILLUSTRATION, WITH THE TUBES OFFERING THE ONLY AMPLIFICATION.

FOR THE SAKE OF ILLUSTRATION, WE HAVE ASSUMED IN FIG. 12 THAT A SIGNAL WITH A STRENGTH OF 0.5 VOLT IS AVAILABLE AT THE OUTPUT OF THE DETECTOR. SINCE THE COUPLING BETWEEN THE DETECTOR AND THE FIRST A.F. TUBE OFFERS NO INCREASE OR "STEP-UP", THIS SAME 0.5 VOLT WILL BE APPLIED TO THE GRID OF THE FIRST A.F. TUBE, WHICH HAS AN AMPLIFICATION FACTOR OF 9. A SIGNAL VOLTAGE OF 9 TIMES 0.5, OR 4.5 VOLTS, IS AVAILABLE AT THE OUTPUT OF THIS TUBE, AND THIS SAME VOLTAGE IS APPLIED TO THE GRID OF THE FOLLOWING TUBE, WHERE IT IS FURTHER AMPLIFIER TO 4 TIMES 4.5, OR 18 VOLTS.

RESISTANCE-CAPACITY COUPLING OFFERS ONE PRONOUNCED DISADVANTAGE, IN THAT SO MUCH "B" VOLTAGE AND POWER IS LOST OR WASTED ACROSS THE PLATE RESISTORS. TO PROVIDE A CERTAIN EFFECTIVE PLATE VOLTAGE AT THE TUBES, IT IS NECESSARY TO PROVIDE A HIGHER "B" VOLTAGE SUPPLY THEN WOULD BE NECESSARY WITH TRANSFORMER COUPLING. IN BATTERY-TYPE RECEIVERS THIS CONDITION REQUIRES EXTRA "B" BATTERIES, WHICH ADD TO BOTH FIRST COST AND UPKEEP. HOWEVER, THIS TYPE OF COUPLING IS EXTENSIVELY USED IN AMPLIFIERS WHERE HIGH-QUALITY REPRODUCTION IS DESIRED.

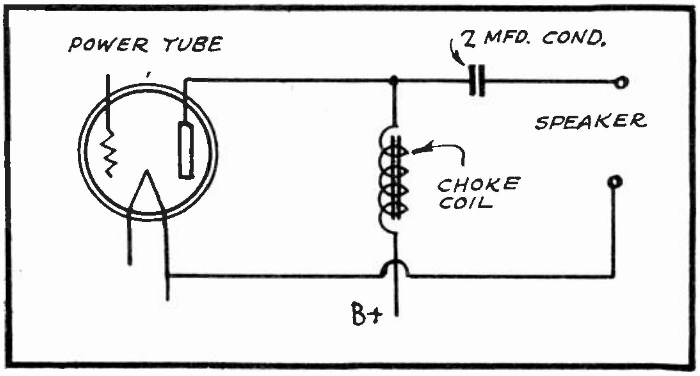

Fig. 17
Choke And Condenser Speaker Coupling

IMPEDANCE COUPLING

TO OVERCOME THE DIS-

ADVANTAGE OF THE VOLTAGE-DROP IN THE TUBE'S PLATE CIRCUIT, ANOTHER COUPLING METHOD HAS BEEN DEVISED, KNOWN AS IMPEDANCE COUPLING. A TYPICAL EXAMPLE IS SHOWN IN FIG. 15. IN GENERAL, THIS CIRCUIT IS THE SAME AS THE RESISTANCE COUPLED CIRCUIT, WITH THE EXCEPTION THAT AN A.F. CHOKE HAS BEEN SUBSTITUTED FOR THE PLATE RESISTOR. THIS CHOKE IS SIMPLY A SINGLE WINDING OF INSULATED COPPER WIRE WOUND ON AN IRON CORE, AND VERY LITTLE D-C OR OHMIC RESISTANCE IS OFFERED BY IT. FOR THIS REASON, THE D-C VOLTAGE-DROP ACROSS THE CHOKE IS RELATIVELY SMALL.

