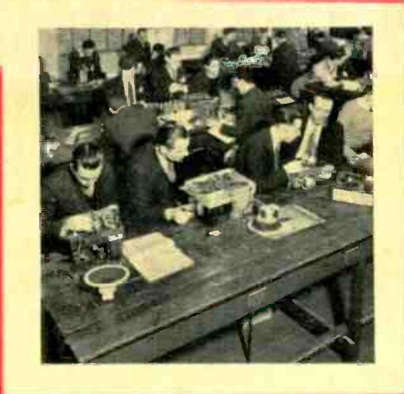

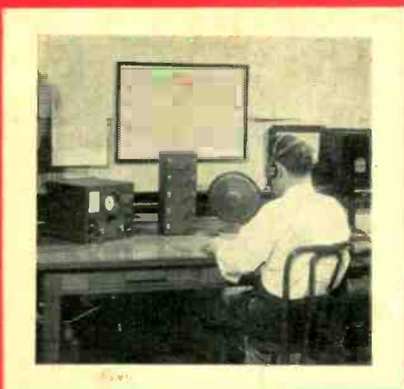

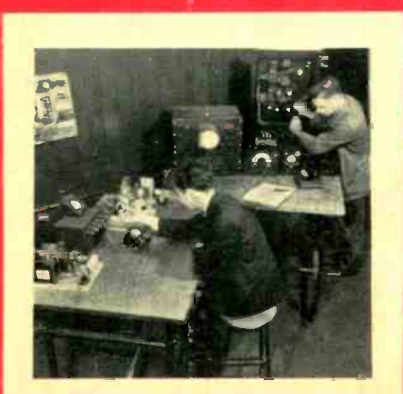

RADIO AS A CAREER

Kitson CAREERS Series

By

JULIUS L. HORNUN

Radio as a Career

By JULIUS L. HORNUNG

Here are all the things one wants to know about getting into radio work. The author conducts the reader on a personal tour of the various branches of the radio industry and describes the work of the radio operator—the ship or broadcast man; outlines the preparation necessary for the position of either; the duties of an operator; advancement in the field; the salaries offered; the future of radio operating in general. He gives the same type of information for the radio service man; his place in the field; training for the position, etc. He presents an outline of the various work in radio engineering with details about the type of engineering courses offered in schools and colleges and stresses the necessity of basic training and study for the prospective engineer before he enters college. There is a brief historical review of radio itself, giving the important advances in the industry during the past twenty-five years. One of the most important sections of the book discusses the amateur operator and his contribution to the development of radio. Mr. Hornung lays emphasis upon the importance of beginning as an amateur experimenter as an opening wedge into the field.

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BY

J. L. HORNUNG

Co-author of "Practical Radio Telegraphy," "Radio Operating Questions and Answers," "Practical Radio Communication"

KITSON CAREERS SERIES

Edited by HARRY D. KITSON, Ph.D.
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FOREWORD

To the young man desirous of attaining knowledge and skill that offer both professional security and the opportunity to render a useful service, Radio is an unusually attractive field of activity.

Relatively new, as a subject of scientific application and development, Radio is an ever-expanding subject for investigation in which new problems will continue to arise for solution. It is then not merely a novel job activity, but a subject for research and application that challenges the best the young man has to give.

In the preparation of this manuscript, both of these phases of opportunity in Radio—that is, job activity and research—are carefully considered. They are basic to the problem of the radio career. The young man desirous of entering this work asks relatively simple yet fundamentally necessary questions:

1. How shall I prepare myself?
2. Am I fitted for the work?
3. What personal qualifications are necessary?
4. What factors of study does an engineering course demand?

In order to provide the most practical information in reply to these questions, several technical and engineering outlines are here included to enable educators, counselors, students and teachers to gain a perspective of radio engineering and non-engineering contents and requirements. They serve the further purpose of showing the nature of material involved and how colleges, residential and correspondence schools present them. The presentation of this material was prompted by the nature of the questions asked of the author during a series of lectures given to public-school pupils some years ago. These questions were asked by boys and young men between the ages of twelve and sixteen—all eager to obtain exact information on the possibilities of Radio as a professional calling. Some of the questioners were interested in engineering, others in the non-engineering phases of the subject. All, however, evinced interest and the most intelligent appreciation as to the exact process to follow in this specialization.

It is the author's desire that the material of this book shall present to the reader a broad picture of what Radio involves, what it offers to the interested young man as a calling, and in what particulars it is a challenge to the inquiring and investigating mind. J. L. H.

Chapter I

WHAT DOES RADIO OFFER AS A CAREER?

THE young man interested in following the radio field as his career is most concerned with the prospect of the future. He is desirous of knowing what his chances are, once he gets into the field. What are the opportunities, and how must he prepare for them? These are the questions of paramount importance.

Radio is a vast industry and a fast-growing one. It employs hundreds of thousands in its various branches throughout the nation, and shows promise of being one of the great industries of the future. Its principles are reaching into newer fields each day and thereby creating new applications and consequently new positions.

Although the word radio was originally intended to express the art of wireless communication and in particular radiotelephony, its terminology today covers a much wider scope. We associate the word radio with almost everything that in some way deals with the vacuum tubes. True, this is not very rigid, but it does convey in a single word the field as a whole.

In this text we will use the word in its broad sense in order to prevent confusion. That is, we will use the word radio wherever the science-art is in some way connected with the general concept of the word.

The radio field from a technical and semi-technical viewpoint may be arranged into approximately five main classes as follows:

1. Manufacturing
2. Engineering
3. Merchandising
4. Operating
5. Servicing and Maintenance

Each one of these branches presents specialized opportunities for the young man of the future, as will be seen from the subdivision of each one of the classes.

Manufacturing

Factories

Transmitter Engineer
Receiving Design Engineer
Mechanical Engineer
Production Engineer
Electronic Tube Engineer
Radio Parts Buyer
Service Manager
Foreman
Radio Draftsman
Junior Engineer
Radio Parts Inspector
Tester
Serviceman
Assemblyman
Research and Development Engineer

In the Field

Sales Engineer
District Service Manager
Salesman
Serviceman
Demonstrator
Installation Engineer
Equipment Engineer

Engineering (Broadcast and Marine)

Studio Engineer
Recording Engineer
Maintenance Engineer
Acoustics Engineer
Antenna Design Engineer
Installation Engineer
Transmitter Engineer
Transmitter Design Engineer
Research Engineer
Meter Design Engineer
Chief Engineer
Chief Operator
Assistant Operator
Field Engineer
Remote Control Operator
Power Engineer
Consulting Engineer
Sound Effects Expert
Radio Compass Engineer
Field Measurement Engineer

Merchandising

Wholesale

Sales Manager
Salesman
Service Manager
Bench Service Expert
Buyer
Home Service Expert

Retail

Sales Manager
Service Manager
Bench Service Expert
Buyer
Amateur Radio Expert
Technical Correspondent

Operating

Ship and Harbor Radio Operator

Chief Operator
Assistant Operator
Radiotelephone Operator
Factory Installation Expert
Radio Operator on Police
Fire, Fishing and Tug Boats
Yachts

Aviation Radio

Airplane and Airship Operator
Transmitter Technician
Receiver Technician
Airport Transmitter Operator
Factory Installation
Aircraft Radio Inspector Technician
Dispatching Operator
Design Engineer

Commercial Radio Stations

Transoceanic Telephone Engineer
Inland Waterways Radio Operator
Facsimile Engineer
Radiotelephone Engineer
Radio Operator
Traffic Supervisor
Remote Control Engineer
Maintenance Engineer
Radio Engineer
Power Engineer
Communications Expert
Antenna Design Engineer

Police Radio

Design Engineer
Installation Engineer
Transmitter Operator
Receiver Serviceman

Automobile Radio

Design Engineer
Factory Inspector
Interference Expert
Installation Expert
Service Engineer

Public Address Systems

Design Engineer
Monitor Operator
Acoustical Engineer
Installation Engineer
Service Expert
Sound Engineer

Electronic Control

Equipment Engineer
Installation Engineer
Electronic Control Engineer
Design Engineer
Industrial Control Expert
Photoelectric Specialist

Television

Experimental Engineer
Receiver Design Engineer
Television Engineer
Transmitter Operator
Transmitter Design Engineer
Lighting Specialist
Pick-up Operator
Installation Engineer
Service and Maintenance Expert
Production Engineer
Antenna Expert
Consulting Engineer

Government Radio

Research Engineer
Associate Engineer
Assistant Engineer
Radio Inspector
Radio Physicist
Airways Radio Operator
Operator in Army, Navy, Marine Corps and Coast Guard
Operator of Radio Beacon and Weather Stations

Miscellaneous

Radio Instructor
Radio Technical Writer
Wire Photo Technician
Cathode Ray Expert
Light and Sound Engineer
Diathermy Design Engineer
Electronic Gadgets Expert
Radio Announcers
Specialized Tube Design Engineer
Facsimile Engineer
Laboratory Assistant
Specialized Equipment Design Engineer
Patent Expert
Script Writers
Lawyer-Engineer

Practically every one of the positions outlined, with the exception of the radio announcer and script writers, requires a technical background. Those which come under the classification of engineer or expert must require an intensive engineering training.

Value of College Training

College training is unquestionably the first prerequisite toward an engineering career. Wherever it is possible, the young man should set this as his future objective. This, of course, does not mean that the young man who does not enter college cannot attain the same accomplishments as the engineer. Thousands of men are actively engaged in the radio engineering profession who have not obtained a college degree. These men have acquired success by the road of good basic learning and experience. Many of the successful engineers have started as amateurs, radio operators, and radio servicemen. In practically every case these men have attained their higher objectives by intensive reading and study of engineering literature; by attending specialized courses of training; by continuing their training education in college; by attending reputable trade and technical schools or by enrolling in recognized correspondence schools.

An Expanding Industry

Let us examine briefly the accomplishments in the radio field during the last twenty years and see how they may be regarded as an indicator that charts the possibilities for at least a decade to come. In practically every sphere in which radio has been adopted as a medium of communication, it has displayed healthy expansion, accompanied by improvement of its facilities.

In transoceanic communication, in ship-to-ship and ship-to-shore service, in aeronautics, in government and military use, and in broadcasting, a large number of transmission channels were put to use, which formerly were considered worthless. There were thus made possible a greater number of fixed and mobile stations; more and better equipment was developed, built, and installed; and, as a consequence, there arose a demand for a larger number of trained technicians.

As we emerge from the past and look into the future, we find that all the curves in our chart point upward; that is, they are optimistic in their indications. No saturation in either expansion or improvement seems to be in sight. In fact, developments along newer lines are reaching the point at which further opportunities for technically trained persons are apparent.

Visual transmission—facsimile and television—aircraft radio, electronics, geophysics, carrier systems, high-frequency diathermy, remote control, and many others of the later developments show a healthy growth. Possibilities in the field of radio are plentiful, and no strain need be placed on the imagination in order to conjure up a picture of the developments yet to come.

What do these strange terms signify?

Well, facsimile refers to the transmission and reproduction of permanent pictures, which may be photographs, maps, handwriting, typing, fingerprints, etc.

Television is our electronic telescope—it is to our sense of vision what sound broadcasting is to our sense of hearing. By means of television, scenes and happenings many miles away may be instantly reproduced on a screen.

Aircraft radio involves more than communication between flying planes and ground stations. Radio beacons, radio compasses, and various types of guiding systems to direct an airplane in flight and in landing form part of aeronautic radio.

Electronics embraces all developments that are based on the use of vacuum tubes—automatic door opening, automatic drinking fountains, automatic traffic control, various types of safety devices, and automatic sorting machines are just a few of the more common electronic applications.

In geophysics, radio waves are employed to determine the presence of liquids, minerals and ores below the surface of the earth—to tell the story of their location inside the earth.

Radio waves guided by electric conductors are the basis of carrier-current systems. Telephone, telegraph, and electric power companies employ this radio development very extensively; more recently, the principle has been applied to industrial intercommunicating systems.

Medicine and surgery have been enriched greatly by the developments in the radio field; the fever-producing machines and bloodless-surgery equipment are outstanding examples of high-frequency diathermy.

Radio also adapts itself readily to the control of equipment at a distance; the radio-controlled airplane is a well-known example.

Qualifications Necessary

Obviously the young man who visions opportunities in the field of radio wants to know what qualifications he must possess in order to be successful in it. Those qualifications are the same that make for success in other lines of human endeavor; but, in addition, he must have a sound knowledge of all the technical subjects that enter into his chosen work.

If he plans to go in for research, development, or general engineering, a college education is highly desirable and oftentimes essential. If he expects to engage in operation, installation, and maintenance, he must possess specialized training such as is given in a good vocational school or which can be obtained almost as well in some cases by correspondence instruction.

Unfortunately, there is many an able and earnest young man who finds it utterly impossible to go to a resident school or college, either because he lacks funds or because he is employed and cannot afford to leave his job. To the person in such a predicament, the home-study school offers an excellent opportunity for the acquisition of the necessary training.

Today there is no excuse for the man who fails to attain success in his chosen field because he lacks training. If he can go to a resident school he should by all means do so, but if he cannot he can bring the school to his doorstep by enrolling for a correspondence course. He has a wide range of subjects from which to choose, according to the purpose he has in view. Some correspondence courses are short and comparatively simple, whereas others compare favorably with college courses in both scope and thoroughness. These will be more thoroughly treated in a later chapter of this book.

There is no magical process by which an education can be obtained. It demands such old-fashioned qualities as earnestness of purpose and willingness to work, coupled with a fixed determination not to be satisfied with mediocrity. Any man thus animated can master a course of study and make it a valuable working tool.

Chapter II

WHAT IS RADIO?

THE terms Wireless and Radio are synonymous. At the beginning of communication without wires, the term wireless telegraph was universally used to describe this type of communication. Since the advent of telephony and the broadcasting of speech and music without wires, the term wireless has disappeared in America, and radio has become the adopted word. Now we look upon "radio" as pertaining to anything that deals either directly or indirectly with the art of telegraphic or telephonic communication. The term has reached such tremendous proportions that it has become a household word with young and old. It is associated with the home, the hospital, the school, the church, the theater, travel, industry, music, government, and so on.

We are all familiar with its many uses and necessities, but just what is radio? A non-technical definition as given by the layman would simply be, broadcasting. However, let us see what its general technical definition portrays.

Radio is the art of communication without wires: it is that system in which waves are transmitted or received through space without the use of interconnecting wires. Of course, wires or radiators are used to transmit these waves or intercept them.

In order to formulate a clear picture of how these waves are transmitted through space, let us take the case of a simple radiating system in the home, the heat radiator. How does the radiator transmit heat to warm your room? Three important elementary factors must prevail in order to transmit these heat waves into space: (1) heat must be generated; (2) heat must be transferred from the generator (fuel) to the radiating system (pipes); (3) the radiating system must be properly designed to throw out the generated heat waves efficiently into space (flanges). Now the question of temperature will arise; that is, how is the heat transferred to the object to be heated? In a simple non-academic sense it may just be stated that the heat travels through the air, or the air serves merely as the conducting medium. Now comes one of the most important points of all—types of transmission and radiating systems, namely, power. Just what is power? How is it produced? We may again answer this question in simple language: power is the time rate in which work is being done, and it is accomplished by some means of generation. To be more specific, however, one should say that power is the rate in which energy is dissipated in heat or transformed, and that it may be generated either by chemical, dynamic, thermal, or frictional means. The chemical may be exemplified by the battery, the dynamic by the electrical generator, thermal by the oil burner, and frictional by the static machine. All these methods of generating power are basically by friction in some form or other. Stated scientifically, it would mean that when mechanical work is transformed into heat or heat into work, the amount of work done is always equivalent to the quantity of heat.

We now see that our simple radiator system in the home is in reality a "broadcast" transmitter of heat. The fuel chamber is the generating plant, the pipes are the conducting links, and the radiator the device which projects the heat waves into space.

The Broadcasting Station

The radio broadcast transmitter is essentially the same sort of arrangement. Let us analyze its component parts and see how it works. Every broadcasting station must have a generating plant, that is, a place where the power is generated. The source of power is either a mechanical generator, transformers or batteries. The first two are the most commonly utilized, while the latter is generally used in small portable or mobile types of transmitters.

Now let us take a typical broadcasting station such as the one we listen to for our programs. It has a generator, a transmitter, and a radiator, just like our simple heating system. The generator or transformer is a device which consists of a number of windings called the primary and secondary. The primary is connected across a typical electrical power line just like the electric lamp in your home. Now, when the current flows through the primary winding of the transformer, and also if it is of an alternating character (surging to and fro), power will be developed in the primary winding. This power will then be transferred into the secondary winding, but of increased pressure, called voltage. The transformer, therefore, raises the pressure and transfers the power. You see, it requires a great deal of power to operate a broadcast transmitter; thousands of watts and volts may be needed.

If we return briefly to our heat-radiating system in the home, we recall that there are certain requirements for the development of power. First we must develop a pressure. The pressure is the heating of the water into steam. The steam then flows through the pipes and to the radiating system. The flow of steam was caused by the pressure, and as a result the power developed by the fuel was transferred to the radiator. In other words, the amount of power developed in the radiating system is the product of the flow and the pressure. Electrically we refer to the pressure as the voltage, the flow of electricity in the wires as the current, and the product of these two as the power.

Now, this power developed in the secondary winding is used to do work. That is, it must light the large vacuum tubes in the transmitter; it must supply power to generate electrical waves. The voltage that is supplied to the vacuum tubes for heating the filaments can be of an alternating character, but the voltage that is supplied to that portion of the vacuum tube called the plate must be of a steady or unvarying character. This requires special vacuum tubes connected to the secondary winding of the transformer for converting the alternating current into direct current. These are called the power rectifiers. Then when the current is rectified to direct current it must be smoothed out so that no irregularity in the flow prevails. The devices which do this particular job are called filters. They act just the same in principle as a fine-meshed sieve connected to the end of your drinking-water faucet: they serve to filter the current.

The Generators

Let us now look into the device in the transmitter where the radio waves are generated before their propagation into space. This equipment consists of a coil of wire and a device known as a condenser. These devices in conjunction with the vacuum tube are the generators of the high-frequency radio waves when provided with the proper power from the power transformer.

But just how does this combination operate to generate such high frequencies? Perhaps the best way to describe it is to visualize a mechanical tuning fork or even an ordinary table fork. These forks possess two fundamental characteristics, mass and elasticity. The mass is the physical dimension or weight of the fork, while the elasticity is dependent upon the character of the metal or its springiness. If we tap the fork on a hard surface, it will vibrate and produce a sound or pitch audible to the ear. This sound is called the vibration rate or frequency. In the broadcast transmitter the coil and condenser is the vibrating body, although it does not actually vibrate physically. The vibrations or oscillations, as they are more commonly called, are developed electrically by the current surging to and fro between the coil and the condenser. The frequency of these oscillations in all broadcast transmitters is beyond the range of human audibility; they range from 20,000 to 300,000,000 vibrations or cycles per second. The reason for using these very high frequencies is the relatively greater ease with which high-rate vibrations penetrate into space. Low frequencies, particularly those in the audible range between 16 and 20,000 cycles, travel through relatively much shorter distances.

The high frequencies, called radio frequencies, that are generated by the coil and condenser produce waves about the coil just as the radiator does in the home, only with this difference. The waves generated by the coil are not heat waves, but are called electromagnetic waves. They do, however, radiate energy in a like manner and actually cause power dissipation in the form of heat. That is to say, these electromagnetic waves must be supplied with power to maintain them just as the fuel system in our heating plant supplies power.

Now these high frequency electromagnetic waves do carry over great distances, but not without the help of a suitable device for throwing them out or radiating them. The arrangement which produces this effect is called the antenna or radiating system. If we follow the sequence of our preceding explanation it is apparent that the waves generated by the oscillatory system must be transferred to the antenna system just as the fuel energy is transferred to the heat radiator through the medium of pipes. Only in the case of the radio broadcast transmitter the transferring medium is a series of boosters or amplifiers, the number of which depends upon the power requirements of the transmitter. These amplifiers are vacuum tubes so adjusted and arranged that the initial high-frequency energy developed by the first vacuum tube and its associated coil and condenser will be readily transferred and amplified. The final tube receiving the energy then transfers it to the antenna through a wire transfer system called the coupling or transmission line current. If all the circuits following the initial tube generator are adjusted (tuned) to the same frequency, including the antenna system, the waves will be radiated into space at radio frequency.

The frequency of these waves will depend upon the mass and elasticity of the first generating coil and condenser. In other words, the greater the number of turns in the coil and the greater the capacity of the condenser, the lower will be the frequency of the oscillations, and vice versa. This is how the engineer tunes his transmitter to whatever frequency his transmitter is required to operate at by authority of the Federal Communications Commission.

We have seen how the radio frequency waves are developed by the coil and condenser associated with the first tube. Here an important supplementary function must be considered. Although the frequency is generally dependent upon the coil and condenser adjustments, it may also be required to have a stabilizing device which will "hold" the frequency at the desired value. This is one of the most important requirements of the Federal Communications Commission for all types of radio transmitters, namely, aircraft, amateur, broadcasting, and marine.

The standard broadcast transmitter has the most rigid requirements. Its frequency must be maintained constantly within 20 cycles, plus or minus, of its assigned value. This means that if a radio frequency wave is 700,000 cycles per second, it must not drift more than 20 cycles above or below this value. This would be almost impossible to accomplish with the ordinary oscillatory circuit of the coil and condenser which we have previously described. The reason is quite technical but it might be said that the instability of the ordinary circuit is due to temperature changes in the tube, its associated circuits, and the power supply. Consequently, a sort of mechanical governor must be employed to hold the frequency within the required limits.