A WINDING HAS NO INDUCTANCE WHEN A D-C CURRENT FLOWS THRU IT, BUT THE PLATE CURRENT VARIATION CAUSED BY THE SIGNALS IS ESSENTIALLY AN A-C CURRENT, AND CAUSES INDUCTION IN THIS COIL, SO THAT CORRESPONDING SIGNAL VOLTAGES WILL BE DEVELOPED ACROSS THE ENDS OF THE CHOKE. THESE SIGNAL-VOLTAGE CHANGES REACT THRU THE COUPLING CONDENSER ONTO THE GRID CIRCUIT OF THE FOLLOWING TUBE, IN THE SAME MANNER AS WITH RESISTANCE COUPLING.

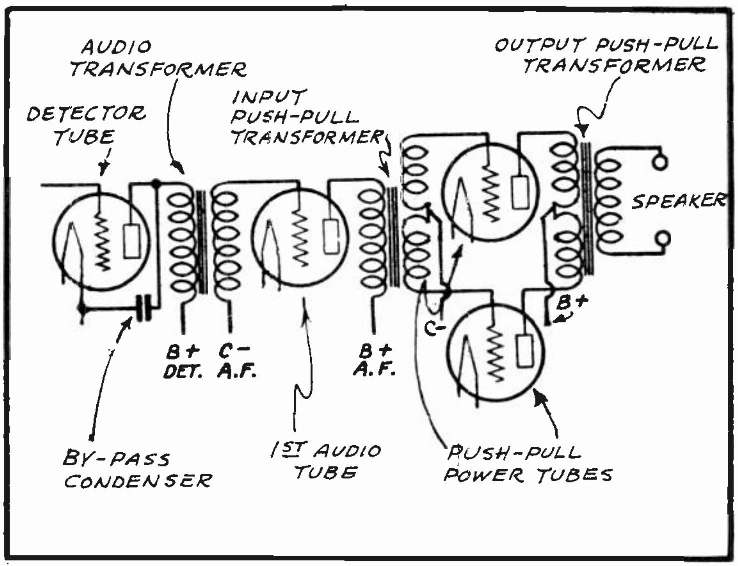

Fig. 18
Push-Pull Speaker Coupling

SPEAKER COUPLINGS

WHEN USING POWER TUBES IN THE LAST STAGE OF AUDIO AMPLIFICATION, THERE IS SO MUCH PLATE CURRENT THAT IF THIS D-C CURRENT WERE ALSO PERMITTED TO FLOW THRU THE WINDINGS OF THE MODERN LOUD SPEAKERS, IT WOULD OFTEN BURN THEM OUT. TO KEEP THESE D-C CURRENTS OUT OF THE SPEAKER WINDINGS, AND YET TO IMPRESS THE SIGNAL VOLTAGE-CHANGES ACROSS THEM, A TRANSFORMER COUPLING IS USED BETWEEN THE POWER TUBE AND THE SPEAKER AS SHOWN IN FIG. 16, WHERE YOU WILL SEE THAT THE PRIMARY WINDING OF THE TRANSFORMER IS CONNECTED IN THE PLATE CIRCUIT OF THE POWER TUBE SO THAT ALL OF THE "B" BATTERY'S DIRECT CURRENT MUST FLOW THROUGH THIS WINDING.

THE SIGNAL VOLTAGE-CHANGES PRODUCED ACROSS THIS PRIMARY WINDING ARE INDUCED INTO THE SECONDARY WINDING, AND THE CONSEQUENT SECONDARY SIGNAL CURRENTS ARE PREMITTED TO PASS THROUGH THE LOUD SPEAKER WINDING. A TRANSFORMER SO USED IS KNOWN AS A SPEAKER COUPLING TRANSFORMER.

ANOTHER SPEAKER COUPLING METHOD IS SHOWN IN FIG. 17, USING AN A.F. CHOKE CONNECTED IN THE PLATE CIRCUIT OF THE POWER TUBE SO THAT ALL OF THE "B" SUPPLY'S DIRECT CURRENT WILL FLOW THRU THE CHOKE. THE SIGNAL VOLTAGES DEVELOPED ACROSS THIS CHOKE ARE FLUCTUATING, AND FOR THIS REASON THEY WILL REACT THRU THE LARGE 2 MFD COUPLING CONDENSER AND WILL OPERATE THE SPEAKER. THE SPEAKER CURRENT RETURNS TO THE CIRCUIT BY WAY OF THE

WIRE CONNECTING ONE OF THE SPEAKER TERMINALS TO THE FILAMENT OF THE POWER TUBE.