This is accomplished by a device called a crystal oscillator or, more technically, a piezo electric oscillator. The oscillator is actually a mechanical vibrator composed of a quartz plate placed between two metal plates. This plate has the peculiar property of vibrating when subjected to the electrical pressure changes (alternating current voltages) supplied by the vacuum tube and its associated coil and condenser. The rate of vibration or frequency will depend upon its physical dimensions, thickness, mode of optical cutting, and operating temperature. For example, a very thin slab of quartz may oscillate at radio frequencies as high as 15,000,000 cycles per second! Think of it: a small glass plate generating vibrations far beyond the range of human audibility and controlling the frequency of a powerful broadcast transmitter!

Now that we have seen how the radio transmitter sends its high frequencies into space and over worldwide distances, let us analyze how the speech and musical frequencies (those vibrations lying between 16 and 20,000 cycles) are carried with the radio frequencies. Before doing so, however, let us consider the broadcasting studio where the artist or orchestra may be performing.

The Broadcast Studio

The basic electrical components of a typical broadcast studio are the microphone and the audible frequency vacuum-tube amplifiers. The latter are most commonly referred to as the audio-frequency amplifiers. The microphone in this set-up is the generator of the electrical vibrations. It operates on the principle of changing mechanical impulses into electrical impulses. How this is accomplished may be more clearly seen if we analyze the fundamental operation of the microphone itself.

The basic structure of most types of microphones consists of a diaphragm or moving membrane delicately balanced and suspended so that it will be free to vibrate when sound waves are impressed upon it. The diaphragm is then attached to a small coil of wire and placed in the vicinity of a small permanent magnet. This magnet has the property of attracting any particles of iron or steel, just like the little toy magnet we are all familiar with. In this case the attractive force is exerted upon the diaphragm coil made of copper wire, but does not attract it, because copper is a non-magnetic material.

Now, when an artist is talking or singing into the microphone, the sound waves developed by the voice impinge upon the diaphragm and cause it to vibrate. The small copper-wire coil, being attached to it, will obviously also be set into vibration, both of these units actually vibrating at the frequency of the sound emanating from the artist. The to-and-fro or up-and-down motion of the coil, being in close proximity to the lines of magnetic force from the permanent magnet, will cause an electrical pressure to be set up in the coil. This is known as electromagnetic induction or the process by which moving lines of force—or moving turns of copper wire—develop an electrical pressure or voltage. The movement of the coil in the presence of the magnetic lines of force makes it an electrical generator. Almost all generators, large or small, operate upon this principle.

You see, the generator does not really create electricity, but merely sets in motion that which is already there.

Electricity is present in all matter, solids, gases, or liquids. It merely requires some force to set it in motion; then, once in motion, it constitutes an electrical current.

The current-flow through the small wire winding of the microphone is made to pass through still another winding called the microphone transformer primary winding. This transformer, with its primary and a secondary, is usually a part of the audio-frequency amplifier unit located at some distance from the microphone proper, but through the medium of conducting wires the two devices become connected as one.

If we now assume that the microphone is still in operation, the small generated currents surging to and fro between the two windings will be developing magnetic fields about them. You see, copper wire will produce a magnetic field only when an electric current is flowing through it. The magnetic field now moving about the primary winding will induce an electrical pressure, but of very small power, to the secondary winding of the transformer. This pressure, or voltage, is of such feeble amplitude that it must be raised to a sufficiently higher level to enable it to be transmitted through the telephone lines to the radio-frequency transmitter.

The required amplification is obtained by a number of vacuum tubes and transformers in the audio-frequency amplifier system. In some of the large networks, programs of feeble voice impulses are actually fed through the originating studio amplifiers and the telephone company's amplifiers over a distance of 2500 miles. This may require more than 300 additional audio-frequency or repeating amplifiers as they are usually called throughout the network. Thousands of vacuum tubes and transformers are employed in a single large network. Hundreds of maintenance and operating personnel must be on duty for a single program. So you see it is not merely a question of sending impulses and amplifying them, but also having men on duty who know all about them; how they amplify, how to control the amplification, what to do in an emergency, and so on.

Now let us continue with the audio-frequency amplifier and see what other factors play an important part. Suppose that the artist reaches a passage in which he or she is gradually raising the volume of sound. The basic theory of operation still prevails, with the exception that the induced voltages and currents rise to larger proportions. They may actually rise to such magnitudes that the original sound wave becomes badly distorted and thereby may seriously affect the qualities of transmission. Here is the point where the studio control-room engineer takes a hand. He is seated at his control board watching an indicating meter called the "volume unit indicator," which is so calibrated that he can instantly detect an excessive signal voltage. It is his duty to adjust the signal to the proper level by a regulating device known as a "gain" control. This device not only preserves the natural sound of the artist but also regulates the amount of power delivered to the telephone transmission lines. This must be rigidly adhered to, since the telephone companies have a definite standard of maximum power that can be transmitted through their lines. These lines are also properly adjusted by telephone engineers, so that the musical frequencies transmitted through them are herein also properly preserved. Special devices known as equalizers and repeating amplifiers are inserted to obtain these requirements.

The radio telephone lines differ considerably from the ordinary speech lines because of the wide range of frequencies that are to be accommodated; for the higher musical frequencies above 5000 cycles per second are lost in the ordinary line, due to their length and the so-called capacity effects. Hence the use of special lines and equalizers. The latter device is simply an arrangement of coils and condensers so adjusted or tuned that those frequencies which are normally diminished are raised to meet the level of the lower speech or musical frequencies. Actually what happens is that the higher frequencies are raised only slightly and the lower frequencies as a result are dropped lower to meet them. This obviously introduces what may be called a compensating loss, but it does tend to develop a flatter over all frequency response. It is for this reason as well as the line losses that additional audio-frequency amplifiers may have to be inserted by the telephone company as well as one at the broadcast transmitter proper.

How Speech Is Sent Through Space

We can now return to the broadcast radio-frequency transmitter and see how the speech and musical frequencies are combined with the high radio frequencies for transmission into space. From the technical point of view this is a complicated process, and therefore will be treated in a manner that will serve to give the layman an idea as to its workings. There are two general methods of sending low-frequency vibrations in combination with high-frequency vibrations. The most common and that used by the majority of broadcast stations throughout the world is called "amplitude modulation." The second method, which is undoubtedly the system of the near future, is called "frequency modulation."

Modulation is just what it implies grammatically; that is, the process of forming or molding, shaping. In radio telephonic communication the radio-frequency wave as generated by the transmitter is a steady, unvarying wave, in which all the crests, following in rapid succession, are of the same height or amplitude. That is why the wave is generally referred to as a continuous undamped or unmodulated wave. Broadcast engineers usually term it the "carrier frequency" to differentiate it from the change which occurs during the process of modulation with speech or music.

Modulation in radiotelephony is a complex problem, but let us look at a simple illustration that may serve to explain its operation. If a water pump is churning at a fixed rate of speed and discharging water into a placid lake, waves of a certain height and depth will be produced. These are pictured as crests and troughs moving out into the lake, but of gradually diminishing amplitude. This would be classified as a damped or decaying wave. In telephony, however, the wave is continuous, so let us visualize the water waves in our example as extending outward in the lake, but of unvarying crest height. We must also visualize that the trough really is another crest extending downward into the water. Now the churning pump is assumed to be sending out a steady or undamped frequency rate of water waves, say 100 per minute.

If we can picture another pump sending out waves of water in such a manner that they are periodically in step with the main pump, we have a periodic reenforcement of the main waves and a resultant increase in the height and trough of this wave. In other words, the two frequencies are in step or in phase with each other. Now if the second pump should be sending out waves of a frequency much less, of say 10 per minute, the waves would combine in such a manner that they would periodically supplement and subtract from the main wave. Hence there should be developed three resultant waves, one of 100, another of 90, and still another of 110 per minute. This analogy is by no means a rigid explanation, but it does serve to give an elementary picture. All we have to do to apply this analogy to the radio transmitter is to raise the 100-per-minute rate to 100,000 per second and the 10-per-minute to 1000 per second. Here we have a radio-frequency and an audio-frequency rate, respectively.

Let us assume that a radio artist is whistling into the microphone at a steady rate of vibration, in the order of, say, 1000 cycles, and that these vibrations are sent through the speech-amplifier system to the transmitter. The transmitter is assumed to have been adjusted to a carrier frequency of 100,000 cycles. Now, if these amplified speech-frequency voltages and powers are supplied to the transmitter oscillatory circuit in such a manner that they will periodically add to and subtract from the carrier frequency, the antenna system will radiate three radio frequencies, namely 100,000, 101,000 and 99,000. You will note that they are all radio frequencies, and as a result can all be radiated into space over great distances. This process of varying the amplitude of the carrier frequency at an audible rate is called "amplitude modulation." Of course, it will be necessary to untangle, or more appropriately to demodulate, this combination of waves at the receiving end so that the 1000-cycle whistle may be heard.

The Radio Broadcast Receiver

Radio broadcast receivers are generally referred to by the public as just plain "radios," and are immediately understood as a box or cabinet which brings radio programs into the home. Just what happens in this box to make the music or speech audible to the listener is generally of little importance, but to some, particularly the young man who is endeavoring to learn something about it, the problem becomes an intriguing one. The radio, as we shall now call it, is similar in many respects to the transmitter in that it requires vacuum tubes, tuning circuits, amplifiers, volume controls, and so on. It is, however, opposite to the transmitter in the resultant effect that it reproduces. The transmitter sends out the waves and the radio receives them. The microphone at the broadcasting studio converts sound variations into electrical variations, while the radio converts electrical variations into sound variations or vibrations. Let us see how all this occurs.

Radio waves emanating from the broadcast transmitter and its associated antenna system are radiating into space over great distances and in all directions. Each station is operating at a different frequency unless they happen to be far removed from each other, in which case they may operate at the same frequency. In any event the ether is constantly filled with thousands of radio frequencies from all over the world. If these frequencies are of low vibration rate they are called long waves, if they are moderately high they are called medium waves, and if they are very high they are called short waves. Short waves, because of their very high rate of vibration, may travel many thousands of miles. Even a small transmitter employing one tube such as is used in the average radio can transmit radio signals thousands of miles under proper conditions. Obviously the radio signals may be of very feeble amplitude or power, and suitable means must be provided to amplify them. Our simple wire or antenna, even if only a few feet long, is in the constant path of these different frequencies. Some are so feeble that the average radio cannot audibly reproduce them.

What is really happening in our receiving antenna system is very interesting. Actually there may be hundreds or even thousands of signal variations present in the form of electrical currents surging to and fro as in the coil and condenser oscillatory system mentioned early in this chapter. The antenna and ground circuit is really an oscillatory system. The antenna wires are the electrical "masses" and the air space surrounding them is the condenser. Now when the radio is connected to the antenna and ground, these current surges at the many radio frequencies produce varying magnetic fields, some strong and some feeble. If we turn on the radio and adjust our manual tuning control or automatic control to a certain station, we hear the station reproduced in the loudspeaker. If the radio is properly designed, we hear only one station, even though many are actually present in our antenna circuit. This is because the tuning circuit, which consists of coils and condensers, acts like a mechanically tuned body; that is, the coils and condensers respond or oscillate only to the frequency to which they are tuned.

The radio signals are additionally amplified through a number of vacuum tubes, each having a specific function. You will recall that the complex radio frequencies transmitted from the broadcast antenna are not audible because they lie in the range above human audibility. The radio, therefore, must not only amplify these frequencies but must ultimately detect them or make them audible. Then, after they have been detected or demodulated, they must be further amplified at the audible frequency by one or more additional vacuum tubes. This is necessary in order to supply sufficient power variations to operate the loudspeaker. Of course the radio signal itself is not powerful enough to operate the loudspeaker; it merely supplies the voltage or pressure variations. The power is actually supplied from the light-socket power line and the vacuum tube called the power tube, and all that the radio signal does is to vary the current in accordance with the modulations produced at the broadcast transmitter. The power supply system in the radio receiver is the same in principle as that employed in the transmitter, with the exception that the amount of power dissipated is by far much smaller.

Although the explanation in this chapter has been confined to the broadcast transmitter and the radio receiver, the entire principle of operation is applicable to marine, aircraft, police and amateur transmitters and receivers. It is hoped that the foregoing sketch of what radio is and how it works will serve in a small way to aid toward a better fundamental understanding of the subject. Radio may mean many more things than that which has been described, some of which are brought out later in this book, but on the whole radio is basically a technical term and with such intent only has it been treated in this chapter.

Chapter III

STARTING IN RADIO

It is the author's opinion that one of the finest ways for the young man to enter the field of radio is to begin as a radio amateur.

Since the beginning of the radio art the contributions of the amateur and experimenter have been outstanding highlights in radio progress. He has been and is one of the real pioneers in its development and advancement. Although most of the great fundamentals have been developed by such outstanding men as Heinrich Hertz, James Maxwell, Michael Faraday, Joseph Henry, Sir Oliver Lodge, Guglielmo Marconi, Lee DeForest and many others, the amateur radio experimenter and operator has been one of the pioneers who have helped to put these principles into practice. He is continuing his precedent today and will continue to do so in the future.

Glancing briefly into the past and viewing the radio amateur experimenter and operator of the pre-war period, we see a young man between 12 and 18 years of age seated at a small table winding a coil of wire on a cardboard tube. He attaches a small rod of metal and a sliding metal contact. On the table is a small crystal of galena fastened to a metal plate. A thin piece of phosphor bronze wire is attached to the metal plate through an insulated pillar bushing, and the wire is then lightly pressed upon the surface of the crystal. A pair of telephones and a small condenser consisting of a few sheets of tinfoil and waxed paper are then connected to the coil and crystal units. A wire is attached to the water pipe for an earth connection, and another is stretched to a nearby clothesline. The radio receiver is now ready for operation.

Hour after hour the young experimenter is delicately adjusting the fine wire resting upon the crystal in the hope of obtaining a signal. If he is fortunate in having all of his electrical connections well soldered and possesses a good crystal, his untiring efforts will finally be rewarded. He listens eagerly to the feeble dots and dashes of a ship at sea sending its telegraphic messages. Hour after hour, day after day, he continues to listen, until he becomes more familiar with their meaning. The process of learning how to receive messages by this slow method, of course, takes a long time. Many of the old-time amateurs have, however, learned to copy in this manner.

Perhaps the most common method employed by the young amateurs of years ago was the one in which each constructed a small crystal receiving set and a small transmitting set. The transmitter usually consisted of a spark coil, a telegraph key, a spark gap, a condenser, and a few dry cells. When the parts were all carefully connected, the key was depressed and a series of sparks jumped between the two electrodes. The antenna and ground is then connected to the spark-gap electrodes so that the spark will energize the antenna system and thereby radiate the electromagnetic waves into space.

I believe this is the point of the amateur's real introduction to the fascination of radio. At the moment when he touched the key and realized for the first time that he was sending waves into space, he was gripped with one of the greatest thrills in his life. Slowly he would tap the key to send out the letter *dit dit dit dah*, which is the international test letter *v*. He would continue to do this until he finally mustered up enough courage to send out the *C Q* or general call. This call is used by amateurs all over the world when they wish to start a conversation with some other amateur. After sending the *C Q* signal very slowly for about half a minute he would follow with the letters *de*—the French word meaning *from*—and then follow with his own call letters or initials as the case might be. Of course, remember we are talking about the amateur of twenty-five or more years ago. In these early days of radio many amateurs would transmit radio messages to each other using only their initials as call letters.

Now comes an even greater thrill. When the young amateur has completed his calling and signing off, he listens patiently with the headphones clamped to his head and carefully adjusts his crystal detector for a sensitive spot. He slides the moving contact on his coil slowly up and down, ever listening for the call that will tell him that his signals have been heard. Finally, after possibly days of persevering, he hears a faint series of dots and dashes calling him. The thrill can never be described in words, it is so charged with emotion and exultation. It is the beginning of a new era for the young man. True, it may appear as only a hobby at the time, but it is a hobby that grows and grows upon you as time goes on. It develops a keen interest and the desire to know more about it, and, finally, the anticipation of making it the objective of the future.

Thousands of young men throughout the world have started in this manner and are now holding responsible positions in the various fields of radio and allied industries. A number of these will be outlined later, together with their names and the positions they now hold.

I believe it appropriate at this point to present the testimony given by Mr. K. B. Warner, Secretary and General Manager of the American Radio Relay League, at a hearing before the Federal Communications Commission in Washington, D. C. It presents an accurate outline of what the amateur has done and how the field of amateur radio represents a great training school for the art and the industry.

Amateur Radio a Vast Training School

We would like first to emphasize the importance of amateur radio as the great training school for the radio art and industry. There is nothing quite like it in any other field of endeavor. Amateurs train and equip themselves at their own expense. They contribute vast resources of technical experimentation and emergency communication without cost to civilization. They constitute a mighty reservoir of self-trained operators available for the military in time of need. They provide the great source of self-trained engineering and operating and even executive personnel for the radio industry.

The bulk of the familiar figures in the radio field today started as amateurs; a great many of them still operate amateur stations. The annual report of the Chief of the Radio Division of the Department of Commerce for the fiscal year ended June 30, 1928, reported the results of a survey made by the American Radio Relay League at the Division's request to determine the extent to which amateurs and former amateurs were occupied in the radio industry. Although figures on a group of the largest organizations were not available, it was found that those engaged in executive positions in the radio industry—45 presidents, 16 vice-presidents, 5 general managers, 69 managers, 37 owners, 324 engineers, 19 announcers and 11 directors—were of amateur extraction. This list did not include operators. From another survey of approximately the same period it was found, of 9725 amateurs classified, that 1503 were engaged in radio engineering as a vocation. A total of 4917 were regularly doing service and repair work on radio receivers as a part-time or whole-time vocation.

Interviews with executives of radio broadcasting stations, radio manufacturing firms and radio communication systems demonstrate the high preponderance of amateur extraction. The operators and engineers of the largest broadcast station of the country are 100 per cent licensed amateurs. This is true of many other stations; in the remainder, there is almost invariably a majority of licensed amateurs. We estimate that 85 or 90 per cent of broadcast engineers and operators are amateurs. In the manufacturing field much the same is true. One large manufacturer has an almost entirely amateur-licensed engineering staff. Another employs amateurs exclusively in his test department, the critical point in the manufacturing process. Amongst commercial operators at shore stations and engineers of communications companies, amateur origins —and, for that matter, present status—are widely prevalent. In short, practically the entire personnel for the radio art and industry is derived from amateur radio.

Contributions to Radio Technique

The amateur's contributions to the technique of the radio art have been manifold. The amateur is an experimenter. He is generally not too much encumbered with ponderous knowledge. Not hesitating to tackle problems that he has not heard were insoluble, he frequently turns up with the answer. When the amateur was first banished to 1500 kc. and above by the Radio Act of 1912, the purpose was to accomplish his gradual extinction by his isolation on frequencies then regarded as worthless for useful communication. But he astonished the world by developing apparatus and methods to communicate at considerable distances on these despised frequencies. He was the first to demonstrate the value of the high frequencies, the first ever to tie the nations of the world together with high frequency and low power; before the amateur there was no occupancy of frequencies above 1500 kc.; the entire vast structure of high-frequency operation as it is known today, with a diversity of services embracing the world, has flowed exclusively from the pioneering developments and demonstrations of the radio amateur in 1923, and subsequently.

Many specific technical developments can be mentioned. The first exposition of what was taking place in high-frequency sky-wave transmission was by an amateur. The first exposition and demonstration of the bending of ultra-high-frequency rays in the lower atmosphere was by an amateur. The most selective telegraph receiver in common use today, generally employed in amateur radio, is an amateur development. So is the startling arrangement recently given to a waiting world for the silencing of man-made electrical noises in radio receiving equipment. The items mentioned are only illustrative and are recent. Throughout the years the amateur has been a pioneer, working out the apparatus necessary for his peculiar problems in a fashion that the scientific and commercial branches of radio have followed with the greatest interest.

One might refer, for example, to the amateur's magazine, *QST*, in which the amateur's technical progress has been chronicled for many years, and refer to the fact that this journal is read in every important radio laboratory on the face of the earth, and that an impressive list of the most important developments in radio as we know it today first found publication in its pages.

Aids to Science and Research

The large number of amateurs, their scattered location over every portion of the nation, and their diversification in talents, interests, abilities and choice of operating frequencies have made of this group an invaluable aid to science. Let something arise on which radio physicists need a large number of observations, and almost instantly a very considerable group of skilled amateurs can be found who are interested in collaborating. Thus amateurs many years ago assisted the National Bureau of Standards in a comprehensive investigation into the fading of radio signals, submitting many hundreds of charts in an organized series of tests run under the auspices of the Bureau. They have similarly participated in investigations into the effects of solar eclipses, in the Navy's early investigation of the skip effect in high-frequency transmission, and, more recently, in the peculiar periodic daylight fade-outs of high frequencies noticed by the National Bureau of Standards.

It need scarcely be emphasized that there exists no other medium of comparable extent or facilities for the making of large-scale observations along these lines. With amateurs existing in more than one hundred countries of the earth, with stations practically in every village and hamlet in the United States, resources are made available to scientific investigators that could be commanded by no commercial agency or for that matter by any government on earth. Finally, in addition to being widely diversified and ubiquitous geographically, it may again be emphasized that amateurs are technically self-trained, making the results of their observations competent and valuable.

While it is generally conceded that the great numbers and diversification of amateurs make of them a uniquely valuable adjunct to the basic field of advanced radio research, another important quality is not so generally recognized. This quality is the very freeness of spirit with which the amateur meets the problems he encounters in his peregrinations into the radio field.

Great as are the attributes of modern organized laboratory research, it must nevertheless be admitted that laboratory developments by highly trained technicians following routine research practices are often encumbered with ponderous fetishes, impressive and involved mathematics, and the conviction that results can be obtained only by following certain rigorous routines. Amateurs shatter these fetishes, which often lead to a singleness of mind that excludes the correlative detail that is often most significant in appraising new phenomena. By the very fact of their limitations in formalized training and laboratory equipment and technique, and the need to secure results by simpler methods, they free the art from many superstitions and often find the true answer to the problem which many are seeking.

Examples of this particular psychic or psychological phenomenon—call it what you will—exist, not only in radio but in allied fields of endeavor. The whole spirit of organized amateur radio trends toward this type of thought in technical matters, and it can be safely said that in no other field of endeavor has there been such free and untrammeled experimentation, unhampered by traditional prejudices, as has resulted from the amateur tradition in the radio art. Its effects are encountered not only in purely amateur circles but in the engineering field, whose personnel, being often of amateur extraction and frequently of current amateur interest, retain much of the amateur spirit.

The Amateur Spirit in Research

This thought can be developed somewhat further. America leads the world in radio technological research. Many reasons for this preeminence have been advanced. We submit the thesis that the fundamental cause is the basic spirit of amateur radio that pervades the entire radio art in this country. We are informed by members of the military that for their purposes an operator of amateur extraction is universally superior to one of any other origin; more, that he is especially better than, for instance, a former land-line telegraph operator. Analyzed, their reasons come down to the essential fact that the amateur is *interested in the art*—every detail of it. Radio is, to him, not only a vocation but an avocation.

This characteristic makes him ten times as valuable as the professional operator, whose mind is simply a machine for the transcription of code signals without spontaneous personal interest in his work. The same characteristic applies in every other branch. The typical radio engineer who is an amateur, it is generally agreed, has the inquiring mind and unfettered viewpoint that lead him to try anything—and it's a system that works. The chief engineer of one of the largest organizations has stated informally that he reads two radio publications—the recognized engineering journal for facts, the amateur's journal for *ideas*. Do we need any better insight than this into the minds of our radio engineers to appreciate the fundamental importance of the amateur spirit in our professional radio activities?

We submit it as a fundamental argument for the amateur that the status of the radio art today, and America's dominance in technological radio fields, derive fundamentally from the institution of amateur radio; that, directly and indirectly, every advancement in the art can be traced to basic amateur origins.

An institution of such potentialities for progress must, in all reason, be preserved. But amateurs contribute to the public interest, convenience and necessity in other, more tangible ways, to an extent sufficient to establish their indisputable and indispensable utility as a *communications* system, apart from their technological value.

The Young Man and His Groundwork

There are several ways in which the young man of today may proceed to build up a good groundwork. These will be itemized and individually treated as follows:

1. Radio amateur and experimenter.
2. Self study in the elements of Physics, Electricity and Radio.
3. Systemized training by attending residence schools.
4. Enrollment in reputable correspondence schools.

The radio amateur of today has a considerably greater opportunity than those of yesteryear to develop his groundwork for the future. True, the radio art has advanced in tremendous strides during the past ten years, but the opportunities have increased in even greater proportion.

To begin as a radio amateur is now a comparatively simple matter, since there has been a great increase of instructive texts and amateur periodicals from which the basic facts may be acquired. Two of the outstanding books for the beginner are *The Radio Amateur's Handbook*, published by the American Radio Relay League in Hartford, Conn., and *The Radio Handbook*, published by Radio Ltd., Los Angeles, California. These texts are used by thousands of beginners and expert amateurs throughout the entire world. *The Radio Amateur's Handbook* in particular serves as an important foundation to start a career. Its great simplicity and ease of practical application make it adaptable to even the young man of twelve. It is unquestionably the finest elementary radio text that has ever been published for the price of one dollar.

Amateur radio is a great teacher! It teaches *responsibility*. The amateur is licensed by the Federal Government, and he is required to observe the rules and regulations of radio communication. He is made to realize the strict responsibility of all activities of his own station. He must keep a log, handle messages, maintain a schedule, and handle traffic with exactness and dispatch. This develops a sense of punctuality and accuracy that will serve him in great stead in the future.

The building of receivers and the ironing out of difficulties in the transmitter, the erection of a good radiation system, all present real problems of clear thinking which help to mold a good groundwork for the future.

How to Begin

The amateur of today can build a simple radio receiver and transmitter at a cost of not more than $15. With this equipment he can communicate by telegraphic code with amateurs all over the United States and in most cases even with amateurs in many foreign countries. Short-wave radio makes this entirely feasible. Thousands of amateurs in these United States have at some time or other contacted amateurs in England, France, Germany, Italy, Australia and many other foreign countries with simple homemade transmitters and receivers.

The young man who desires to enter the radio profession via the amateur route should begin by purchasing a copy of *The Radio Amateur's Handbook*, previously mentioned. In it he will find the complete story of amateur radio, how to get started, elementary radio principles, terms and definitions, vacuum tubes, receiver design and construction, transmitter design and construction, operating procedure, instruments and measurements, power supplies and many other facts of interest to the beginner.

Suggestions for an Amateur Radio Course

The Radio Amateur's Handbook has frequently been used as a text for study of high-frequency radio communication courses arranged to cover both operating and technical background in a limited number of hours. In response to requests from prospective users, some suggestions have been outlined covering possible time divisions for the subject matter of such a course. Depending on whether this text is used in connection with radio classes at established public or private educational institutions, or in connection with studies in progress by groups of beginning amateurs supervised by radio clubs, or whether night-school study or time division with other subjects is necessary, modifications (in several respects) of the plan here suggested can and should be made, as local conditions may indicate. Reports reach the American Radio Relay League that the *Handbook* is used in connection with both regulation courses for college and high-school credits, and in unofficial courses organized by school clubs for informal group study—or organized for public education by informed amateurs, interested persons, YMCA's, social betterment groups, and amateur radio clubs.

In connection with lecture courses or classroom discussions, students can profitably be required to keep a complete set of notes, turned in weekly for checking. This is desirable for many reasons, but mainly because the process of learning is definitely made easier and the retention of the subject matter by the student improved by the process of writing and recording material touched upon in verbal discussions. While not essential to successful instruction, some *Handbook* users have issued diplomas or certificates, at the end of the course, to each student passing a satisfactory examination. The practical accomplishment demonstrated by passing the government examination in itself confers a certificate of practical utility from the U. S. Government.

Outline of time-division successfully tried (77 hours total):

1. Fundamentals—6 hrs.
2. Receivers—9 hrs.
3. Frequency Measurements, Monitors, Instruments—3 hrs.
4. Transmitters—17 hrs.
5. Power Supply—8 hrs.
6. Keying and Interference Elimination—2 hrs.
7. Antennas—3 hrs.
8. Amateur Operating Procedure and Traffic Handling—13 hrs.
9. Keeping Traffic and Station Records—1 hr.
10. Radio Laws * and Regulations—5 hrs.
11. Reviews—2 hrs.
12. Coaching for Exam. (Questions and Answers)*—8 hrs.

1. Includes electron theory, explanation of conductors and insulators, sources of electric current, voltage and current, alternating and direct current, series and parallel resistance, Ohm's Law, inductance, capacitance, L&C reactance, magnetism, heating effects, radiation, diagrams, tuned circuits, practical problems, vacuum-tube operating principles, amplifier classifications, oscillation. (Study Chapters on Radio Principles, Radio Circuit Terms, Definitions and Equations, and Vacuum Tubes.)

2. Tuned r.f., superhets, theory and several models, receiving tubes, radio frequency and audio amplifiers, vacuum-tube functions, quartz crystal filters. (Study Chapters on Receiver Design and Construction, Vacuum Tubes.)

3. Necessity for measurements of freq., Freq. meter construction and calibration. Method of use. Necessity, construction and use of monitors. Of wavetraps. Electron coupled oscillators, ohmmeters, test oscillators, oscilloscopes. (Study Chapter on Instruments and Measurements.)

4. Vacuum tubes, theory and construction of transmitters, push-pull and parallel arrangements, crystal control, MOPA, HARTLEY, COLPITTS, TPTG, TNT, radiotelephony, modulation principles, neutralizing, frequency multipliers, amplifiers Classes A, B, & C, phone

* See the *Radio Amateur's License Manual* for this material. Sent, postpaid, price 25c, from American Radio Relay League Headquarters.

transmitters, typical audio sections, transmitter adjustment. (Study Chapters on Transmitter Design and Construction, Vacuum Tubes, Radiotelephony and Ultra-High Frequencies.)

5. Tube rectifiers, mercury vapor tubes, filter circuits, chokes, plate supply design, dynamotors, motor generators, filter condensers, transformers, regulation, voltage dividers, bias supply. (Study Chapter on Power Supply.)

6. Best keying methods, as adapted to different transmitters. Key thump filters. Break-in, remote control, interference problems. (Study Chapters on Keying Methods and Power Supply.)

7. Antennas and Feeder System, Impedance Matching, Directive Properties, Antenna Size for a Given Frequency. (Study Chapter on Antennas.)

8. Using code practice tables in school code room. Complete records of each QSO are kept and turned in at end of each period for checking as to correctness and use of proper procedure. Constant supervision maintained during handling of traffic over nets (practice) too. Getting fills. Standard operating abbreviations. (Study Chapters on Getting Started, Operating a Station, Q Code, and other tables in Appendix.)

9. Keeping a log, servicing a message, keeping file of traffic handled. (Study Chapters on Operating a Station and Message Handling.)

10. Radio law, FCC regulations, secrecy of correspondence. Interference rules, penalties. (Laws and Regulations are given in detail in the Appendix.)

11. Typical questions and answers,* including those commonly included in the U. S. Government examinations for operator's license.

* See the *Radio Amateur's License Manual* for this material. Sent, postpaid, price 25c, from American Radio Relay League Headquarters.

A 72-Hour Night-School Program, Three Hours Nightly, Three Days a Week for Eight Weeks

Week 1. 1st day, 2 hrs. fundaments, one hour ama. procedure
2nd day, same
3rd day, same

Week 2. 1st day, 2 hrs. receivers; one hour freq. measurements
2nd day, 2 hrs. receivers; one hour wavetraps
3rd day, 2 hrs. receivers; one hour monitors

Week 3. 1st day, 2 hrs. receivers; one hour, power supply
2nd day, 2 hrs. receivers; one hour, power supply
3rd day, 2 hrs. power supply; one hour REVIEW

Week 4. 1st day, 2 hrs. power supply; one hour xmtrs
2nd day, 1 hr. power supply; one hour xmtrs
3rd day, 2 hrs. transmitters; one hour keying

Week 5. 1st day, 2 hrs. transmitters; one hour keying
2nd day, 2 hrs. transmitters; one hour antennas
3rd day, 2 hrs. transmitters; one hour antennas

Week 6. 1st day, 2 hrs. transmitters; one hour antennas
2nd day, 2 hrs. transmitters; one hour handling traffic
3rd day, 2 hrs. transmitters; one hour REVIEW

Week 7. All 3 days, handling amateur traffic, FCC regulations, radio law, and amateur procedure all periods

Week 8. 1st day, 1 hr. stn. records, 2 hrs. coachings * for exam.
2nd and 3rd days, 3 hrs. each coachings * for exam.

Publicity regarding meeting to organize instruction groups, radio clubs, etc., will usually be given freely by the local papers in any community on request. A good way to get a group together is to arrange a lecture on radio to be held at some readily available location, following which the number of individuals interested in the proposed course can be ascertained.

Chapter IV

SELF-STUDY PREPARATION

To prepare the groundwork for a radio career by the self-study method without the aid of supervised instruction is entirely feasible. Of course it will serve only as a basis for future training, but that in itself is the beginning of a good foundation. It will also serve to prove whether or not the young man is fitted to go on for more advanced learning.

The author does not wish to give the impression that self-study preparation is different from the amateur method, because actually they are the same with one possible exception. That is, in this chapter we are endeavoring to outline a course of study for those who may not be particularly interested in amateur radio as the method of approach toward the radio career. Undoubtedly there will be thousands of young men who desire to prepare for radio during their primary and secondary school years so that they may formulate some opinion as to their future procedure.

Radio is a science, and like all sciences requires a good basic training in the fundamentals which go to make up scientific background. Mathematics is the most important prerequisite to the understanding of any science. It is the building block to a more complete understanding of any of the scientific arts.

Radio is a broad scientific field, since it covers mathematics, physics, chemistry, and electricity. Mathematics as applied to these basic branches of science is not of the simple arithmetical variety but is of a considerably more complex nature. It will, therefore, be necessary for the primary and secondary school readers to make a great effort to perfect the fundamentals of mathematics during their respective school years, so that they may readily proceed with advanced learning as time matures. A poor student in mathematics is generally poor material for any of the engineering professions. Of course, there are some exceptions to this rule. The author is personally acquainted with men engaged as marine radio operators, broadcast operators, radio service men, and sound technicians who, by virtue of their practical ability, have attained success in the radio profession. Obviously there will undoubtedly be many successful radio men in the future who have only a limited knowledge of mathematics, but this does not detract from the argument that a good knowledge of mathematics is essential. Students who show mathematical and mechanical aptitude are unquestionably the best suited for the radio profession, particularly engineering.

Young men who have a desire to enter the radio field should make certain of these prerequisites. One method of ascertaining whether or not a young man should follow this or any other scientific field would be to have a competent educator specializing in psychology arrange a series of aptitude and intelligence tests for him. This method, although not entirely flawless, serves as a splendid means of acquiring an approximate idea as to one's qualifications. Thousands of students have been correctly guided by this sort of advice, and it should be highly recommended to all prospective engineering students for the future.

Let us assume that a young man has not completed his secondary school training but has shown a fair degree of proficiency in the elementary school. Circumstances prevent him from going on with his education, yet the radio field is still his goal. Can he attain success? He most certainly can, provided he has the inherent qualifications and the will to learn.

His first step should be to learn the important phases of mathematics that are necessary to a good understanding of radio. These may be itemized as follows:

Elementary Algebra
Intermediate Algebra
Plane Geometry
Solid Geometry
Trigonometry
Calculus

This may seem impossible to accomplish by the home-study method. In many instances it will be, but that does not say it cannot be done. Again it depends upon the inherent ability of the young man and the system he employs.

The proper choice of text with each one of the subjects listed is perhaps the most vital. The text should be of an elementary nature. It should have an abundance of homework problems at the end of each chapter, together with correct solutions. The student should make an exhaustive investigation of the many textbooks dealing with each subject, so that a proper choice will be made. Consult with your librarian or teacher as to what texts would be most advisable. If you have any amateur friends, engineers or advanced students who might be willing to assist you, by all means seek their advice and aid.

After the student has obtained a fair understanding of the mathematical principles outlined, he may proceed with the next step. If he is an apt pupil, he may even combine the succeeding texts with his mathematics by a systematic procedure of arranging his time appropriately for each subject. In most cases this is the suggested procedure, since it will break the monotony of single-subject study.

The subjects that are to be supplemented to mathematics are chemistry, physics, and electricity. Chemistry is to be treated somewhat more lightly than the other three subjects, in view of its lesser use in the radio art. It must, however, not be neglected, because it will lend itself to a better solution of many of the problems in physics and electricity.

An elementary textbook on chemistry should be chosen that will give the student a basic concept of matter, namely, solids, liquids, and gases. The latter two are of particular importance, since they are used extensively in the manufacture of batteries and vacuum tubes.

Physics and electricity are the next in order to be learned. These two subjects, with the exception of mathematics, are the two main building blocks of radio communication. Without them a good groundwork is impossible. The physics of light and sound in particular is indispensable. The proper choice of an elementary physics textbook is, therefore, of the greatest importance.

The textbooks on physics should include approximately the following topics to be satisfactory for preparatory uses.

GENERAL PHYSICS

Kinematics

- Metrology
- Fundamental and derived units
- Dimensions
- Motion and rest
- Axes of reference
- Translation and rotation
- Measurement of length and distance
- Measurement of change in direction
- Velocity
- Uniform and accelerated motion
- Angular velocity and acceleration
- Vectors
- Composition and resolution of velocities
- Simple harmonic motion

Dynamics

- Newton's laws of motion
- Inertia
- Force
- Units of force

Dynamics (*Continued*)

Impulse and momentum
Stress and strain
Graphical representation of forces
Resolution of forces
Moment of force
Equilibrium of moments
Moment of inertia
Centrifugal force
The law of gravitation
Gravity
Equilibrium in orbital motion
Weight
Stable equilibrium
Determination of mass
Work and energy
Units of work and energy
Power
Potential and kinetic energy
Energy of a rotating body
Conservation of energy
The pendulum
The physical pendulum
Levers
Pulleys
The inclined plane
The wedge
The screw
Friction (sliding, kinetic, rolling)
Uses of friction
Efficiency

Solids

Structure of matter
States of matter
Elasticity of solids
Volume elasticity
Longitudinal elasticity
The torsion pendulum
The torsion balance
Impact of elastic bodies
Impact of inelastic bodies

Gases

Fluids
Character of gas
The kinetic theory of gas
Pressure of a gas
Avogadro's law
Dalton's law
Boyle's law
Elasticity of gases
Mechanical air pump
Mercury air pump
Diffusion of gases
Buoyancy of air

Liquids

Liquid pressure
Transmission of pressure
Pressure of liquid on walls of a vessel
Buoyancy of liquids
Density and specific gravity
Density of solids
Density of liquids
The siphon
Efflux of liquids
Lateral pressure of a moving stream
Viscosity
Surface tension
Unit surface tension
Surface tension compared to an elastic membrane
Pressure due to surface tension
Diffusion of liquids
Osmotic pressure

Heat

Heat and temperature
Expansion
Determination of expansion coefficient
Expansion of liquids
Expansion of gas
Law of Charles
Absolute temperature
Pyrometry
Calorimetry
Thermal capacity
Specific heat
Molecular heat
Change of specific heat with temperature
Latent heat
Specific heat
Fusion and solidification
Evaporation
Vapor pressure
Humidity
Transference of heat
Conduction
Radiation
Source of waves
Measurement of radiant energy
Laws of radiation
Thermodynamics
Effect of molecular forces
Ratio of specific heats of gases
Elasticity of gases

Light

Experiments of Hertz
Light
Source of light waves
Optics
Theories of light
Wave front and Huygens' principle
Interference of waves
Rectilinear propagation
Velocity of light
Reflection (plane, curved)
Spherical aberration
Parabolic reflection
Refraction
Index of refraction
Critical angle
Refraction by a prism
Spectrometer
Refraction of spherical waves at a spherical surface
Lenses
Optical center
Spherical aberration
The spectrum
Wave length of light
Prismatic spectra
Kinds of spectra
Limits of the spectrum
The spectroscope
Chromatic aberration
Color
Complementary colors
Color resulting from absorption
Polarized light
Polarization of reflection
Brewster's law
Polarization by refraction
Polarization by double refraction
Circular and elliptic polarization
Rotation of the plane of vibration
The Zeeman effect
Artificial light
Candle-power
Intensity of illumination
Cold light

Sound

Nature of sound waves
Phenomena of sound transmission
Velocity of sound transmission
Effect of changes in temperature and pressure
Musical tones
Pitch
Intensity
Resonance (tubes, chambers, etc.)
Quality
Nodes in resonant air columns
Velocity of sound
Vibration of strings
Diatonic scale
Scale of even temperament
Acoustics (reverberation, absorption, etc.)

Chapter V

THE RADIO OPERATOR

THIS is perhaps one of the most alluring phases of the radio field for the young man. The inherent desire of most young men is to make a sea voyage at some time in life, and radio operating presents a most excellent opportunity to satisfy this end. It not only takes care of the characteristic wanderlust but also gives the necessary insight into the radio field and its vast possibilities.

Many of the outstanding radio engineers and executives started in this manner. Some of these are known to everyone. Mr. David Sarnoff, Vice-President and Chairman of the Radio Corporation of America, started his career as a radio operator. His climb to the top of the ladder of success is an unusual one, but thousands of others have attained high goals in the field of radio after serving as marine radio operator.

The author himself has trained hundreds of students over a period of 23 years at the Y.M.C.A. Trade and Technical School, New York City, and these young men are now successfully engaged in the various fields of radio, namely, Broadcasting, Aircraft Radio, Radio Servicing, Design Engineering, Sound Engineering, Technical Writing, Teaching, etc. Many of them started as radio operators. Some are still in the operating profession.

Radio Operating from a commercial point of view may be divided into three main classes, i.e., Radio Marine, Aircraft Radio, and Broadcasting. New classes of radio operating will appear in the future, such as Television operators, Facsimile operators, and Teletype operators.

The Army and Navy also present a splendid training ground for the young man in the operating field with an ambition to enter one of the many branches of the government radio service.