IN FIG. 18 YOU WILL NOT ONLY SEE HOW THE LOUD SPEAKER IS COUPLED TO A STAGE OF PUSH-PULL AMPLIFICATION BY MEANS OF THE SPECIAL OUTPUT PUSH-PULL TRANSFORMER, BUT ALSO THE RELATION BETWEEN THE DETECTOR AND THE COMPLETE TRANSFORMER-COUPLED AUDIO AMPLIFIER.

COMBINATION RESISTANCE-CAPACITY AND TRANSFORMER COUPLING

DURING YOUR CAREER IN THE RADIO PROFESSION YOU WILL OFTEN SEE THE TERM FIDELITY, BY WHICH IS MEANT THE ABILITY OF ANY RADIO APPARATUS -- SUCH AS A RECEIVER, AMPLIFIER, TRANSMITTER, ETC., TO PROVIDE AN ACCURATE REPRODUCTION OF THE SOUND AS IT WAS ORIGINALLY PRODUCED AT THE BROADCAST STATION. SINCE THIS EXPRESSION IS MUCH USED, IT IS WELL TO REMEMBER IT.

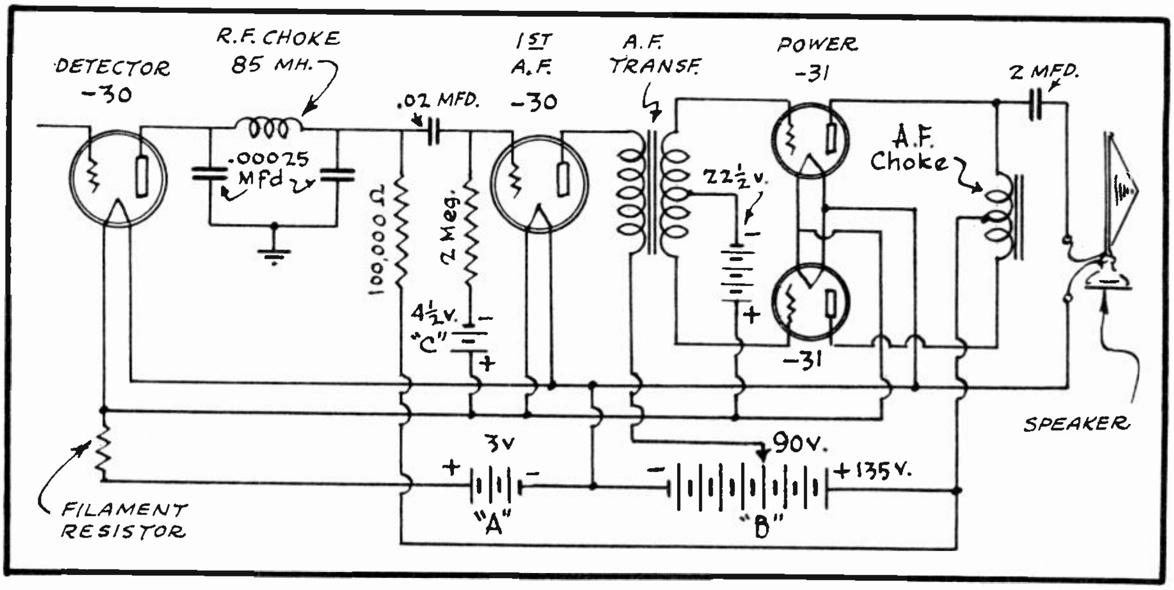

Fig. 19
Another A.F. Amplifier Circuit

TO CONSTRUCT RECEIVERS WHICH OFFER GOOD FIDELITY, IT IS A COMMON PRACTICE TO DESIGN THE CIRCUITS TO INCORPORATE BOTH RESISTANCE-CAPACITY AND TRANSFORMER COUPLING IN THE A.F. AMPLIFIER. THAT IS, THE DETECTOR STAGE FREQUENTLY FEEDS THE FIRST A.F. STAGE BY MEANS OF RESISTANCE-CAPACITY COUPLING, WHILE TRANSFORMER-COUPLING IS EMPLOYED BETWEEN THE FIRST A.F. AND THE POWER STAGE, AS ILLUSTRATED IN FIG. 19. THE CHIEF ADVANTAGE OF A CIRCUIT OF THIS TYPE IS THAT IT OFFERS MORE UNIFORM AMPLIFICATION THROUGHOUT THE AUDIO RANGE.