Duties of the Radio Operator

The radio operator on shipboard is classified as an officer. His duties are primarily to transmit and receive code messages to coastal stations and other ships at sea. He must keep a rigid account of all call letters heard and messages handled. He must know the handling charges of the messages transmitted to other stations, so that an accurate accounting of all transactions may be made to the steamship company or radio company upon his arrival at port. He must be ever alert for traffic calls and emergency signals. He must maintain all of his equipment in perfect mechanical and electrical condition. He must be thoroughly familiar with the theoretical function of each part of his transmitting and receiving equipment, so that he will be qualified to make the necessary repairs in the event of failure or breakdown of any of the component parts. Upon his shoulders lies the great responsibility of maintaining constant touch with the outside world, so that, should an emergency arise, he will be capable of fulfilling his assignment to the utmost. In times of distress he is next to the ship captain in importance; it is up to him to see to it that distress messages are properly transmitted and received and that no errors are committed. Incompetency has no place in this ever-important position, where the safety of life at sea is a paramount issue.

The future radio operator may not be called upon to be as exacting in the reception of telegraphic distress messages as his predecessor, due to the development of the automatic alarm receivers which are now being installed on all vessels carrying a limited number of operators. On the other hand, however, he must be doubly competent in both theory and practice, so that his equipment is at all times in a state of working precision. True, the equipment has been previously adjusted by trained experts who are highly specialized in their field. In the case of breakdown at sea, none of these specially trained men are available, and it will be up to the operator to effect the necessary repairs. Again it must be stressed that the operator be thoroughly acquainted with every component part of his equipment and its theoretical function. Then only can he be classed as a competent radio operator.

Unfortunately a common fault of many radio operators lies just here. The author is personally acquainted with some who are actively engaged at sea in this capacity but have made no effort, or very little, to keep up with new developments. Of course they have learned by experience what to do and what not to do, but this is not sufficient. Operating is not just a matter of sending and receiving messages. It is a question of how well this is done. How competent is the operator in the handling of his equipment, and does he know its theoretical function? The new radio operator cannot rely on experience. He must be thoroughly trained in the rudiments of theory and practice; much more so now than in the past.

The duties of the operator in the aircraft service are fundamentally the same as those of the marine service, with the exception that he must have considerably more experience. That is to say, junior radio operators in the maritime service are taken directly from the radio operating training schools, provided, of course, that no experienced men are available. In the commercial aircraft service, radio operators must have had commercial experience before they are acceptable.

The Department-of-Commerce Airways Radio Service occasionally issues applications for radio operators. These are then filled by the young men who can prove that they have had sufficient actual operating experience, education, and physical development. They must present proof of their qualifications and give character references before they will be considered.

The radio operator in all branches of the radio field is licensed by the U. S. Government. Consequently, when he has completed a prescribed course of study he must prepare for his examination. This preparation should not be difficult if he has absorbed the technical contents of his course thoroughly. The examination for all classes of operators' licenses is based upon *Basic Law, Basic Theory*, and *Practice.*

Advanced Theory and Practice

These examinations are divided into six sections or elements and cover the entire radio operating field of telegraphy and telephony. Several of these elements are given to each applicant, depending upon which type of license he is preparing for. For example, the applicant who is taking the examination for a license as an operator on shipboard would receive elements 1, 2, 5, 6. In addition to this he must pass a code test in transmitting and receiving at a speed of not less than twenty words per minute. A passing mark of 75 per cent must be obtained for each of the elements he has been examined in. Failure to pass will require a reexamination after two months have elapsed.

Training to Be a Radio Operator

The young man who aspires to become a radio operator in the maritime or aircraft service must prepare himself in three principal subjects—telegraphic code, theory and practice, and radio laws. He may prepare this groundwork by first becoming a radio amateur to familiarize himself with the code and traffic handling, and then by enrolling in a reputable residence school to learn the theoretical and practical phases by actual operation of standardized equipment; or he may start right from the beginning in a residence school to learn the entire operating field from the ground up. This procedure is advisable in any case where the young man is desirous of completing his studies in the shortest possible time. It is practically impossible to learn the code and acquire the high code transmission and reception speeds necessary in the marine operating field in less than six months by any form or home-study methods. There are, of course, some exceptions to this rule, and these are generally traced to amateur training.

Radio code preparation demands a systematic routine of properly learning the code, sending messages, and receiving messages. It requires a minimum of three hours per day at least three days per week to attain a speed of twenty words per minute (five letters to the word) in a period of less than one year. Actual tests over a period of twenty years have shown that students who attended residence schools have been able to complete their commercial code requirements somewhere between four and seven months. This provided that they attended classes five days per week and received code instruction of not less than four hours per day. Evening classes, generally based on three-hour sessions convening three or four evenings per week, require between nine months and one year for completing commercial code requirements. These figures approximate the average student findings and do not consider the exceptional cases where students have completed the high-speed requirements in less than four months. On the other hand, some students have required as long as eighteen months or even two years to attain commercial speeds. These exceptionally long learning periods are in nearly every case due to age! Men who have reached the age of 30 or over generally find code speed acquirement very difficult.

The young man who has completed his primary and secondary schooling should by all means, whenever possible, attend a residence school in training for this position. Correspondence-school methods of instruction are recommended only in instances where that is impossible. This does not detract from the valuable preparation that may be obtained through the medium of these schools, but the time element and the practical handling of commercial equipment are of prime importance to the student of radio operating. In cases where the young man cannot attend a residence school for six months or more, he may enroll in one of the correspondence schools, and then, after completion, take a short-period residence course to finish up his training. This method may prove satisfactory, provided he has successfully completed his correspondence course and feels quite sure of himself. Otherwise he may find himself in the position of many others who, failing in their correspondence-school work, entered a residence course only to find themselves inadequately prepared. Obviously they could have saved the needless expense by enrolling in the residence school in the first place.

The young man who is less than 18 years of age, say between 12 and 16, may attend a residence school for systematized code learning and practice, but he must be aware that no position will be open to him until he is of the required 18 years of age. In view of this, might it not be much better to complete his basic education in primary and secondary schools, and prepare for radio by the amateur, self-study, or correspondence-school method? Undoubtedly this would be the best procedure, because it would not only serve for his educational betterment but also enable him to make up his mind as to what future procedure he should follow.

Advancement and Salaries

The position of radio operator in the maritime and aircraft services lends itself to advancement commensurate with ability and experience. The young man who starts as a junior operator can advance himself to the grade of chief operator. This advancement depends upon his proven ability and period of service. After the operator has been advanced to the chief operator's rating, his limit of advancement at sea has been reached. If he is desirous of advancing farther in the operating field, he must then prepare himself for additional technical training and choose which branch of radio he would desire to specialize in. Remember, radio operating at sea presents a splendid stepping stone into the radio field provided you have the necessary qualifications and aggressiveness. Radio jobs do not come to you; you must go to them. Naturally, if you follow the latter course you must be prepared. If, therefore, the radio operator is inclined to leave the sea, he has several alternatives from which he can choose for advancement in the future.

First, he should inquire as to what shore jobs are available in his line. That is, those jobs which are closely related to his previous activities at sea, such as shore-station operator, airways radio operator, airport transmitter operator, dispatching operator, transmitter technician, radio inspector, installer, broadcast operator, studio technician, etc.

Secondly, he may obtain temporary employment in some phase of the radio field, and then continue his technical training in college or in specialized radio courses. He may set as his future objective any one of the specialties outlined in Chapter I. If they are of an engineering caliber, the course of study to be pursued should be along engineering lines, as will be outlined in the chapter on

Radio Engineering. If they are of a more practical nature, such as radio servicing, then a resident school specializing in these subjects is recommended. Correspondence-school training may be substituted if local residence schools are not available or if the applicant is employed in the radio field in a capacity which does not permit him to attend systemized residence training. In any event it is imperative that continued study be pursued if any degree of success is to be attained.

Radio operating in the marine or aircraft service has a salary range between $90 and $180 a month.

Radio operating in the broadcast service, including the work of transmitter and studio operators, has a salary range between $100 and $300 a month.

Chapter VI

RADIO SERVICING

RADIO servicing, one of the largest phases of the radio industry, presents many excellent opportunities for the young man to make a living.

This branch, unlike any of the other branches of the radio field, offers both full-time and part-time earning facilities. Thousands of young men are employed as radio-service experts throughout the country in factories, laboratories, service organizations, department stores, radio stores, shops, etc. Many are engaged in part-time jobs and home repairing while continuing in their regular positions or completing their education.

Radio servicing in its general sense is that part of the radio industry which takes care of the repair and testing of home radios, automobile radios, public address systems, electronic amusement devices, and television receivers. It is a combination of technical and mechanical requirements and offers to the young man a splendid opportunity for developing his practical and technical instincts for further advancement in the radio field.

The good radio service man must be thoroughly adept in the practical construction of radio receivers; he must be master of such details as parts layout, wiring, soldering, handling of tools, testing, analyzing. He must have a thorough working knowledge of the circuit diagram and component parts function. He must be familiar with the signal channels in the receiver, so that he may quickly ascertain where the signal should be and where it should not be. All these things require good mechanical aptitude and technical ability, and unless the student fulfils these qualifications he cannot be a successful service man.

The radio receiver industry of today, particularly with the advent of television, will require a much more exacting technical ability than in the past. More basic theory and operational analysis of complete circuit function will be necessary. Those men who have been servicing radios by the hit-and-miss methods so common today will gradually pass out of the picture.

The exacting and competent service man will always have a place in the radio field, no matter how much competition prevails.

The most lucrative phase of radio servicing lies in home radio repair. Millions of radios are sold each year by the manufacturers. Millions of older radios are reconditioned and resold. New radios and old alike must constantly be kept in perfect working condition to obtain efficient results.

Next in order lies that branch of radio servicing which specializes in automobile radio servicing and installation. This field offers great possibilities for men who are actively engaged in the automobile service and repair field. Automobile mechanics, particularly those who are experts in the electrical and ignition systems of the automobile, are the best suited to combine these two specialties. A man who can qualify both as an ignition expert and as a radio technician should have an unusual opportunity for a successful future.

This situation may be logically analyzed when one considers that there are considerably more automobile repair shops, especially those of smaller caliber, throughout the United States and Canada, than there are radio shops. Many of these shops cannot afford to employ both ignition and radio experts. Obviously, an employer would rather hire a man who is competent in both fields and pay him a greater salary than have two men in his employ. This is particularly true in small towns, where business is generally conducted by one man, and where radio repairmen may not be available. Young auto mechanics who are thoroughly familiar with the car electrical and ignition systems should seriously consider learning radio servicing to entrench themselves more securely and also increase their earning power.

These men may prepare themselves to be radio service experts by preferably enrolling in a reputable radio servicing resident school, or, if this is impossible, in one of the nationally known correspondence schools. The latter method should not be considered unless the school offers actual practical working projects, with material for constructing and testing, together with a comprehensive course of technical training. Some schools that are known to give this sort of instruction are listed in Chapter XI, together with outlines of their respective courses of training.

Do not expect to be a successful service man unless you adhere to all study assignments religiously. The young man mechanically inclined will probably have little difficulty in the constructional side of radio servicing, but he must realize that his success depends almost entirely upon his technical ability. A good groundwork, again, is essential for a thorough understanding of the subject.

Training to Be a Radio-Service Technician

Radio servicing, as it applies strictly to the repair and servicing of radio and television receivers, does not necessarily require a college or highly specialized engineering course of training. The author's experience and contact with men in this branch of radio shows that approximately 90 per cent of the men actively engaged in service work are non-college graduates. Most of these men have acquired their basic training either as amateurs or as radio operators, or as graduates of resident-school or correspondence-school courses.

As time goes on, this percentage may be lessened, for many college students are beginning to enter this field as an avenue to other branches of radio. Many have told me that they find radio servicing a splendid training course for developing their "practical feel of things," and that it enables them to fit themselves better for the engineering field. This theory has often been demonstrated in the past with college students, since many of them, although familiar with the technical angle, are entirely unsuited for practical servicing and testing. Of course, once they have attained the practical side of things, they are generally unbeatable.

Advancement toward the goal of an expert radio-service technician is basically along the same lines as that of the radio operator, in so far as the theory is concerned. In servicing, however, a great deal more of practical training is required along with the theory. Several methods of preparing a groundwork may be used. These follow in the order of preference:

1. Radio-servicing resident-school training
2. Correspondence-school training
3. Self-study training

The last-named method is recommended only in those cases where the first two are impossible or where it is solely preparatory to enrolling in a resident or correspondence school. In the latter case, self-studying as a preparatory undertaking is highly recommended; it will give the prospective student some idea as to the kind of subjects he must become familiar with.

The argument is sometimes presented that there is no necessity for home study if the student has definitely made up his mind to enter the radio field, because the resident and correspondence schools start him off from the bottom anyway. So, why get started by learning things the wrong way first, and then find the school methods so vastly different that more harm has been done than good? This reasoning would be sound if the student studied at random and did not consult some competent person as to the routine to be followed. If, on the other hand, he is properly guided and still finds the subject beyond his grasp, he is probably much better off in the end than if he had wasted his money by enrolling in a course which was destined to be of little or no benefit to him.

A suggested outline of a self-study program preparatory to entering a resident or correspondence radio-servicing school follows.

The first step in preparing for this type of position would be to begin with a treatment of the fundamentals of electricity. Electrical principles are the building blocks of radio receiving and transmitting circuit functions. They *must* be thoroughly mastered before a good understanding of radio circuits can be obtained.

Many texts dealing with the fundamentals of electricity are available in the public libraries, but for those who have not these facilities a number of published works are listed at the end of this book.

Radio Servicing Self-Study Outline (Theoretical)

Part 1 (Electricity)

1. Basic Concepts of Electricity: Static electricity—Charged bodies—Attraction and repulsion of charged bodies—Atoms and electrons—Conductors—Insulators—Lines of force—Potential
2. Methods of Generating Electricity: Frictional—Chemical—Dynamic—Thermal
3. Magnetism: Magnetic bodies—Laws of attraction and

repulsion—Molecular theory of magnetism—Magnetic lines of force and their behavior

4. Electrical Pressure, Flow, Resistance and Power: Simple hydraulic analogies of each—The electric circuit—Voltage, current, resistance and power—Modern concepts of current flow in conductors of gases and liquids—The electron current viewpoint—Types of conductors and insulators
5. Fundamental Electric Circuit Calculations: Ohm's law—Series circuits—Parallel circuits—Series and parallel circuits—Problems and their solutions
6. Electromagnetism: The production of magnetic fields by current flow—Coils—Electromagnetic induction—Simple direct-current and alternating-current generators—Simple motors
7. Electric Symbols

This basic program of electrical theory should be thoroughly mastered in its elementary form before proceeding with the radio section of the preparatory assignment.

Part 2 (Radio)

1. The Inductance and Capacity: What is inductance? What is capacity? How are they measured?
2. Alternating Currents: Frequency—The Transformer—How alternating currents act through resistance, inductance and capacity—Power in AC circuits—Problems and solutions
3. The Radio Circuit: The series resonant circuit—The parallel resonant circuit—Frequency and wave length—How AC elements are applied to the radio circuit—Coils and condensers—The radio frequency transformer
4. The Radio Antenna: Its purpose—How it is constructed—Radio waves and how they act upon the antenna—Tuning the signal

5. The Vacuum Tube: The two-element tube—The three-element tube—The multi-grid tube—How the tubes work
6. The Vacuum Tube as an Amplifier: The radio-frequency amplifier—The audio-frequency amplifier
7. The Vacuum Tube as a Detector: How the tube and its circuit detects the signal—Various types of detectors
8. The Power Amplifier: Why used—Circuit adjustments—Types of power tubes—Classes of power amplification
9. The Loudspeaker: How it works—Various design considerations—Types of circuit connections
10. The Tuned Radio-Frequency Receiver: Cascade connections—Types of circuits—Triode and pentode tube connections in this type of circuit—By-pass condensers, their purpose and connections—Circuit improvements such as grid and plate filtering systems—Tuning and adjusting the circuit
11. The Power Supply: Batteries for plate and filament supplies—How they are connected—Power transformer, rectifier and filter systems—Rectifier circuits for AC and AC-DC radios—How the rectified currents are filtered—Types of tubes used in rectifier circuits
12. A Complete Radio Receiver and Its Connections with the Power Supply: This to include 2 stages of radio-frequency amplification, detector, audio-frequency and power amplifier—Loudspeaker
13. Vacuum Tube as a Generator: How a vacuum tube circuit oscillates—Types of oscillating circuits—Frequency control—Stability of the oscillations
14. The Super Heterodyne Receiver: Basic theory—Why used—Adjustment considerations
15. The AC-DC Radio: How this type differs from the AC type receiver—Advantages and disadvantages—Adjusting the circuit

16. Symbols: A careful study and complete memorizing of all radio symbols should be made

The foregoing is a general theoretical outline and is not meant to give the impression that it is a detailed course of study. It will, however, serve as a useful introduction to the radio servicing art and go far toward fitting the applicant for any future studies.

It is, of course, possible that a student who diligently follows this outline and associates it with intensive reading and study may actually be able to repair radio receivers—that is, provided he follows a systematic procedure of testing with the proper kind of analyzing equipment. Young men who have satisfactorily completed this or any similar course may find the following testing procedure useful in locating actual trouble in radio receivers. It is preferably intended for those who have had some previous training as amateurs or radio operators, and who find it impossible to attend resident or correspondence schools

Radio-Set Testing Procedures

Elementary Method

The fundamental procedure for testing a radio receiver by the new student who has thoroughly mastered the set analyzer and elementary circuit principles will be outlined. No attempt is made to give detailed instructions for all tests; this is merely an elementary introduction showing how radios may be serviced by using simple instrument tests such as Voltmeter and Ohmmeter methods. This is commonly known as the point-to-point method of servicing.

We will assume that a radio is received for repair. How should the prospective serviceman proceed to diagnose the trouble?

1. Test all the tubes and ascertain if any are defective.

Replace any or all tubes that indicate leakage, low emission or questionable readings in the tube analyzer. Do not proceed until this test has been carefully completed. (This applies to all radios.)

2. Do not plug the set into the power socket until the DC resistance from the filament or cathode of the rectifier tube to chassis has been tested. (Some rectifier tubes use filaments and others use cathodes. Determine carefully, by referring to the RCA or Sylvania tube manuals, which of the two elements is used as the high-voltage positive terminal.)

AC Receivers (Power Supply Off)—If the receiver utilizes a voltage divider system, this reading should be between 7000 and 100,000 ohms, depending upon the manufacturer's design. Rarely if ever does this reading go below 10,000 ohms in modern AC receivers. Trouble is generally apparent when the reading is below 10,000 ohms, and power should not be turned on until the circuit has been carefully checked to ascertain the proper voltage divider value.

For example, let us assume that the ohmmeter reads between 5000 and 10,000 ohms. Disconnect the positive end of the voltage divider resistance so that the output load of the rectifier tube is removed. Check the reading again, and if the same low value appears, the trouble is possibly in one of the main filter condensers. Remove each positive lead of the filter condenser and test it for leakage. A good electrolytic filter condenser should read 100,000 ohms or more on continuity test. If the reading is lower, reverse the test leads and see if it is still below the prescribed value. (An electrolytic condenser may read much lower than 100,000 ohms in one direction and yet very high in another direction and still be in good condition. Condemn it only if it reads low in both directions.) In any event, if the reading is higher than these values, it will be reasonably safe to turn on the power. Once the power is turned on, no more tests must be made with the ohmmeter; only the voltmeter is used under these conditions. In DC or AC-DC radios this reading may be considerably lower in view of the fact that the speaker field winding may be connected directly across the power line or from cathode to chassis. In the 25Z5 or similar tubes used in AC-DC radios the resistance from cathode to chassis is generally between 2000 and 3000 ohms.

3. Turn on the set and note if the tubes light. If they do not, inspect the entire supply circuit. In AC operated radios using a power transformer, the tubes will not light if any of the following troubles prevail:

(a) Line fuse blown
(b) Set fuse blown (some radios have an internal fuse)
(c) Defective line cord or plug
(d) Defective line switch
(e) Transformer primary burned out
(f) Filament winding (sec.) burned out (rare)
(g) Filament winding (sec.) shorted. This will cause serious overheating of the transformer and may eventually cause it to burn out or short-circuit
(h) Defective filament connections from transformer to termination

Transformer primary windings generally have a DC resistance anywhere between 1 and 50 ohms; high-voltage secondary windings, 100 and 1000 ohms; filament secondary windings, less than 1 ohm. The resistance of the latter is generally so small that the winding may appear to be short-circuited. In DC or AC-DC operated radios (no power transformer is used) the trouble may be due to any one of the following:

(a) Line fuse blown
(b) Defective line cord or plug

(c) Defective line switch

(d) Defective filament resistance. This may be actually a part of the line cord itself. Some radios use a line cord resistance enclosed in asbestos wrapping and others use a separate filament resistance mounted on the radio chassis

(e) Open filament circuit due to a broken socket, burned out tube or poorly soldered contact

(f) Tubes may have been incorrectly forced into the socket. (Some of the older types of radios have had their socket holes so badly worn that the tubes may fit into the wrong position.)

4. With the tubes all lighted, make a simple preliminary test, beginning with the power amplifier tube (not the power rectifier). Pull the tube in and out rapidly and note if a click is heard in the loudspeaker. If this test responds satisfactorily, proceed with the other tubes and work toward the first radio-frequency amplifier. Each should give a slightly clicking response with the possible exception of the detector tube. This tube may be of the pure diode variety, when, of course, no click will be heard. Ordinarily, detectors may not produce a click because they are so adjusted that practically no plate current flows. If all tubes produce a fairly loud click (excepting the detector, as mentioned), it is a fair assumption that there is some plate current flowing in the respective tube-plate circuits. Next proceed to remove the grid caps on all screen-grid tubes and note if a click is also heard in the loudspeaker when they are touched to the cap terminal of each tube.

This preliminary test is a quick method of determining with a fair degree of accuracy if the plate voltage and bias supply circuit is O.K. It is, of course, possible that all voltages are correct and yet no clicking response is heard in the loudspeaker. This may indicate that the speaker circuit itself is defective. (Secondary of output transformer or voice coil open, speaker cone jammed and unable to vibrate.)

5. If clicks are heard in all stages but no signals are received, proceed as follows:

(a) Inspect the antenna and make certain that it is not grounding to a metal object or nearby antenna.

(b) Touch antenna to grid cap of the first RF tube. (This should be done through a .00025 or .0005 fixed condenser in series so that the antenna does not touch directly to the grid cap.)

(c) Vary the tuning condenser and note if any signal is heard. If not, proceed as follows: Use the continuity tester on the low ohm scale and shunt across each of the variable tuning condensers. Vary the condenser gang through its entire capacity range and observe if any short circuit prevails in any of the condenser sections. If the ohmmeter shows a full-scale deflection (zero ohms) look for the short in the tuning condenser. This might be due to the rotary plates scraping along the stationary plates or a short-circuited trimmer condenser which is connected in parallel with it.

(d) Test the continuity of the antenna coil primary. Find this coil and test directly across it. Do not test continuity for this winding across the antenna and ground terminals, because the winding is generally in series with a small condenser and would therefore not give a reading even if it were in good condition.

(e) Since this trouble may occasionally be due to an *open* by-pass or coupling condenser in the radio-frequency or detector circuits, it is well to test all of these by the very simple method of placing a small fixed condenser (.1 mfds.) in parallel with each condenser, one at a time, and then ascertain if a signal is coming through. If all condensers have been bypassed and no signal is received, it is then advisable to test for receiver alignment with an oscillator. Of course, all tube-socket, wave switches and electrical connections also should be carefully inspected to eliminate the possibility of their causing the trouble.

Poor Reception or Distorted Signals—It is generally more difficult to service the radio that has poor or distorted reception than the one that does not play at all, since the possibilities of trouble cover a far wider range. In view of this, a much more detailed analysis must be made in order to diagnose the trouble correctly. The starting procedure should be as follows:

Obtain a complete set of readings at each tube socket, beginning with the power amplifier tube:

Plate voltage between P and K or P and F if no cathode element is used.
Screen-grid voltage between SG and K or F as above.
Grid biasing voltage between CG (control grid) and K or F, depending upon the tube.
Plate current by inserting the milliammeter in *series* with the plate circuit.
Screen-grid current by inserting the milliammeter in *series* with the screen-grid circuit.

When troubles of an unusual nature present themselves, it is advisable to make a complete test by the resistance point-to-point method with the ohmmeter. This method, particularly if a circuit diagram is available, enables the student to make a thorough test from each of the socket terminals to some point of termination. By carefully computing the various component resistance values from a given point to some terminating point, an accurate check may be made to ascertain if the resistance conforms with the manufacturer's specified rating.

A brief outline of this procedure follows. (Discontinue the line plug for these tests.)

1. Test all control-grid circuits for resistance continuity to chassis. (In RF stages it is preferable to make this test to the rotary section of the gang tuning condensers instead of to the chassis, because some makes of receivers do not connect the grid return to ground or chassis.)
2. Test all plate circuits for continuity from the plate terminal in the socket to the filament or cathode (whichever type is used) of the power rectifier tube.
3. Test all filaments and cathodes to chassis for continuity.
4. Test all screen-grid circuits from the screen terminal on the socket to the filament or cathode of the rectifier tube as in (2).
5. Test all plate circuits to ground for leakage or short circuits of by-pass condensers.
6. Test all screen-grid circuits in the same manner.
7. Test the primary winding of the antenna coil.
8. Test the volume control.
9. Test the voice coil and output winding of the speaker transfer. (See instructor.)
10. Test across the variable-tuning condensers for short-circuited plates.
11. Test carefully the DC resistance of all RF and IF and AF coils for accurate values. (All modern circuit diagrams include the resistance values of all component parts.) Be careful when making this test to have the ohmmeter on the lowest resistance setting.
12. Test for continuity the speaker field winding. This may be a part of the filtering circuit and may already have been checked in the previous tests. In some types of DC, AC-DC or automobile radios, however, this winding may be separately excited.

Advanced Servicing Methods

The more advanced methods of servicing procedure are generally the quicker methods, particularly in cases of more serious trouble. These methods require more modern and expensive analyzing equipment and consequently raise the cost of entering into the servicing field; they do, however, greatly increase the speed of locating the trouble, and consequently raise production. The beginner will probably find the elementary method satisfactory for the solution of the more common radio-set troubles, but eventually he must consider the short-cut and quick-locating methods for diagnosing some of the more intricate problems which arise.

These more modern methods come under the classification of the signal-tracing system of servicing. In this system the actual picture of the radio signal as it enters the antenna and leaves the loudspeaker is followed on its complete journey.

Chapter VII

THE RADIO ENGINEER

Radio engineering is a branch of the electrical engineering profession which specializes in the various phases of radio communication. It is in reality not a separate entity, since all the technical phases of radio communication are essentially electrical engineering principles. In other words, the radio engineer is an electrical engineer or physicist who has specialized in that branch of engineering which has to do with the transmission or reception of waves through space and the associated equipment which can effectively produce these results.

The radio engineer may be defined, (1) as that person who has successfully completed a prescribed course in either electrical engineering, mechanical engineering, chemical engineering or physics, and has supplemented this training with specialized courses of study in high-frequency communication; (2) as that person who has by proficiency and experience obtained the equivalent knowledge and is recognized by the engineering profession as having attained a parallel to that of the graduate engineer who has specialized in these subjects.

Unfortunately there is no specific degree of radio engineer, and it is, therefore, impossible to give an absolutely accurate definition. It is possible that there are many persons in the radio engineering field who classify themselves as radio engineers, and justly so, but who do not come under the two classifications. Then there are, on the other hand, many who class themselves as radio engineers and are in reality nothing more than operators or technicians.

In view of these uncertainties and this lack of standardization, we recognize the radio engineer by his technical training and accomplishments, listed under the two essential classifications. Perhaps an outline of the various activities in the radio profession which deserve the title of radio engineering should be listed. These are approximately as follows:

1. Transmitter circuit design
2. Receiver circuit design (high frequency)
3. Public address amplifier design
4. Radio-frequency laboratory equipment design
5. Specialized meter design
6. Antenna design
7. Vacuum-tube design
8. High-frequency transmission line design
9. Transmitter installation and adjustment
10. Field measurements
11. Government radio inspector
12. Research and development
13. Loudspeaker and microphone design
14. Technical instructor in radio communication (academic)
15. Technical writing in radio engineering subjects (academic)
16. Broadcast studio and transmitter maintenance, adjustment

The successful radio engineer is not only a qualified technical man but one who has the ability to analyze problems quickly and accurately. He must be resourceful. He must be able to handle men and must understand how to treat them in order to obtain the best results. Great care must be exercised in the analysis of all technical and associated problems. He must constantly keep in touch with the radio field and its new developments by intensive reading of technical literature. He should be a member of an engineering society; attend technical meetings and discussions. He should possess a good technical library including textbooks and technical periodicals. These should be properly indexed and classified under the Dewey decimal system of classification. Quick references and the ability to interpret them is one of the important assets of the engineer.

The engineer is not necessarily required to know everything in this broad field, but he must know where to obtain the information he desires as quickly as possible, and then be able to interpret it intelligently.

The field of radio engineering is broad. It extends into practically all phases of life: the home, education, industry, transportation, commerce, communication, amusement, medicine, and national defenses. It offers unlimited opportunities for the competent young man of the present and the future. New fields are constantly opening up and stimulating new endeavors in the field of radio engineering.

Qualifications and Preparatory Groundwork

The young man who aspires to enter the field of radio engineering must first become familiar with the qualities required in that field, and then he must ascertain whether or not his personal qualities fit into them. He should examine carefully the outlined prerequisites and proceed to answer each one in the order of their importance.

RADIO ENGINEERING

Qualities Required	*Personal Qualifications*
General Education	Good
Mathematics	Very good
Physics	Good
Chemistry	Fair
Practical training	Could get
Health	Good
Imagination	Good

RADIO ENGINEERING (*Continued*)

Qualities Required	*Personal Qualifications*
Creative instinct	Have mechanical aptitudes
Ingenuity	Believe so
Executive ability	Don't know
Travel	Like travel

The young man who believes that his qualifications fit him for the radio engineering profession should then consult a competent vocational counselor and should confer with some one who is engaged in radio work. Much time, discouragement, and needless expenditure of money may be averted by submitting to the proper counseling and advice. It is a step most emphatically recommended for all engineering aspirants.

If the young man meets with these requirements and has in particular completed his general education, he should then proceed with his practical training. This is to be done before he plans to enter college or the specialized engineering school.

Future years will see the successful engineer as being a thoroughly practical as well as a thoroughly technical man. I believe that the time is not far distant when every man must have a college education as well as a trade to insure for himself and his family the necessary security in a world of economic stress and competition. Possibly only those with exceptional academic qualifications will be able to succeed without the aid of a trade or a manual vocation. This opinion is shared by a goodly number of engineers in the electrical and radio engineering profession. Many are endeavoring to educate their own sons along these lines.

Preparing for the profession of radio engineer, therefore, will require careful consideration of all these facts. The preliminary groundwork should include a good elementary and secondary school training—a basic groundwork such as is explained in Chapters III and IV. A practical course of training in electrical and radio principles. A thorough knowledge of engineering mathematics, physics, electrical and radio engineering principles. Coupled with these, the relatively minor but not insignificant subjects of English, economics, accounting, drafting, chemistry, and a language, preferably German. This language is recommended in view of the wealth of engineering literature available in German and in no other tongue. Some of the world's foremost texts have been written in this language. Professor Osgood's mathematics is an outstanding example.

After the student has completed a thorough course of preparatory study, what are the opportunities awaiting him? What kind of work does the radio engineer do? These have been generally outlined in Chapter I, but a more detailed account of the radio engineering field and its possibilities is desirable at this point.

First, let us examine the list of radio engineering branches before presenting the duties and qualifications for each.

Radio Communication—This covers a broad scope, as will be seen from the following list.

MARINE

Transmitter design engineer
Receiver design engineer
Antenna design engineer
Radio-compass design engineer
Installation engineer
Radio inspector
Transmitter installation technician and wireman
Constructional engineer

BROADCASTING, TELEVISION

Studio engineer
Recording engineer
Field engineer
Maintenance engineer
Antenna design engineer
Transmission engineer
Research and development engineer

Manufacturing

- Tube design engineer
- Parts design engineer
- Installation engineer
- Receiving-set designing engineer
- Transmitter design engineer
- Research and development engineer
- Test equipment design engineer
- Electronics or industrial engineer
- Equipment engineer

Industrial

- Special equipment design engineer
- Research engineer
- Maintenance engineer
- Field engineer

Government

- Radio physicist
- Senior radio engineer
- Junior engineer
- Radio inspector

This list presents a generalized division of the strictly radio engineering field but does not include positions such as those of consulting engineers, supervising engineers, technical directors, sales engineers, professors and teachers. Men who hold these positions are generally those who have started as engineers, and who, by virtue of their long experience, have obtained the higher offices. This does not, however, generally apply to teachers, since they may have obtained their positions through extensive academic learning, inherent teaching ability, or both.

It is the author's firm opinion that no matter which phase of the radio industry the young man wishes to enter, he should first get a course of training in some reliable vocational school or trade and technical institute where the subject is taught in a practical manner. This is particularly true where he is preparing for the engineering profession. My experience in training radio men for a period of over twenty years substantiates this belief.

Many students with high educational qualifications have entered the practical courses to fit themselves better along this line. Some of these cases have been exceptionally interesting in view of their previous training. For example, engineering students, engineering graduates, men holding doctors' degrees in medicine and engineering, have found it to their benefit to enroll in these practical courses. These men did not enter our radio courses to improve their intellectual ability, since they were highly trained academically, but they found themselves lacking in the practical applications of their theoretical knowledge.

To illustrate, we will take the cases of Mr. M. and Mr. S., the former a fourth-year student in electrical engineering at one of the local universities and the latter a graduate engineering student holding a degree of Ph.D. in engineering. Both men were capable of solving any of the general engineering problems commonly encountered in the electrical and radio engineering fields, but they found themselves extremely awkward in the application of their academic knowledge to actual practical problems. Both of them admitted that a practical course of training prior to their entrance upon an academic career would have been of immeasurable value. The author is personally acquainted with many men actively engaged in the engineering profession who possess the highest technical qualifications. They are capable of designing circuits, teaching, etc., yet are actually incapable of locating troubles in a piece of equipment. True, this may not be a handicap, since specialized practical technicians may be on hand to do the actual repairing, but on the other hand it seems quite logical that the rating of a good engineer should be based upon both theoretical and practical knowledge.

There are thousands of teachers in radio engineering who are successfully teaching future engineers but who may not have had any actual field engineering experience themselves. Those who find themselves gifted in this art should by all means pursue that course, since it is they who are primarily responsible for the future development of our engineers.

General Duties and Requirements

We will now proceed with the analysis of the general duties and requirements for the various positions of radio engineer previously listed.

The Transmitter Design Engineer—The duties of this position are almost strictly along the lines of transmitting circuits and their operation, and very seldom demand a knowledge of receiving-circuit design. That is to say, the transmitter engineer specializes so intensively in this phase of the work that he finds little or no opportunity to branch into the other fields. In many cases the transmitter engineer finds himself so highly specialized that it is difficult for him to enter into another branch of the work.

The transmitting field demands a thorough knowledge of electrical engineering principles. A fundamental working knowledge of alternating and direct current theory, motors and generators, control devices, transformers, safety devices and general power supply equipment is essential. The engineer must be thoroughly versed in the specialized branches of the transmitting field, such as vacuum-tube theory, circuit theory as it applies to high-frequency transmission, coil design, condenser design, antenna design, circuit arrangement for greatest efficiency, mechanical rigidity, etc. He must be adept at the drafting board for the setting up of circuit blueprints. He must possess originality and foresight.

The transmission engineer arrives at his goal through one of either of the two general channels. He may enter the laboratory of a large manufacturing organization as a student engineer after graduation from college or he may follow the long road through experience.

The Receiver-Design Engineer—This branch of the radio engineering profession deals with the mechanical and electrical aspects of radio receiver design. It demands an intensive knowledge of alternating current theory, vacuum-tube theory, high-frequency and low-frequency circuit theory. Great ingenuity is required in this field, since it is up to the receiver-design engineer constantly to improve the circuit design so that it will meet with the high standards of the engineering profession as well as the demand of the public for improved models. His problems involve such important factors as sensitivity, quality of reproduction, selectivity, ease of adjustment, mechanical layout, and so on. He must possess a good knowledge of cost and production, mechanical engineering, and economic problems. He must have fair executive ability, especially if he is employed by one of the larger manufacturing organizations.

This type of position requires a college training in electrical engineering supplemented by a period of apprenticeship in a laboratory. In general, the design engineer reaches his goal through long experience in large industrial organizations working as a laboratory assistant, tester or serviceman. After gaining the basic experience he generally branches out into some specialized branch of the receiver-building industry where his broad training will enable him to qualify with other large or small organizations. In many cases he may find ample opportunity in the larger companies to advance to higher positions through work in the various departments. Rarely is this type of position open to the non-college-trained man unless he has had years of practical experience in smaller organizations.

The salary range of receiver-design engineers is wide, depending upon their field experience and established reputation. The starting salary is generally $40 a week, and rises in some cases to more than $100 a week.

Antenna-Design Engineer—This is a highly specialized field, particularly where the design relates to transmission and its associated phenomena. Here an intensive knowledge of transmission principles, such as alternating-current theory, high-frequency phenomena, mechanical structures and mathematics is required. In practically all cases these men are college graduates and attain their goal through exceptional ability and practical experience in the transmission field. Positions in this field are rare, since they are mostly filled by engineers who have had long experience in other branches of the radio field such as transmission and design engineering. Highly specialized branches such as this are not filled immediately by men leaving college. Too much practical experience is required before this position can be suitably handled. The pay is usually high, ranging from $50 to $150 a week.

Radio Compass Design Engineer—This is another of the highly specialized departments of the radio engineering profession, and is in reality closely related to the antenna-design engineer. These engineers are directly responsible for the development of radio direction finders in the marine and aeronautical fields. College training and a vast amount of practical engineering experience is essential. The salary range is similar to that of the antenna-design engineer.

Installation Engineer—This position, as applied to the marine field, does not necessarily require a college education, but it calls for a good foundation of radio principles and practical operating experience. Good mechanical aptitude and the ability to read blueprints are the essential prerequisites. Installers are generally men who have had years of experience as radio operators and have kept up with theoretical advances in the art. The title of engineer is rather misleading in this sense, since installers may or may not be graduate engineers. The position of installation engineer, as applied to the broadcasting field, is of a relatively more involved nature and does require a more intensive theoretical knowledge. These men are in nearly all cases transmission engineers and possess the qualifications associated with this group. They may be justly called installation engineers, since they must possess the engineering ability associated with transmission engineers.

The salaries for the marine installer range between $35 and $60 per week, while that of the broadcast installation engineer ranges from $40 to $75 per week.

Radio Inspector—The radio inspector in the marine field is in most cases a practical engineer who has attained his goal through long years of experience in the marine radio operating field. It is his job to maintain all marine radio equipment in first-class condition. He must make all the necessary adjustments on the transmitter to comply with the Government regulations.

The radio inspector in this branch should have a good practical knowledge of radio engineering principles. He must have a good knowledge of the radio laws and their specific application to the marine field.

The radio inspector does not necessarily have to be a college graduate, but he must be a man of vast operating experience and good technical knowledge. He must possess a thorough knowledge of transmitting circuits and their practical adjustments. The salary of the radio inspector varies between $35 and $50 a week.

Construction Engineer—The construction engineer in marine radio is generally a radio engineer or mechanical engineer whose job it is to draw up electrical and mechanical specifications of the transmitting and receiving equipment. He is usually a design engineer who specializes in transmitting equipment. He must be thoroughly familiar with the engineering requirements necessary for efficient operation, compactness, and mechanical structure.

This position requires a comprehensive knowledge of circuit theory and mechanics together with a large degree of ingenuity. A good mathematical knowledge is also required, since practically all the phases of electrical and mechanical layout must be accurately computed. This position requires a college training in either electrical or mechanical engineering and a considerable amount of practical laboratory experience. The construction engineer is rarely a non-college-trained man, with the possible exception of those who have had many years of laboratory and practical experience. The salaries in this field range between $40 and $100 weekly.

Tube-Design Engineer—This is unquestionably one of the most important positions in the radio engineering profession. Vacuum tubes are the heart of the radio industry. They are used in all the listed branches throughout the entire world. It is primarily due to the tube-design engineers that the great progress in the radio and allied industries has been made possible. We cannot begin to enumerate the many fields in which the vacuum tube plays the important role. Excluding the radio field, we find the vacuum tube used in industry, medicine, aeronautics, education, military, and the home.

The tube-design and research engineer must possess unusual qualifications. He must be thoroughly proficient in physics, chemistry, mathematics, mechanics, and he must possess great ingenuity. Perhaps the most important prerequisite is the knowledge of higher mathematics and atomical physics. These subjects require special training and must therefore be obtained after the completion of the general college courses in engineering.

The young man who aspires to enter this fascinating section of the radio field must first complete a prescribed course in mechanical or electrical engineering. Then he must choose the proper electives in physics, chemistry and mathematics of a post-graduate nature leading toward a doctor's degree in engineering or physics. He may choose the alternative—after graduation from an engineering college—of obtaining employment in one of the large industrial laboratories, and there obtain experience in the field itself. In most cases, the men entering the field of higher physics, chemistry and mathematics, hold doctors' degrees. Of course, there are always the exceptions. Some young men are actively engaged in the tube-design field who have not had the good fortune of higher education, but who, by virtue of their practical experience, have attained success. They are, however, exceptionally well versed in chemistry, physics, and mathematics.

The salaries for tube engineers vary over a wide range, depending upon the nature and uses of the tubes designed. The minimum is generally $50 per week, and salaries as high as $300 weekly are known.

Parts-Design Engineer—This is perhaps the broadest field of all the engineering branches. It includes the entire electrical industry in which parts are made for use in radio and its allied branches. This field is so vast that it is almost impossible to cover all its phases in a book of this kind. We will try, however, to cover the more important parts used in radio. Each of the listed items may require dozens or even thousands of men and women to effect their final production. In view of this, only the technical and engineering will be listed, or those which require at least some fundamental knowledge of electrical principles.

Let us take a broad glimpse into the parts field and see how many of the major branches will require technically trained men. Then we will discuss some of the engineering duties of the more important branches and the qualifications that the men must have and how they must train for it.

Engineering in the respective parts field is generally of a specialized nature depending upon the character of the part and its uses. The engineer is generally trained as an electrical engineer, physicist or chemist, but with a good knowledge of radio engineering. He must have a thorough knowledge of the specialized branch in which he is working, together with a broad view of the field requirements. He must be constantly on the alert for new developments, so that he may be in a position to fill the demand for his product without delay. He must have the ability to make recommendations to his superior for newer and better products, so that his organization may compete with other manufacturers. The successful parts engineer must possess unlimited ingenuity for new ideas, since his field is in most cases highly competitive.