AS YOU WILL OBSERVE IN FIG. 19, A TYPE 30 TUBE IS EMPLOYED IN BOTH THE DETECTOR AND FIRST A.F. STAGES, AND A PAIR OF 31'S IN THE PUSH-PULL POWER STAGE. A MAGNETIC SPEAKER IS CONNECTED TO THE OUTPUT OF THE POWER STAGE, THRU A 2 MFD CONDENSER, AND AN A.F CHOKE SERVES TO CARRY THE PLATE CURRENT OF THE POWER TUBES, AS WELL AS ASSISTING IN FORCING THROUGH THE 2 MFD COUPLING CONDENSER THE SIGNAL VOLTAGES ACROSS THE SPEAKER WINDINGS. YOU WILL STUDY SPEAKER CONSTRUCTION AND OPERATION IN AN EARLY LESSON.

Another interesting and important feature of the circuit shown in Fig. 19 is the R.F. filter system included in the plate circuit of the detector tube, consisting of an R.F. choke connected in series with the detector plate circuit, and a .00025 mfd. fixed condenser connected between each end of this choke and ground. Three different forms of R.F. chokes frequently used for this purpose are illustrated in Fig. 20. The unit at the left consists of insulated copper wire of a very small size, lattice-wound on a washer made of an insulating material. Each end of the winding is provided with a terminal to which the circuit connections are made.

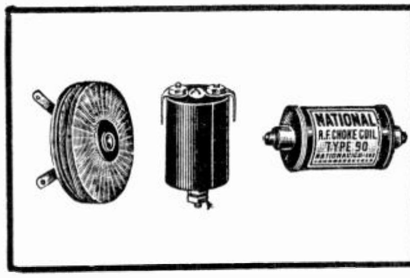

Fig. 20
Typical R.F. Chokes

The other R.F. chokes shown in Fig.20 are similar in construction, except that they are wound on a spool and then enclosed in fiber cases, two terminals being provided for circuit connections. Such chokes offer great opposition toward any R.F. ripples which find their way into the plate circuit of the detector tube, and will force them to ground thru the .00025 mfd condenser. These condensers offer very little opposition to high frequency currents and this very effective system for eliminating all R.F. energy from the A.F. amplifier is extensively used.

While on the subject of ground connections, it is well to mention that in a majority of the modern receivers the chassis base, upon which all of the various parts are mounted, is of all-metal construction. Cadmium-plated sheet-steel is generally used for this purpose, and it is a common practice to make all ground connections of the circuit by soldering directly to the chassis base, or to solder lugs firmly fastened to this chassis base.

In this lesson we have covered A.F. amplifiers only in a general way, but in more advanced lessons you will study their construction and operation in much greater detail. Bear it in mind that the more that you know about the operation of receiver circuits, the easier will be your tasks when repairing and servicing radio receivers in practical work.

Now that you are in a general way familiar with A.F. amplifier circuits, it is well to study several complete receiver circuits of simple design, and which make use of an audio amplifying system in combination with a detector circuit.

Please bear in mind that for the present it is advisable to center our attention upon battery-operated receivers -- the A-C type receivers, as well as those employing radio frequency amplifier systems, screen-grid circuits and other more advanced features, will be dealt with in detail in later lessons.

TWO-TUBE RECEIVER

In Fig. 21 you are shown the circuit diagram of a simple two-tube

RECEIVER, CONSISTING OF A 30 TUBE ACTING AS A GRID-LEAK DETECTOR, AND ANOTHER 30 TUBE ACTING AS AN AUDIO AMPLIFIER. THIS CIRCUIT IS DESIGNED FOR THE USE OF HEADPHONES.

IT IS SUGGESTED THAT YOU STUDY EACH PART OR SECTION OF THIS CIRCUIT VERY CAREFULLY, NOTING HOW ALL OF THE VARIOUS COMPONENTS THUS FAR DISCUSSED INDIVIDUALLY ARE RELATED TO EACH OTHER TO FUNCTION AS A UNIT.

THE 10-OHM RHEOSTAT IS USED IN THIS CIRCUIT TO REDUCE THE A BATTERY VOLTAGE OF 3 VOLTS, SUPPLIED BY TWO SERIES-CONNECTED DRY CELLS, TO THE REQUIRED 2 VOLT FILAMENT POTENTIAL. ALSO OBSERVE HOW THE VARIOUS "B" POTENTIALS ARE OBTAINED FOR THE TWO TUBES, AND THE C BIAS FOR A.F. AMPLIFIER TUBE.