Let us take a few of the larger parts industries and analyze briefly the duties and requirements of their engineering staffs. Three of the major branches—after the tube branch—are condenser, resistor and loudspeaker manufacture and design. Every radio marine, police, and broadcast receiver requires condensers, resistors and a loudspeaker (or telephones). Every type of transmitter requires condensers and resistors. All devices which operate upon the vacuum-tube principle require numbers of condensers and resistors. No electronic device can operate without them.

The condenser designing engineer is operating in one of the highly specialized fields of engineering. He must have a thorough knowledge of electrical engineering principles with particular emphasis upon electrostatics, ceramics, mechanics, and mathematics. The subject may be more accurately summarized as basic physics and chemistry, and their application to radio engineering practice. It is the duty of the condenser designing engineer to calculate design and study the performance of the condenser. This requires an abundant knowledge of dielectric materials, temperature changes, moisture absorption, losses at various alternating-current frequencies, and circuit application. He must be thoroughly adept in the handling of laboratory instruments and the correct interpretation of his findings. This, in addition to a good understanding of manufacturing procedure, makes it almost imperative that he have a good college training in electrical engineering. Here once more we find the exception of the engineer who has acquired his training through the medium of practical experience. We hear of many successful engineers in the condenser manufacturing field who are highly efficient without college training, but these men have in most cases grown up with radio since its infancy. Consequently theirs has been a long pull on the road to success.

The resistor-designing engineer comes under almost the same qualifications as the condenser-designing engineer, with the exception that his field covers even a more extensive area. That is to say, resistors are used in many more phases of the engineering field than are condensers. This is, of course, a mere generality and does not intend to fix the resistor field as a more important commercial unit. Both are essential.

The resistor-designing or research engineer must have a thorough knowledge of electrical engineering principles, physics, and some knowledge of chemistry. He must be most thoroughly informed on subjects which deal with conduction, heat, and power losses of resistive materials. He must have a good knowledge of ceramics as applied to dielectric losses at high radio frequencies. He must have a thorough knowledge of laboratory and manufacturing procedure; the ability to improve a design and develop new products. His prerequisites must be along engineering lines, particularly electrical engineering.

Most of the engineers in this profession are college graduates, particularly those employed by the large manufacturing corporations.

The loudspeaker-designing engineers also are essentially electrical engineers but more generally men who have specialized in subjects relating to acoustical engineering. This is another of the highly specialized branches. This type of engineer must be thoroughly familiar not only with electrical engineering principles but also with mechanical and acoustical engineering. He must have a thorough knowledge of mathematics, physics, mechanics, and acoustics. He should possess a good knowledge of music, although this is not essential.

Loudspeaker design over the past five years has shown a tremendous improvement, but it is still one of the difficult problems in the broadcasting field. This is mentioned here in view of the fact that loudspeaker development has always been relatively behind in comparison with the broadcast-receiver field. Radio receiver design capable of faithfully passing musical frequencies along the entire audible frequency spectrum is common enough, but in the majority of cases the loudspeaker is not yet capable of faithfully reproducing all these frequencies. It is still more or less the weak link in the chain of boadcast reception. There are many technical reasons why it is difficult to surmount this difficulty. One of these is the small (midget) radio broadcast receiver. This popular product obviously demands compactness in size, and the loudspeaker must suffer to accommodate this requirement. Physical size and suitable reflecting surfaces play an important part in the design of a loudspeaker. Without the proper physical dimensions, good loudspeaker design is impossible. Here is one of the great problems confronting the speaker engineer. He must design speakers of all sizes to fit the various needs in the field, and he must design them so that they will have good frequency response regardless of size. Small speakers have a poor low-frequency response, while large speakers have a poor high-frequency response, relatively. This demands considerable ingenuity on the part of the designing engineer to effect a compromise, so that it will sound equally well on high and low frequencies. Obviously, his technical background must be such that he may obtain these results by electrical design, mechanical construction, and acoustical relationships to the electrical and mechanical factors. This necessitates a thorough knowledge of mathematics, physics, mechanics, and acoustics. Unquestionably the loudspeaker-designing engineer must be a college graduate, this with very few exceptions.

In the three branches of parts engineering, namely, condenser, resistor and loudspeaker, only those positions of design engineer, research engineer, and expert laboratory technician are assumed. Many other jobs, such as testers, assemblers, etc., are part of the field, but those do not require any academic training as a rule.

The salaries of the academic group for the three branches vary between $40 and $200 a week. The semi-technical, production, sales and service salaries range from $30 to $75 weekly, not including the executive branches.

Installation Engineer—Large industrial organizations have at their disposal one or more engineers for the purpose of supervising the installation of equipment. These engineers may travel all over the country to make installations and see that they are put into proper working order. It is their job to instruct the operating personnel in the maintenance, adjustment and efficient operation of the completed installation. These engineers must possess a thorough knowledge of the mechanical, electrical, and operational detail of each component part of the equipment. For example, in the radio broadcasting transmitter construction field the installation engineer is generally on the staff of the designing group, probably functioning in the capacity of designing engineer. He is working in the laboratory until the time when he is called upon to make inspection, servicing or installation tours. When he installs a new broadcast transmitter, it is his job to supervise the installation, and in many cases he may make the entire installation himself. Then he must put the whole equipment into operation and perform such duties as tuning the transmitter and making all the necessary adjustments conform with the Federal Communications Commission regulations. This is an involved procedure and requires a complete theoretical knowledge of all associated equipment, besides practical mechanical ability. Here is a fine illustration of the ideal engineering qualifications: theoretical ability and the mechanical aptitude to put it into practice.

The men operating in the installation field, particularly with the large industrial organizations, are in most cases college-trained men who, after having served their apprenticeship as laboratory testers or designers, are qualified to go into the field as installing engineers. Many organizations train these men by placing them in various departments, each for a definite time, until they are thoroughly familiar with the workings of the entire plant. In this way they are so thoroughly familiarized with all the finer details of each department that they can make installations and repairs in the field without any appreciable assistance.

The smaller organizations operate along similar lines, with the possible exception that their engineers may not in all cases be college graduates. Many of these organizations employ young men who have, through years of proficiency as amateur radio operators, distinguished themselves as good practical engineers. Hundreds of these young men are actively engaged in the designing and installation field and are doing a splendid job. Many of them are completing their college training or specialized technical training while on their jobs, thus acquiring the equivalent training of the full-fledged college graduate.

Salaries in this field vary from $35 to $75 a week, and in some cases go as high as $125 a week.

Test Equipment Design Engineer—This branch of engineering in radio deals with the design of special testing apparatus such as voltmeters, ammeters, ohmmeters, tube checkers, set analyzers, signal generators, signal tracers, combination checkers, cathode-ray units, inductance-capacity-resistance bridges, and many other specialized types of testing equipment. It covers a rather broad field of engineering prerequisites, but it is essentially an electrical engineering branch. Engineers in this field must have a good knowledge of mathematics, electrical engineering, radio communication, with particular emphasis upon electrical and radio-circuit function. They must possess unlimited ingenuity and alertness to the developments in the field; new improvements, standardization and precision must be their watchwords. Success in this vast and important branch of the radio field depends upon experience and education. Very few men can attain success in it without a good engineering education as well as good imagination and intuitiveness. In general it is a highly competitive field, and the man who lacks creative ability will soon fall by the wayside.

The salary range for parts-design and development engineers is wide, depending upon the organization and the nature of the design work involved. The average salary is approximately $50 a week, with a minimum of $30 and a maximum of $200.

Chapter VIII

BROADCASTING
(Technical)

BROADCASTING may be divided into four groups: A—Studio Engineers, B—Field Engineers, C—Transmitter Engineers, D—Miscellaneous Engineering, which includes Transmission, Recording, and Supervisory Engineering.

The requirements are a bit involved for the beginner. It is generally necessary that the young man start as a radio operator or serviceman in order to become thoroughly acquainted with the operational principles of radio. He must in both cases have a radio telephone license, particularly in the case of studio and transmitter engineer.

THE STUDIO ENGINEER

First let us see what program material he has to handle. From symphony to jazz, including all the intermediate steps of groups and soloists. Great plays to single speakers, with a sprinkling of skits, musical comedy, and various divisions and miscellaneous applications of the same. From the above you will immediately see that you must have a large assortment of talents if you want to excel in this particular field. You will need the following:

(a) Knowledge of drama
(b) Knowledge of music and musical instruments
(c) Voice and dynamics of speech
(d) Audio engineering and its applications
(e) Acoustics and acoustic principles
(f) Recording principles

(g) Radio engineering and its principles
(h) Experience
(i) A pleasant personality

This is rather an imposing array of requirements, but it is not too difficult if you possess courage and determination. If you have the basic requirements such as a Government license and a high-school education, it should not be very hard to attain these qualifications. For example, let us take the case of the majority of the studio engineers in the broadcasting field; how have they climbed the ladder of experience?

From Grade School they obtained the following:
- (a) Vocal music
- (b) Fundamentals of mathematics
- (c) Basic training in English

From the Boy Scouts:
- (a) First interest in radio
- (b) A radio transmitter and receiver
- (c) Knowledge, and a good one, too, of
  - 1—Morse code
  - 2—International Morse
- (d) How to do things for himself
- (e) Additions to his educational fund
- (f) Character foundation
- (g) More music

From Private Teachers:
- (a) Piano
- (b) Ear training
- (c) Vocal training
- (d) Saxophone
- (e) Clarinet
- (f) Oboe and English horn

From the YMCA:
- (a) Manual training
- (b) Short radio course
- (c) More vocal music

From Correspondence Schools:
- (a) A course in radio engineering
- (b) A course in electrical engineering
- (c) Advanced radio and television

From Extension Courses:
- (a) A course in French
- (b) Short course in Italian
- (c) Courses in psychology

Night College:
- (a) Physics
- (b) Mathematics
- (c) Music
- (d) Acoustics and acoustic materials
- (e) More acoustic courses
- (f) General mathematics

From Experience:
- (a) Construction of transmitters and radio apparatus
- (b) Operating experience
- (c) General receiver design
- (d) Field engineering
- (e) Sound engineering—movies
- (f) Recording—commercial

From Clubs and Church:
- (a) Dramatics
- (b) Music

From Observation and Study:
- (a) Orchestration
- (b) Compliments of the orchestra
- (c) The opera and its music
- (d) The ballet and its music
- (e) Musical forms

The above represents a constant effort to better oneself by acquiring more education. There are several sources of information you may use, but it is up to you. Observe that you need plenty of training to stay on top or even get a start; you can expect to do a lot of studying and hard work. Boiling the essentials down, we find:

(a) Sound technical knowledge
(b) Basic musical knowledge
(c) Basic dramatic knowledge
(d) Sound educational background

All may be had for a mere pittance and a lot of hard work. The average salary in small stations not unionized is $25 minimum weekly—$40 maximum. In Chain stations and larger stations it is $40 minimum weekly—$90 maximum.

Realize that some studio engineers are more than engineers, they are diplomats, musicians, artists, actors, directors and writers. Nearly every one of these men has ambition, which helps him to improve. Studio engineering is an art in itself, and through the studio engineer's efforts the program is finally produced.

The Field Engineer

The field engineer has about the same training as a studio engineer, with the addition of some telephone engineering, Morse code, radio engineering, and a large amount of ingenuity. Often he has problems to solve which never happen in the studio. For example, two N.B.C. engineers were ordered out in the field to report a flood. They assembled about a ton of equipment and together with an announcer started for their destination by car. They had to leave the car and most of their equipment before going very far. Now, here was a decision to be made quickly. They chose a small portable transmitter and a regular field amplifier and battery box. The announcer's bag of clothing was unceremoniously placed in the back seat. They loaded his bag with batteries and hired an engine and caboose, and off they went broadcasting via the short-wave transmitter. Along the route in remote sections were other field engineers with receivers picking up the signal and feeding it into telephone lines. One of these could not get to line facilities. He thought quickly. The railroad station and telephone booths, why not use them? The water was rising. He bargained for a rowboat and made for the railroad station. Arriving there, he sent the boat back to pick up his announcer. Meanwhile he deposited a nickel, got the wire chief, and made arrangements to use the line as a radio line. The facilities were so crowded that he had to take a loop through the west and finally had a 600-mile circuit, although he was only 150 miles from his studio. He broadcast from his position until water forced him out. Although he had not slept for many hours and was rather tired, he found another point and kept at work until the flood receded.

Field engineering takes you into situations where quick thinking and sound technical training are always needed. The salary is about the same as for studio work. A studio engineer doesn't envy a field engineer, and vice versa. In the larger stations they are usually segregated, but occasionally necessity causes emergencies which draft the studio men for field, and vice versa.

Transmission Engineer

This department is usually found in large chains such as N.B.C., C.B.S., and M.B.S. The transmission engineer is usually a radio engineer with a lot of telephone experience. He is responsible for level control for the station and its networks, and labors constantly at equalizing the lines and setting the equalizers for outside pickups. He is also present at conferences between various departments whenever a large-scale pickup is in the offing, such as a visit of a royal party from Europe. He makes a large-scale layout with the field and studio groups, and does the switching during the pickup period. He is usually a college-trained man with a great deal of experience.

The salary attached is correspondingly large and runs from $50 to $100 weekly. There are only a few such positions in radio. The greater part of this branch is in the telephone field, where such men are equally valuable.

Recording Engineering

Here is a field which is fully established and yet is really new. There are so many branches interrelated that I shall only touch on the radio side at the moment. Since the innovation of acetate recording, nearly every station has some sort of recording apparatus. There is one general type of recording widely in use, that is acetate. The following are some of its uses in the broadcasting field:

Reference recording consists of recording program material for future use, such as speeches of political or scientific interest. It may be used also for protection purposes, that is, to cover *ad lib.* speeches over which the station has no control.

The use of reference recording for audition purposes is, of course, another use. You may make an audition record in New York and send it to Hollywood for a client who doesn't wish to come to New York to hear it.

Another use is that of recording special sound effects in the field. This is rather a special use, but is part of the recording engineer's duties. Likewise the recording engineer may do many a field job, just as any field engineer does.

Audition recordings are becoming more and more popular as a media for artists to submit to clients.

The final and most important use in small stations is that of recorded shows in library form. Here the recording man is a combination of engineer and program builder.

The salary of a recording engineer is about the same in broadcasting as those of studio and field engineers.

Supervisory Engineering

The field here is very limited and for a brief moment I should like to call your attention to one fact. That is, 90 per cent of the top-ranking men are self-trained, which should be an incentive for anyone who has set his mind on a radio job.

Beginning with a general discussion of field broadcasting, let us first see just what the radio picture is today. Roughly we have

(a) Independent station
(b) Intra-city
(c) Chain or network broadcasting

Let us therefore investigate the independent station. For example, we have a certain station which operates 24 hours a day. The engineering personnel is as follows:

One chief engineer
One assistant chief engineer
Eight studio engineers
Three field engineers
One chief control engineer (supervision)
One assistant chief control engineer (supervision)

At transmitter:

One chief transmitter engineer
Three operators

The duties of each man employed are a combination of all branches and include every branch of communication. The reason for the three operators, in this case, is the transmitter location. Everyone in this station carries a first-class commercial license, and the owner of the station even has a ticket (license). The personnel is shifted about to cover reliefs, and no two days are ever alike. The station pays from $35 weekly to $200 a month or $50 a week for men who can cover all branches. There are no vacancies. A working apprentice is always at hand as a relief man.

In contrast to this is the pocket edition of the above. This station has two studios and a recording booth, a duplex control room, in which are the transmitter and studio controls. Here the engineers also cover the transmitter. This pays $35 to $50 weekly.

The Intra-City System—Here four small independent stations group together, employing the larger station as a "key" station. Each maintains its own staff and pays the expense of field engineering, line charges, and other joint expenses from a common fund. Here occasionally the radio consultant gets a bit to do. He is usually retained at a small fee for a stipulated number of hours.

Chain Broadcasting—Here you will find four separate systems:

A—N.B.C.
B—C.B.S.
C—M.B.S.
D—A new one, not yet carrying identification

National Broadcasting Company—N.B.C. is a combination of systems, but its three networks, the Red, the White, and the Blue, employ a large and diversified engineering personnel. They have three classes of stations:

A—Owned and operated
B—Associated stations
C—Swing stations

The owned and operated carry a full personnel of engineers of every description, grouped roughly into the following:

A–*Operating Group*–Studio, field, transmitter, maintenance, construction

B–*Development Group*–Laboratory, development, system, audio facilities, video facilities (television), video engineers, cameramen, sound engineers, acoustical, shop model

C–*Design*–General engineering and design, drafting and layout

Group A, the Operating Group, in New York contains men of long experience, many of whom are college men. Those who have not been college trained have acquired an education equal to or better than that offered for a B.S. in engineering. A great many carry an additional professional engineering license, which in itself is a gold seal of excellence. Others have been chief engineers of small stations, while there is a goodly number who have special training in music or dramatics.

Group B are nearly all college men whose lives have been devoted to development. Here we find the salary scale increasing. Many men have been drawn from such companies as American Tel. and Tel., General Electric, Westinghouse, etc. They have all served apprenticeship with small pay and large opportunities and finally arrived at a steady equilibrium. The television group are the top men from the operating group who have special training. The salary is slightly higher than in the operating group.

Group C, general engineering and design. This is the specially trained group of design engineers, all of whom are college trained. They are equivalent in salary to the development engineers.

Columbia Broadcasting System–The Columbia picture is like that of N.B.C., except for labor affiliations in the operating group.

Mutual Broadcasting System–The key station WOR has a system parented to that of Western Electric, American Tel. and Tel. In organization of departments it is closely paralleled to N.B.C.

All three are about the same in salaries, except for slight differences due to length of service.

N.B.C. once had separate divisions for field, studio, and maintenance. Although the skeleton of the system remains, the three departments are now interchangeable, and a new fourth division, reference recording, draws men from any of the three. This change was for economy's sake, but a lot of headaches came with it. The smooth running of a division is badly disrupted by sudden shifting of men. Columbia and Mutual still follow the separate division method.

Television and Associated Activities—This phase of radio or video engineering is in the infancy stage, and thus far the men have been required to have a radio as well as a special television training. Optical recording and audio engineering are all parts of the new department which will be described in a later chapter.

Development Engineering

Here is a field in which the college graduate finds his place. Most development engineers are those with engineering degrees. Occasionally you will find a high-school graduate who has completed a long apprenticeship in some large company such as General Electric, Westinghouse or American Tel. and Tel., but the majority are those who have earned a B.S. in some branch of engineering.

The increasing use of radio and radio principles in everyday life is worth observing. If you are eating a morning cereal, for instance, notice the uniformity of color. Once this varied from deep to light brown. Now, with the use of the photoelectric cell and its associated amplifier equipment, the color is controlled by simply controlling the excess heat by means of a silent but alert photo-cell watchman.

Other developments include the magic-eye photo-cell door opener; the colorometer, a device for assuring uniformity of color; the new control for street-lighting systems.

Recording Engineering

Much confusion has arisen over this branch of radio. The term recording engineer is too loosely used. Some of the best men in the recording field are not engineers and have no technical knowledge of radio except that necessary to read a meter. This condition has been changing recently. To better understand the recording field we will make four divisions:

A—Movies
B—Commercial phonographic
C—Reference recordings
D—Transcriptions (broadcasting)

Having made this division, we now make a division of the kinds or methods used in the above fields.

- A—Movies—Recording on film
  - 1—Variable width (RCA)
  - 2—Variable density (E.R.P.I.)—A.T.&T.
    - (a) Light gate method (E.R.P.I.)
    - (b) Flashing lamp (Fox-Case)
- B—Disc Recording
  - 1—Wax
    - (a) Variable width (Victor)
    - (b) Variable depth (Hill and Dale; Edison)
  - 2—Other materials
    - (a) Acetate-coated metal disc
    - (b) Copper alloy, aluminum, etc.
    - (c) Celluloid and allied products
    - (d) Other materials

C–Metal Tape
Magnetized molecular field in a special magnetic alloy
D–Facsimile
1–(a) Picture transmission over wire
(b) Picture transmission via radio
(c) Picture transmission via cable
2–News, documents, fingerprints transmitted by wire, radio and cable
3–Other miscellaneous applications

The term "recording engineer" means, in the real sense of the words, a man especially trained in the installation, operation and maintenance of such equipment. He must be thoroughly trained in all phases and types of equipment, processing, and methods. He usually has special training in radio and telephone engineering. The following terms are used rather widely in the industry.

Movies–The movies have the following divisions:

1. Wax recorder, wax man
2. Film man, film recorder
   Additional tags, Ex-ERPI or WE, Ex-RCA, denote the system which the man originally came from
   Victor wax man and Hill and Dale man are used to denote the same in the wax field
3. Stage man or set man, does stage patching of camera motors and signal systems
4. Recording-room men are the wax and film and dubbing men. Dubbing consists of taking parts from disc and film and re-recording them on a single sound track
5. Monitor men are the boys who watch the level and mix the various components of music, voice, and sound
6. Lab men are a combination of radio, chemical and

optical engineers concerned with the development of the sound tracks on film or the processing of wax
7. Sound supervisor, the sound boss on the set in charge of all branches
8. Sound—the term used for the entire sound crew

Where do these men come from? As a rule they are radio and telephone men who started when the industry was young. Very few additions are made to this field.

Even the movies split the sound department into two divisions:

A—Field (news)
B—Studio

The setup is not unlike that for radio; however, a bit more on the technical side. Salaries are set by union agreement; the minimum must be paid. There is no maximum stated.