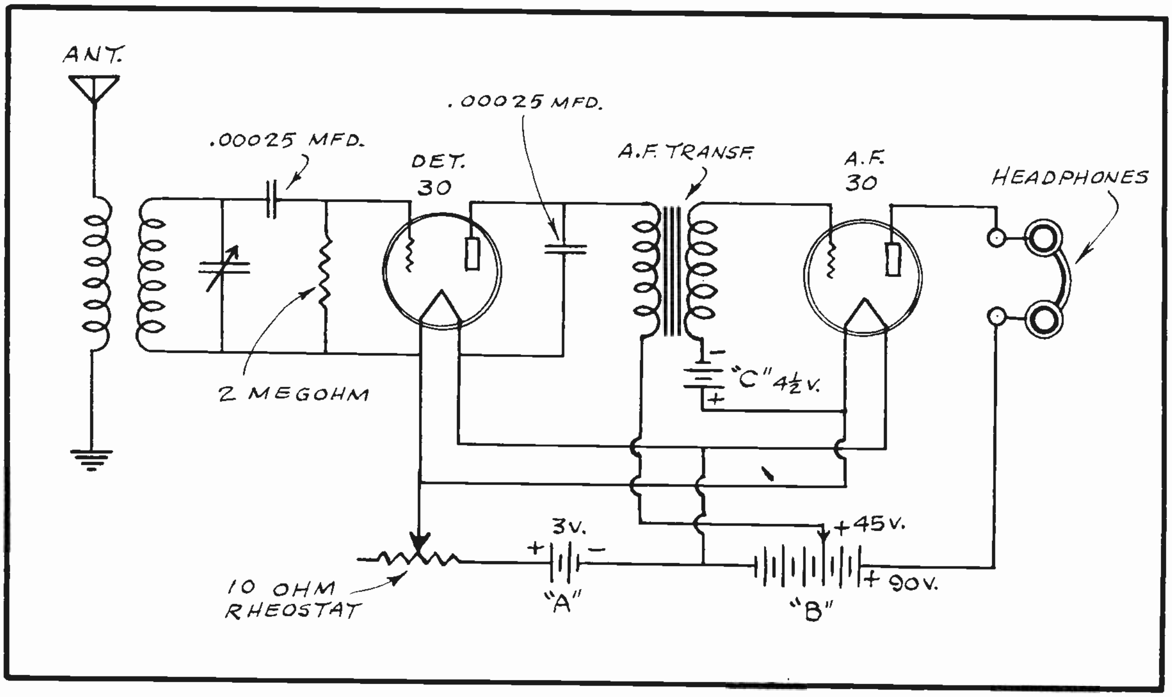

Fig. 21
Two-Tube Receiver Circuit

ANOTHER INTERESTING POINT REGARDING THIS CIRCUIT IS THE USE OF THE 0.00025 MFD. FIXED BYPASS CONDENSER WHICH IS CONNECTED BETWEEN THE PLATE TERMINAL OF THE DETECTOR TUBE AND ITS NEGATIVE FILAMENT CONNECTION. THE INDUCTANCE OFFERED BY THE PRIMARY WINDING OF THE A.F. TRANSFORMER CAUSES ANY REMAINING R.F. ENERGY TO BE REJECTED FROM THE PLATE CIRCUIT OF THE DETECTOR TUBE SO THAT IT WILL NOT GAIN ACCESS TO THE AUDIO SECTION OF THE RECEIVER.

FOUR-TUBE RECEIVER

THE CIRCUIT ILLUSTRATED IN FIG. 22 HAS A PUSH-PULL POWER STAGE ADDED TO THE OUTPUT OF THE AUDIO-SYSTEM, AND WHICH FEEDS THROUGH AN OUTPUT PUSH-PULL TRANSFORMER TO OPERATE A DYNAMIC SPEAKER. FOR THE TIME BEING IT IS ONLY NECESSARY TO NOTE THAT THE SECONDARY WINDING OF THE OUTPUT PUSH-PULL TRANSFORMER IS CONNECTED TO A SMALL WINDING KNOWN AS THE VOICE COIL, WHICH IS ATTACHED TO THE PAPER CONE OF THE SPEAKER UNIT.

THIS TYPE OF SPEAKER WILL BE EXPLAINED TO YOU IN A LATER LESSON.