Commercial Phonographic—Here we find a bit different type of engineer. Once upon a time the following divisions were made:

1. Mixer (mixing engineer)
2. Recorders
3. Processing Men
   (a) Masters
   (b) Stampers
   (c) Pressings

Now the men are interchangeable and may work in any department. Some of the smaller firms still cling to the above divisions.

A man for this branch of radio should have the same basic radio and musical training as for a studio engineer in radio, except that a license is not required.

The system often employs one man for musical balance, taking that responsibility out of the engineer's hands, although it is really his job.

Some of the companies have entered the radio transcription field and have called in radio engineers, especially those of the studio engineering group, to fill the places on the staff. Others do this by the job method, that is, by the contract period of 13 weeks. This has been borrowed from the smaller companies of the movies, who line the sound crew for the duration of the picture. Salaries are from $50 to $80 a week.

Reference Recording—This branch of the recording field is quite new and consists of recording auditions and programs from

1. Off the air
2. Direct lines

Acetate is used almost exclusively because of its convenience. Acetate equipment is similar to wax, but requires less careful attention as to levels and handling. Many companies process these records and claim better quality than wax can produce.

Salaries are what you can get—$20 to $75 a week in some cases.

Qualifications—experience in recording and a general knowledge of radio and music.

Transcriptions—A great number of small companies and the big four—RCA-Victor, World, Decca and Columbia Phonograph—make these recordings for use in the radio field. RCA-Victor and World have a library service to small stations. All this work comes under general grouping of recording engineering. Occasionally a radio consultant is used by smaller firms who can not afford a large staff. The consultant usually has a wide field of experience and is an all-round technician. Salaries, $35 to $75 a week.

Chapter IX

TELEVISION

One cannot with any certainty predict the future development of television as an art or as an industry; therefore any discussion of its occupational possibilities must be based upon "intelligent guesses." At the present time television equipment is relatively costly, and production costs are considerably greater than those for radio programs. Consequently, we should not expect very rapid growth in this new medium of entertainment; it is more apt to expand gradually until finally it is on a "paying" basis similar to the present broadcast industry. Assuming that this gradual expansion takes place, let us consider some of the positions, technical and non-technical, that may be open to properly qualified individuals in the future.

Technical Positions

Presupposing a normal engineering development of television, there are certain rather broad classifications into which most technical positions will fall, namely:

(a) Research and Development
(b) Manufacturing
(c) Operations
(d) Miscellaneous

For purposes of simplicity we shall outline each type of position within each group in the following manner: first, the job and the duties connected therewith; second, the type of men now doing this job, their educational background and practical experience; and third, possible changes in the work, with attendant raising or lowering of personnel requirements.

Research and Development—Under this head there are two principal subdivisions—tube research and apparatus design. Tube research and development includes design of "pick-up" tubes such as the "iconoscope" and the "image dissector." The pick-up tube is that part of the system which accomplishes the transition from light to electrical energy by means of photoelectric emission. At present there are a limited number of men doing this kind of work; but a good deal can yet be done in an effort to increase light sensitivity and improve color response. Besides this there is room for improvement in conventional tubes if they are to be used in television circuits. High transconductance, low interelectrode capacities, and freedom from microphonics are required to a greater degree than in sound broadcasting.

To do this kind of work successfully, a tube engineer should have university training in electronic physics, as well as a thorough knowledge of conventional radio circuits and theory.

Men who elect to do apparatus design should have at least an electrical engineering background, with some specialized training in the communication field. This specialized training will include a knowledge of filter theory, transmitters and receivers, widband amplifiers, multivibrators, etc. In many cases the apparatus engineer will be a specialist in one particular type of equipment, as video amplifiers, synchronizing generators, coaxial cable, etc.

In general, television apparatus in design calls for a high order of precision. To take one example, distortion caused by phase shift is permissible in an audio amplifier, for the ear is not sensitive to phase differences; but phase shift, in a television amplifier, must be linear—the eye does not compensate.

As to the future, it is doubtful that design problems will ever become less complex; any change is likely to be in the other direction. Therefore it is quite safe to assume that the educational requirements for work in television research and design will not be any less than they are now, i.e., an E.E., B.S. or M.S. in physics, with specialized training in electronics or communications theory.

It might be well to add that if apparatus ever does become standardized, there will probably be less research, and some of the men formerly employed on apparatus will be shifted into production or operation.

Production—Let us consider the production group, which will include production engineers, test men, etc., a factory personnel similar to that now engaged in radio receiver and transmitter construction. These men need not be familiar with design, but must know production methods, machinery, blueprints, wiring diagrams, and test methods—particularly modern testing employing cathode-ray oscilloscopes.

Qualifications for work in this field are the same as in radio manufacture, with the exception that perhaps greater adaptability to change will be helpful, since not only equipment, but test methods as well, are progressing with the development of television.

Operation—Television operations are based to a certain extent upon broadcast practice; the setup today, however, is such that one may be called upon to perform a great many different jobs. In the future, as operations become more routine and equipment more standardized, we may expect to see specialization. Thus the requirements for any particular job may not be as broad as they are at present.

Perhaps the easiest way to break up this group into its component parts is to follow a picture from pickup to transmission. First, there will be cameramen in the field to pick up sporting events, parades, spot-news, conventions, etc.; as well as cameramen in the studio, who will take dramatic programs and variety shows that have been previously rehearsed. The television cameraman must be a radio engineer to the extent that he is familiar with radio circuits, a cameraman to the extent that he is familiar with optics and picture composition, and a maintenance man to the extent that he must be able to make quick repairs to any part of the camera—either optical or electrical. In addition he must be alert to follow action, for in television there can be no "retakes"; the scene is transmitted as it occurs, and there is no opportunity to correct errors.

It would seem as if television cameramen would constitute a new profession, requiring several specialized types of knowledge. It is hard to specify any particular educational requirements for such a position. Most men doing this work today are former radio engineers, with training in communications or physics, who were previously employed in broadcasting, and who have studied optics or photography to equip themselves for work in television.

It may be that as equipment is made more "foolproof," the cameraman will not need to know circuit theory. On the other hand, when pickup tubes become more sensitive, contrast filters may become necessary, thus requiring greater knowledge of photography on the part of the cameraman. Whatever the future trend, it is safe to say that basic knowledge of radio theory and optics will be essential.

The job of cameraman will be an important one, and such qualities as resourcefulness, alertness (mental and physical), and the ability to cooperate will have equal weight with technical training.

There must also be men to handle microphone booms or movable supports or arms from which are suspended the "mikes" which pick up the sound portion of the program. In radio broadcasting, the "mike" remains stationary and the artists usually place themselves at the proper distance from it. In television, the action must be unrestrained, so that as the artists move about, the "mike" must follow them, and yet must be kept out of the field of the camera so as not to show in the picture. A man handling a microphone boom should have a knowledge of acoustics, and should be familiar with the characteristics of whatever type is in use; although the work he does is largely manual. This particular job might in the future serve as a training ground for men breaking into television, as it would afford them an opportunity to become familiar with camera operations.

Next in line we have picture control men or video engineers, who perform the same functions for television that an audio-control engineer does for broadcasting. They will work in a monitor room adjacent to the studio or pickup point, and operate the controls that affect the brightness and contrast to keep the proper picture level, just as a sound engineer controls the sound level. They will use a C.R.O. instead of a volume indicator. A video engineer will also be responsible for switching from one camera to another as the sound engineer switches from one "mike" to another. In some cases, on programs using more than one camera, there may be need for two picture-control engineers—one to switch cameras, the other to keep the level and shading of the two cameras nearly the same, so that switching may be done smoothly. There must also be an audio control man who mixes the sound from the different microphones; his job is identical with that of the control man in broadcasting.

From this control point the picture may be sent by short-wave radio or by coaxial cable to the main transmitter. Here there are transmitter engineers who keep a check on the level, both sound and picture, who watch the carrier frequency, percentage of modulation, etc. In short they perform the same duties that a broadcast transmitter engineer does, with the difference that television transmitters are considerably more critical as to frequency stability, neutralization, and modulation capability. The FCC requires a first-class telephone license, although most employers for the present would consider only those with previous experience at high-power broadcast transmitters. There is still a lot to be done experimentally with television transmitters. Efforts are being made to increase efficiency, for considerable power is spent in transmitting synchronizing signals; and to improve definition (obtain greater band width) by utilizing single side band transmission. Much of this work comes under the head of research and development; but it may fall to the practical transmitter engineer to try under actual operating conditions many of the changes suggested by the research staff. Of course, as soon as the FCC grants commercial instead of experimental licenses to television stations, transmitter work will become more routine, and development work will be strictly divorced from operations.

In addition to all of the above, there will have to be a maintenance staff. These men should have a thorough knowledge of all television equipment and circuits. This means that in addition to their routine duties they must keep themselves informed about new and constantly changing equipment. They must also have an equally thorough knowledge of the theory of operation of the equipment; this will often save a great deal of time in locating trouble, particularly since in television faults may originate in any one of half a dozen pieces of equipment. It may come to pass that there will be "specialists" within the group—one man might concentrate on learning all there was to know about monitors, another might work on video amplifiers, etc. Such a group might lose flexibility, but would perhaps have a greater overall efficiency, for it is not possible for any individual to have a complete A-to-Z working knowledge of every piece of equipment in a television system. One thing is certain, however; the maintenance engineers should be essentially practical men, not necessarily overburdened with theoretical knowledge, who can quickly locate and repair any equipment troubles that arise.

In many cases a television program will consist of sound film. This will require the services of a projectionist, whose duties will no doubt be the same as those of any motion-picture projectionist. The picture signal must still pass through the same chain of equipment as if it originated within a studio, so that, besides the projectionist, who will take the place of a cameraman for this type of program, there must be a picture-control engineer and possibly a sound-control engineer. This setup may be the means of enabling those with film experience to work into television, starting as projectionists.

Looking at television operations as a whole, it is apparent that anyone entering this field should possess a sound background of radio theory and broadcast operations, since television procedure is based upon broadcast procedure. In addition, he should possess some knowledge of optics and photography. Many men in broadcasting today were radio telegraph operators who more or less grew up with the industry, and in like manner probably many of those in television at the start will be drafted from broadcasting and will grow up with this new industry. Of course, this may leave room in the broadcast field for many who wish to get into television but have not as yet the necessary experience. In this way they may be able to serve their apprenticeship in this allied field while preparing themselves for the more advanced technical work that is television.

Miscellaneous—We have still a great number of possible television jobs to consider which do not fall within any of the above groups. For example, there will be a definite need for service men to install and repair television receivers. Many present radio-service men have sufficient knowledge of basic theory to make it easy for them to learn the intricacies of television circuits. They should be familiar with advanced methods of testing, the use of the cathode-ray oscilloscope and square-wave generator. In addition, those who install receivers should acquaint themselves somewhat with wave propagation, so that they may locate and erect half-wave dipoles for reception and install reflectors, if necessary, to increase signal to noise ratio in that area.

In the television studio there will be some opportunities for scene painters, lighting men, make-up men, etc. Each must possess specialized knowledge and some experience in his particular field; but in addition each should have a good general idea of the whole television system. For example, a television make-up man would find it very useful to know the color response of the pick-up tube; the lighting expert should have data pertaining to the light sensitivity of the pick-up tube; the scene painter also might well consider color response. And as the television art progresses it may gradually follow the pattern of the theater; in time there may conceivably be openings for property men, stage hands, stage managers, etc. However, at the present time this is a subject for speculation only.

Another important job in television will be that of the video-effects man. This, in truth, constitutes a new profession, so new, in fact, that as yet there are no qualifications or standards to determine one's ability to enter this still very limited field. The video-effects man is to television what the sound-effects man is to broadcasting. A large part of his work will undoubtedly be the construction of small-scale models, in many cases working models, that will be used to reproduce scenes otherwise impossible to "take" within the small area of a studio. Distant mountains, villages, trains, waterfront scenes, animals, and the like, are at times necessary to provide smooth continuity of action in a dramatic presentation; one shot of this sort may be the equivalent of several hundred words of explanation by one of the characters. The technique is the same as that used in most motion pictures today. It will be up to the video-effects man to provide the material, i.e., model houses, model trains, papier-mâché mountains, etc., for such shots. The field seems to offer untold possibilities in the future. As to the requirements for obtaining work of this nature, perhaps all that can be said is that a good video-effects man will need 25 per cent knowledge of mechanics, model construction, paints and lacquers, optics, and 75 per cent ingenuity and imagination.

Non-Technical Positions

Among the non-technical jobs there will be openings for writers, actors, and producers. Writing for television will require a technique similar to that of the stage dramatist, with the advantage that in a television program the scene can be changed instantly by simply switching cameras. It will be different from radio writing in that, wherever possible, dialogue will merely supplement action, not replace it. A capable writer who knows his medium can soon learn to use it to best advantage.

Television actors will be called upon to memorize their lines. This gives an advantage to those with previous stage experience—as opposed to those with only radio or motion-picture training. Beyond this, the qualifications would be the same as for an actor in any other branch of the entertainment field.

Television producers will be drawn from radio broadcasting and from the little theater. The producer should be able to cast, rehearse and direct his show just as if it were a stage presentation—to get good results from an artistic point of view. In addition he should know something about the system, any inherent limitations that may be present, the viewing angle of lenses with different focal lengths, lighting, make-up, etc. The more knowledge he has of the technical side of television, the less likely he will be to attempt impossible shots. A good producer will cooperate to the fullest extent with the technical staff, for television is still in the hands of the engineers. It is equally true that if an engineer is familiar with the problems of the production director, he will be able to anticipate certain shots, so that the director can obtain just the desired effect. A television program calls for very close cooperation between producer and engineer—a thing that is sometimes difficult to obtain from two such dissimilar types—but the final result will justify the effort in ten cases out of ten.

In conclusion, let us consider the outlook for careers in television on a long-range basis. For the present there will probably be no "big paying" jobs, since the industry is not on a self-sustaining basis as yet. Millions have been spent on development, and it may be a number of years before there is any appreciable income from the operation of a television station. Furthermore, for reasons already given, the art of television will probably expand slowly, and at the outset remain limited to centers of population. The number of openings will probably be small to start with, because many will enter this field from some allied industry where they obtained their practical experience.

Ability to meet changing conditions, to learn new techniques and procedure, to cooperate with fellow workmen, will, as always, be a definite asset. No doubt the virtue of patience will be helpful, particularly to those who may find it necessary to gain experience in some other field before getting into television.

However, there will be jobs—and at a reasonable rate of pay—plus an opportunity to grow up with this new industry.

Chapter X

GOVERNMENT RADIO SERVICE

THE United States Government offers many opportunities for the young man who is desirous of entering into the radio profession. It also offers many splendid positions for men with previous experience in the radio field, both in the operating and in the engineering department.

In preparing for the service of Uncle Sam, it is best to enroll in some recognized resident school, or, if that is impossible, in some reputable correspondence school before enlisting. This is particularly true for those desiring to enter the military service in, say, the Signal Corps of the United States Army, the radio communications division of the United States Navy or the Coast Guard. The reason for this suggestion is that the young man who holds a government radio operator's license has a better chance of getting into the radio division of these services as well as a better opportunity to advance into the higher brackets. In other words, young men equipped with technical training in the operational field will find themselves in greater demand, and, if they have the ability, will have a better chance to obtain positions in line with their desires. This, of course, does not mean to imply that easier and less hazardous jobs are found in the technical branches of the military service; on the contrary, the well-qualified men who handle technical equipment and operations have a great responsibility. It is their job to be constantly on the alert for emergencies and to be able to handle their assignments with exactness and dispatch. Their individual duties may be of such major importance that the lives of a great many men may be in their hands. The great importance of radio communication in the services need not be recited here, since it has definitely proven itself in the past and will continue to do so with even greater amplitude in the future.

A letter recently received by the author from the War Department in answer to an inquiry as to the future possibilities for the young man in the Army communication services is as follows:

> In connection with your inquiry relative to the future possibilities for young men in Army communication, would advise that the same are excellent. All enlisted personnel who enter the service are enlisted in the lowest grade, that is, the grade of private. By proper application, however, there is no reason why a soldier of excellent character should not reach the grade of master sergeant, which is the highest grade for enlisted men, well in advance of his retirement from active service.
>
> R. B. Moran, *Major, Signal Corps*

In order to familiarize the young reader with the Signal Corps training school at Fort Monmouth, N. J., a complete outline of the radio course is herewith presented.

RADIO COMMUNICATION COURSE

SIGNAL CORPS SCHOOL

Fort Monmouth, N. J.

Objective—The objective of the radio communication course is to qualify personnel in one or more of the following subcourses:

(a) Field radio operator
(b) Radio operator
(c) Radio repairman
(d) Intercept radio operator, Universal

Subjects—The following table indicates the subjects taught in the subcourses listed above. Only that portion of a subject pertaining to a given subcourse is taught as a part of that subcourse.

Subjects	*Field radio operator*	*Radio operator*	*Radio repairman*	*Intercept radio operator Universal*
Code practice	Yes	Yes	Yes	Yes
Code practice, Universal code				Yes
Installation and adjustment of tactical radio and telegraph equipment	Yes			
Installation and adjustment of permanent and semi-permanent radio equipment		Yes		
Installation and adjustment of special radio equipment				Yes
Electricity and magnetism	Yes			
Shop work, basic	Yes			
Shop work, advanced			Yes	
Elements of radio, elementary	Yes			
Elements of radio, advanced			Yes	
Circuits and tests of tactical radio and telegraph equipment, basic	Yes			
Circuits and tests of radio equipment, advanced			Yes	
Shop maintenance of tactical radio equipment	Yes			
Radio procedure, tactical nets	Yes			Yes
Radio procedure, permanent nets		Yes		
Radio procedure, special				Yes
Radio net operation, tactical	Yes			
Permanent net operation, radio and land line		Yes		
Field exercises	Yes			
Athletics	Yes	Yes	Yes	Yes

Analysis of Subjects

(a) Field Radio Operator

(1) Code Practice—Instruction is practical and covers practice in transmitting and receiving telegraph signals in Continental Morse code.

(2) Installation and Adjustment of Tactical Radio and Telegraph Equipment—Instruction is entirely practical and is intended to familiarize the student with the nature, use, and method of installation and adjustment of field radio and telegraph sets and their associated equipment in tactical operations.

(3) Radio Procedure, Tactical Nets—Instruction covers the proper procedure and methods employed by radio operators in sending and receiving tactical radio messages.

(4) Radio Net Operation, Tactical—Instruction covers the operation of both table and field radio nets. It is designed to develop skill in handling traffic and to give practice to students in the installation, operation, and field maintenance of radio sets. It is the practical application of the subjects taught under (1), (2), and (3) above.

(5) Electricity and Magnetism—Instruction covers so much of the basic principles of electricity and magnetism as will enable the student to understand the technical directions for operating field radio equipment and to prepare him for later study of radio circuits and associated electrical equipment. Practical laboratory work is the main feature of this course of instruction.

(6) Shop Work, Basic—Instruction covers the use and care of the tools commonly employed in the repair of field communication equipment. The instruction is entirely of a practical nature.

(7) Elements of Radio, Elementary—Instruction covers the elementary principles of radio theory and of basic radio circuits. Instruction is made practical by requiring the student to construct and analyze the different types of basic circuits.

(8) Circuits and Tests of Tactical Radio and Telegraph Equipment, Basic—Instruction is given in the physical construction of field radio and telegraph sets: and the correction of faults.

(9) Shop Maintenance of Tactical Radio Equipment—Instruction covers the reading of simple drawings of radio circuits; the dismantling, inspection, wiring, assembly, cleaning, painting and minor repair of field equipment, and the servicing of motor and generator units employed with field sets.

(b) Radio Operator

(1) Code Practice—Instruction is practical and covers practice in transmitting and receiving telegraph signals in Continental code. Reception is taught for tone and sounder, and the telegraph typewriter is employed. In addition, selected students are given practice in Wheatstone automatic transmitter tapes, the transmission of same, and the reading of ink-recorded tapes.

(2) Installation and Adjustment of Permanent and Semi-Permanent Radio Equipment—Instruction is entirely practical and is intended to familiarize the student with the nature, use, and method of installation and adjustment of radio sets and other associated equipment employed in permanent and semi-permanent stations.

(3) Radio Procedure, Permanent Nets—Instruction in this subject covers the proper procedure and methods employed by radio operators in sending and receiving radio messages in permanent radio stations.

(4) Permanent Net Operation, Radio and Land Line—Instruction covers the operation of permanent-system radio nets. The object of this course is to develop skill in handling traffic and to give practice to students in the operation of permanent-system equipment. Messages of the type transmitted over the War Department net are used for instructional purposes.

(c) Radio Repairman

(1) Code Practice—Sufficient instruction is given to maintain speed developed in previous subcourses and to advance the speed of the student.

(2) Elements of Radio, Advanced—Instruction covers the principles of radio theory and radio circuits. Instruction is made practical by requiring the student to construct and analyze different types of radio circuits. This course is similar to elements of radio described above, but more advanced.

(3) Circuits and Tests of Radio Equipment, Advanced—Instruction is given in the characteristics of radio circuits, the testing of radio sets and associated equipment, and the correction of faults in this equipment. Selected students who are particularly apt are given a course in machine-shop practice, which includes screw cutting, lathe, and milling-machine exercises.

(d) Intercept Radio Operator, Universal

(1) Code Practice, Universal Code—Instruction is practical and covers transmitting with hand key and automatic key and receiving the Universal code on tone and sounder, using the telegraph typewriter with special keyboard.

(2) Installation and Adjustment of Special Radio Equipment—Instruction is entirely practical and is intended to familiarize the student with the nature, use and method of installation and adjustment of all types of goniometric and intercept radio equipment available.