WITH THE EXCEPTION OF THE PUSH-PULL POWER STAGE, OTHER FEATURES OF THE CIRCUIT APPEARING IN FIG. 22 ARE PRACTICALLY IDENTICAL TO THOSE FOUND IN THE CIRCUIT OF FIG. 21.

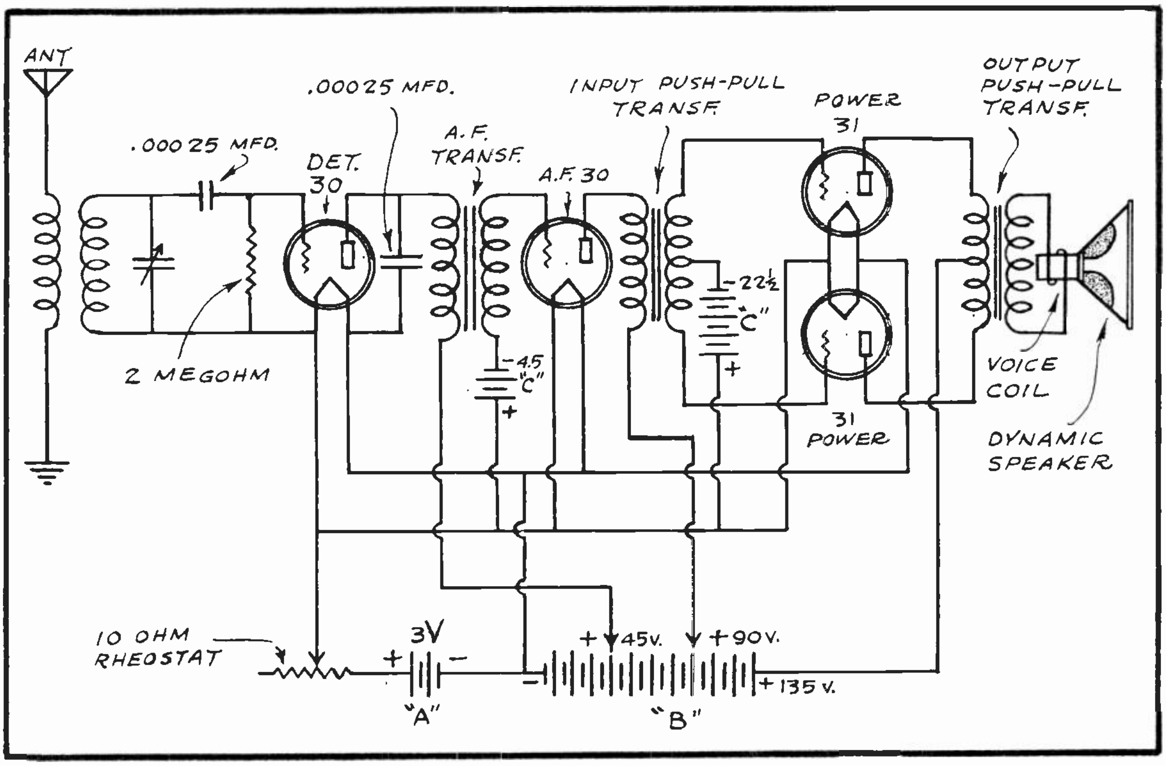

Fig. 22
Four-Tube Receiver Circuit

ALTHOUGH THE AUDIO FREQUENCY AMPLIFIER IS ILLUSTRATED IN COMPLETE FORM IN FIG. 22, THE RECEIVER CIRCUIT AS A WHOLE, HOWEVER, IS ONLY OF EXPERIMENTAL OR EDUCATIONAL VALUE, SHOWING HOW THE SIGNAL, AS "PICKED-UP" BY THE ANTENNA, IS FED INTO THE A.F. AMPLIFYING SYSTEM AND IS THEN GRADUALLY BUILT UP IN INTENSITY SO THAT A LOUD SPEAKER UNIT CAN BE OPERATED.

IN THE NEXT LESSON YOU WILL LEARN HOW THIS BASIC CIRCUIT CAN BE MADE MORE EFFICIENT AND PRACTICAL BY INCLUDING A SERIES OF RADIO FREQUENCY AMPLIFYING STAGES BETWEEN THE ANTENNA SYSTEM AND THE DETECTOR CIRCUIT.