(3) Radio Procedure—Instruction in this subject covers the proper procedure and methods employed by radio operators in sending and receiving messages in tactical, permanent, and commercial nets.

The United States Navy Department offers a similar course, but follows a slightly different procedure. In this service the radiomen are basically trained aboard ship for active duty, after which they become elegible for certain radio schools. These are referred to as the Radio Material School, maintained by the Navy for the higher ratings in this branch. This course is a truly well-rounded outline of basic radio engineering study, and should provide a splendid incentive for the competent naval radio operator.

This branch of the service gives courses in the following subjects:

- Mathematics
- Direct current
- Alternating current
- Theory and practice
- Motor starters
- Transformers
- Tests and measurements
- Keying circuits
- Antennas and transmission lines
- Mechanical training
- Polyphase and AC rectifiers
- Direction finders
- Power-supply systems
- General radio instruction
- Radio receivers
- Radio transmitters
- Batteries
- Radiotelephony
- Sound
- Mechanical drawing

The salary rates in the Army, Navy, and Coast Guard radio services range from $60 to $126 a month. The warrant electrician (radio) in the United States Coast Guard service receives a monthly salary of $250.

Civil Service Positions

The engineering branches of the United States Government offer some splendid opportunities for the qualified radio engineer, the most common of these being the radio physicist, senior radio engineer, junior radio engineer, and radio inspector. New positions in the government service are being opened each year, and the prospect for good jobs in the future is encouraging. One of these recently added is that of civilian radio instructor in the U. S. Signal Corps aeronautical division. The qualifications and duties for the various positions listed will be briefly summarized.

Radio Physicists—This is one of the best positions offered by the government in the radio engineering branch. It is particularly attractive to the academic group of young men and middle-aged men who have had many years of engineering training, teaching, and development experience. Their qualifications must be of the highest order, since the nature of the work they are to perform deals with the most involved problems of the radio engineering profession. Most of the men who qualify for this job hold the degree of doctor in engineering or physics and in addition have had an intensive amount of research and development experience. No man can qualify for this position unless he is exceptionally adept at mathematics, physics, radio engineering, and research. The basic prerequisite, therefore, is the completion of a prescribed course in electrical engineering or physics, preferably the holder of a doctor's degree, coupled with many years of laboratory or research experience.

The salary range of the radio physicist in the government service is between $3000 and $6000 a year.

Senior and Junior Radio Engineer—This position is similar to that of the radio physicist and differs only in that it may not require the exceptionally high standard of academic learning. That is, the man who has had years of engineering experience in a responsible capacity may qualify for this position. He need not necessarily have a doctor's or master's degree, but should have a good basic training in electrical engineering or hold a bachelor's degree in electrical engineering. A long term of field engineering experience is one of the most important requirements for this position.

The salary range is from $2000 to $5000 a year.

The Radio Inspector—This is one of the most popular branches of the government radio services. It is the one branch that gives the man with long experience in the operational field an opportunity to obtain a fine position.

Many of the present inspectors are old-time radio operators who have won their spurs on the long road of experience. They have maintained a constant vigil over the advancing art, and careful study of radio engineering subjects has qualified them for these positions.

The duties of the radio inspector are primarily in connection with the enforcement of the Communications Act of 1934, as amended; the General Radio Regulations (Cairo Revision) annexed to the Telecommunications Convention of Madrid; the International Convention for Safety of Life at Sea, 1929, and the Rules and Regulations of the Federal Communications Commission. These duties will include the inspection of radio equipment on ships, on aircraft, and at the various land stations, requiring the carrying of testing and measuring equipment; the making of frequency runs, harmonic analyses, and field intensity measurements; the examination of radio operators for amateur, marine and telephone licenses, the composition of involved technical reports, and the performance of such office work and other related duties as may be required. Inspectors in the Field Division are required to do considerable traveling and drive inspection cars and mobile laboratories. The Communications Commission may transfer employees from one district to another whenever and wherever the needs may require.

The requirements for the position of radio inspector are quite reasonable in view of the fact that experience may be substituted for college education, year for year. This presents a splendid opportunity for the man who has spent many years in the radio operating field but who has not had the opportunity to complete his college education. For example, the government requirements state that the applicant must have—except for the substitution—successfully completed a four-year course leading to a bachelor's degree in electrical or communication engineering in a college or university of recognized standing. In addition he must have had at least one year's technical experience in installation and testing, operation and maintenance responsibility, or the testing and inspecting of radio transmitters of at least 100 watts of power output.

Those who have not had the four years of college training may substitute their radio engineering experience, year for year. This experience must have been of such grade and nature as to give evidence that the applicant possesses a broad knowledge of the theory and practice of radio engineering. One year of technical experience in connection with installation and testing, operation and maintenance responsibility as previously mentioned, must be supplemented. Also a knowledge of telegraphic code, transmission and reception—at a speed of 25 words per minute—is required. Preferably, the applicant should be a holder of a first-class radiotelegraph operator's license.

The starting salary for government radio inspector ranges between $2000 and $2600 yearly.

Chapter XI

HOME STUDY

Correspondence Schools

THE problem of training young men through the medium of correspondence schools is one that has given educators great concern. This is particularly true in the field of electrical and radio engineering, where the success of the student depends largely upon his ability to handle technical problems and to apply them; that is, to make practical tests and measurements. Unfortunately, this is quite impossible through conventional correspondence-school methods. Some of the large institutions do make an effort in this direction by supplying test kits in conjunction with their theoretical projects, but these are in all cases incomplete and do not sufficiently acquaint the student with the vast practical applications in the field. Another great disadvantage of this method of learning, and perhaps one of the most important, is the tendency on the part of the student to take his work less seriously than if he were attending a residence school. This is largely psychological, in view of the fact that he lacks the proper environment and other important factors such as supervision and systematic classroom routine.

This does not imply that the correspondence or home-study method of learning is not recommended. Its value, however, depends entirely upon the individual. For example, if a young man enrolls in a recognized correspondence school, inspired thereto solely by a desire to learn and not by any high-pressure sales promotion on the part of the school in question, then his chances of obtaining real benefit are good. Undoubtedly thousands of students enroll in correspondence-school courses only because of the highly efficient sales technique which tells of the marvelous opportunities any young man may have if he enters the field of radio. There are marvelous opportunities in the field of radio for the right man, but unfortunately many young men do not possess the qualities necessary to attain success, and, as a result, they enroll in a course only to drop out after a short time because they find it impossible to continue.

Here once more the question of vocational guidance is paramount. No young man should enroll in a correspondence school unless he has obtained the proper guidance and knows that he is going to carry through with it. It is important to remember that this method of training *is* of great value as a groundwork and can be used as an instrument to attain success *provided you are fitted for this kind of work.*

Perhaps one of the greatest contributions offered by reputable correspondence schools is the supplementary training for those already engaged in the profession, or for those who cannot enter residence schools because of employment or location. Under the latter condition it is again necessary to remind the prospective student that he should be thoroughly sold upon the idea by his own desires rather than by the sales ability of the school in question.

Young men who are actively engaged as amateurs, radio operators, radio servicemen, engineering students, would do well to enroll in reputable correspondence-school courses to advance their knowledge in their respective fields.

Several correspondence schools are recommended, not because of their prominence due to extensive advertising but primarily because of their merits. The author is listing only those which have been carefully examined both as to technical scope and as to the manner in which instruction is carried on. The author has personally examined all of the technical material supplied in these courses and has interviewed several students who either have attended or are attending the various schools at this writing. Several other correspondence institutions are undoubtedly carrying on efficient courses, but the author has not had the opportunity to examine them and therefore cannot very well make recommendations. It is even possible that some of the other courses are more efficient, and for that reason it is advisable for each prospective student to make a thorough survey before enrolling in any one of the recommended group.

The names of several reputable correspondence schools and the specialized branches of radio that they cover are as follows:

Capitol Radio Engineering Institute, Washington, D. C.; radio engineering, home study and residence

International Correspondence Schools, Scranton, Pa.; general radio theory, radio operating, radio servicing

National Radio Institute, Washington, D. C.; general radio theory, radio operating, radio servicing

Nilson Radio School, 51 East 42nd Street, New York City; general radio theory, radio operating

Sprayberry Academy of Radio, Washington, D. C.; general radio theory, radio operating, radio servicing

Two complete outlines of correspondence school courses are presented; one for the field of radio engineering, and one for the operational field, such as radio operating and radio servicing.

There is no desire to slight any of the other schools. Space does not permit the inclusion of all the other courses. It might be mentioned that the Nilson Radio School is at the present time specializing only in a short-term radio operating course. This course is primarily designed to qualify applicants for all the new government license examination elements, 1 to 6 inclusive.

One of the best outlines of a home-study course preparatory to entering the radio engineering profession is that given by the Capitol Radio Engineering Institute of Washington, D. C. The outline of this course is herewith presented to give the reader a complete picture of the basic training required as well as a guide for teachers engaged in conducting radio classes.

The course is divided into two primary sections, namely, introductory section and advanced section. Supplementary to these sections are a series of specialized subjects which serve as a splendid postgraduate course for those who have successfully mastered the introductory and advanced sections or for those requiring more knowledge along specific lines.

Introductory Section

1–A. *Introduction to Radio Communication*–Need for a broad understanding of the field of radio communication by every radioman; relation between various branches of the industry; communication systems, low, intermediate and high frequencies, their uses and characteristics; aviation radio communication; radio telephone systems; broadcasting; functions of the Federal Communications Commission

2–A. *Arithmetic*–Multiplication, division, fractions, decimals, weights and measures, the metric system, measurement of time, angular measurement, temperature conversion ratio and proportion, powers and roots, methods of proof

3–A. *Mensuration*–Elements of algebra, addition, subtraction, multiplication, division, powers, roots, equations; elements of geometry, plane figures, equilateral and right triangles, solution of sides and area; the circle, circumference, diameter, radius, area, chord, arc, segment, quadrant; circular and square-mile measure, geometric construction

4–A. *Electricity and the Electron Theory*—Construction of the molecule, the atom, the electron; positive and negative charges, mass of the electron; a physical conception of electricity, necessity for visualization

5–A. *Current and Voltage*—Current flow, drift of electrons, direction of current flow, ampere, unit of current, effects of current flow; the factors of diameter and temperature of a conductor; voltage, difference of potential, electromotive force, the electric field, definition of the volt

6–A. *Conductors and Insulators*—Physical conception from the electronic point of view; forces that affect conducting and insulating properties of a substance, heat, frequency, difference of potential; properties of conductors, diameter and conductivity, resistance, reason for, ohm, unit of resistance; the copper wire table; insulating properties of various substances

7–A. *Ohm's Law*—Statement of law and its importance; law in equation form, voltage division along a circuit; series circuits, current and voltage relation; parallel circuit voltage and current relations; power, unit of power, equations

8–A. *Alternating Currents*—Meaning of the term; cycles, alternations, sine curves, magnetism, the magnetic field, basic laws of electromagnetic energy, how a difference of potential is generated in a magnetic field, movement of field, of conductor, polarity, reversal of field or of movement and effect on generated voltage

9–A. *Batteries, Battery Charging*—Cell and battery, contact potential, development of EMF by chemical action; primary cell, dry cell, B and C batteries, polarization and how prevented; storage batteries, lead-acid and Edison types, construction and care, how to charge, charging circuits; air-cell batteries; wind chargers for rural use

10–A. *DC Generators, DC Motors, Meters*—The alternator, generator action during a cycle, parts and construction of alternator, types of alternators, RPM and frequency; direct-current generator, commutation, axis of sparkless commutation, series, shunt, and compound winding; DC motor, torque, repulsion of fields, CEMF, series and shunt motors, differential and cumulative compound motors, motor starters; measurements of current, ammeter, milli- and micro-ammeters, radio frequency ammeters, current squared meters, wattmeter, voltmeter, construction and operation of meters

11–A. *Inductance*—Meaning, symbol, retarding effect on current; unit of inductance, self-inductance, mutual inductance; transformers, power, audio and radio frequency, frequency range, coupling, construction, voltage and turns ratio

12–A. *Capacity in Radio Circuits*—Meaning, symbol, how energy is stored in a condenser; electro-static field; dielectrics, dielectric constant, dielectric strength, tables; fixed condensers, variable condensers, construction, losses, how to select

13–A. *Radio Circuits*—Series circuit, L, C, R in series; phase relations, resonance and what it means; wavelength and frequency, electrical length of circuit, effect of R; impedance Z; parallel resonance, selectivity and the C/L ratio, practical uses in radio receivers; LC product and LC ratio; equation of the bridge circuit; values of F, L, C and R encountered in radio receivers

14–A. *The Vacuum Tube and Vacuum Tube Circuits*—What the tube will do: amplify, convert AC to DC and DC to AC, deliver power to antenna, and receive power from antenna and convert to sound waves; construction of the vacuum tube, its elements, purpose of each element; types of receiving tubes; power for tube operation; tube circuits: amplifiers, audio and radio frequency, detectors, various types, oscillators, rectifiers, full and half-way filters

15–A. *Radio Receivers*—Receiver development; TRF circuit; neutrodyne; superheterodyne; advantages and disadvantages of each; superheterodyne operation; receiving tubes, 6A8, 53, 2A6, 2B7; description and purpose of each; circuit analysis of typical modern home and auto radio receiver circuits; modern trends in receiver design

16–A. *Public Address Systems*—General considerations; carbon microphones, single and double button types, condenser microphone, dynamic microphone, velocity microphone, crystal microphone; phonograph pickups, electromagnetic and crystal types, scratch filters, volume controls; amplifiers, gain and power requirements; speakers, baffles, sound-distribution requirements, types; decibel, explanation and use, with tables

17–A. *Transmitting and Receiving Antennas*—Radiation of energy; electromagnetic waves, "wave-length"; function of the transmitting antenna; closed and open electric fields; types of transmitting antennas, description, where used; receiving antennas, general consideration; modern all-wave antennas for broadcast reception; the ground system

18—A. *Types of Radio Transmission*—FCC classification of types of A1, A2, A3 and A4, emission; description of how CW, ICW, ACW, telephony (single and double side band), facsimile and program broadcasting are accomplished with modern transmitting equipment; high-percentage modulation, reason for use; analysis of interference, harmonic radiation and its relation to interference

19—A. *Radio Transmitters*—Types of tubes used, air- and water-cooled, internal construction, special problems relating to power tubes; transmitter power supplies, methods used to obtain various tube voltages; telegraph transmitter circuit, general considerations and various circuits employed; telephone and broadcast transmitters, general considerations, high- and low-level modulation explained

20—A. *Radio Direction Finaers*—Use of direction finders, tracking, general types of RDF, loop RDF theory, the figure-eight receiving pattern, loop design, deviation, antenna effect, pickup errors, displacement currents, quadrature effect, polarization errors, the unilateral RDF, Bellini Tosi RDF, the Adcock system

Advanced Section

1—B. *Positive and Negative Numbers*—Exponents, conversion factors, square root, practical problems covering each subject

2—B. *Logarithms*—Principle and use, multiplication, division, roots and powers; practical work in types of problems encountered in radio work, practical use of "log" tables, slide rule

3—B. *Algebra*—Essentials of algebra, addition, subtraction, multiplication, division, powers, roots, factoring, derivation of equations; practical work in types of problems encountered in radio-frequency work

4–B. *Geometry*—Use of geometry in radio problems; addition and subtraction of forces along a line and at various angles; conversion to right angles; practical problems; graphs and curves, curve plotting and reading, relation between curves and equations, examples of plotting linear, direct and inverse functions

5–B. *Trigonometry*—Functions of the angle; solutions of right triangles; practical use of tables of functions; practical problems; the radian, converting radians to degrees; applications to vector addition of voltages, the load line

6–B. *Vector Analysis*—Combination of the use of geometry and trigonometry in the solution of forces and determination of angle of resulting force; practical problems explained step by step to their solutions; graphical solutions

7–B. *Electron Physics*—Construction of matter, molecules, atoms, electrons, protons; table of atomic weights; planetary and nuclear electrons; atomic structure of elements; chemical combinations, valency, isotopes; forms of matter; conductors and insulators, from electron viewpoint; factors affecting electrons, charges, voltage, heat, etc.; electrical resistance; temperature coefficient calculations; electron emission from hot metals, factors involved

8–B. *Ohm's and Kirchoff's Laws*—Ohm's and Kirchoff's Laws and their practical applications; practical problems in series, parallel and voltage divider circuits, meter shunts and multipliers; bridge circuits, theory and principle of operation; commercial Wheatstone bridge, construction and operation; experimental bridge; capacity bridge circuits

9—B. *Magnetic Circuits*—Comparison of magnetic and electric circuits, magnetism, theory, electromagnetism; magnetic units, magnetomotive force, reluctance, permeability, flux, flux density; the B-H curve; magnetic circuit calculations; hysteresis, calculations using Steinmetz formula for hysteresis loss

10—B. *Alternating Current Theory*—Generator action; EMF and difference of potential, generation of an EMF; mechanical and electrical degrees; the sine curve, method of plotting, instantaneous values, sine values of electrical angles; average and maximum E and I; effective or RMS values, how computed; meter scale to read RMS values; radio frequency ammeters, hot wire and thermo-element, calibration, construction and operation; materials used in thermo-couples

11—B. *Phase Angles, Single and Polyphase AC Systems*—Ohm's Law for alternating currents; leading, lagging and in-phase currents; calculation of phase angles; vectors and sine curves; angle in radians; polyphase AC Systems: alternator and transformer connections; vector analysis for voltage current and power relations for delta and wye connections; transformer connections

12—B. *Inductance*—Induced currents, Lenz's Law; theory of mutual- and self-inductance formulas for air-core coils; calculations for inductance, turns, wire size, etc.; table of K (form factor); inductances in series and in parallel

13—B. *Inductive Reactance, Impedance, Q of Coils*—Angle of lag; effect of current change on CEMF; reason for 90-degree lag; reactance, definition and reason for; effect of variations of F and L on XL; derivation of equation for XL; resistance in inductive circuit, impedance, angle of lag; calculations in practical load circuits; Q of coils; factors affecting radio-frequency resistance of coils, frequency distributed capacity, reflected resistance, skin effect; comparison of RFDC resistance of coils; practical considerations in coil design

14—B. *Inductive Coupling*—Methods used; effects of coupling; mutual inductance; transformer action; requirements of coupling circuits; reflected impedance; current, voltage, turns, reactance and resistance relations for coupled circuits; coefficient of coupling; optimum coupling at radio frequencies; mutual reactance; calculations; effect of excessive coupling; band-pass filter, band-width calculations

15—B. *Power Transformers*—Transformer theory, relations shown vectorally; leakage reactance; current and voltage relations; types of transformers, core and shell; core construction; windings; power relations; tables for current density, terminal voltage, volts-per-turn rating and transformer space factor; transformer design; complete design of a 5-KVA transformer

16—B. *Capacity*—Electro-static field; mechanical analogy; pressure and capacity of condenser; charge and discharge; instantaneous comparative values of voltage and current in the condenser; unit of capacity; capacity reactance; condensers in series and in parallel

17—B. *Capacity*—Charge in a condenser; effect of capacity on amount of charge; spacing of condenser plates; dielectric permeability and break-down voltage; condenser construction; losses in condenser and power dissipation; how to select condenser; derivation of equation for capacity reactance; calculations of phase angle, power losses, break-down voltages, etc.; electrolytic condensers

18–B. *The Series Circuit*—Calculation of impedance; angle of lead or lag, calculations; effects of frequency variation on impedance; series resonance, impedance, current, voltage and phase angle; effects of high resistance on selectivity; L/C ratio for good selectivity; circuit Q, calculations involving Q

19–B. *The Parallel Circuit*—Impedance in circuit containing L, C and R; phase relations of currents and voltages; parallel resonance; effect of resistance in resonant circuits; L/C ratio for good selectivity; plate output circuits; calculations using Z-L/CR formula; shunting effect of grid input circuits

20–B. *Series-Parallel Circuits*—LC tables, mathematical analysis of complex circuits; impedance, currents, voltages, phase relations, power, etc.; the LC table, examples of use

21–B. *Practical Applications of Series and Parallel Circuits*—Tuned antenna circuits; tuned grid and plate circuits; selectivity, effects of frequency; series by-pass circuits; parallel trap circuits; transmitter tank circuits; band-pass filters; low-pass filters

22–B. *Radio Frequency Chokes*—Reasons for using; ideal choke coil; distributed capacity of choke; desirable ratio of inductance to capacity; frequency of operation; standing wave effect; danger frequencies of choke; types of chokes; modern design for maximum inductance to capacity ratio; series arrangement for minimum capacity with maximum inductance; universal winding; design for very high-frequency operation

23–B. *Power in AC and RF Circuits*—Expenditure and calculation of power; RF resistance, half-deflection method of measuring; power calculation in circuits not operated at resonance; power calculations in high-frequency tube circuits; power output of vacuum tubes; RF losses in transmitter power; effective current and voltage distribution; circuits

24—B. *Radio Frequency Measurements*—Design of RF Driver; measurements of fundamental frequency of coils and circuits; distributed capacity of coils; true and apparent inductance; calibration of condensers and measurement of capacity; heterodyne frequency meter, operation and use in calibrating transmitters and receivers; signal generator, design, requirements, use

25—B. *Radiation Theory*—Relations of moving magnetic and electric fields; phase relations, time element, induction field, radiation field, components of fields; velocity of propagation of energy; wave-length; power input; frequency and percentage of output flat top; effective height; directional effects; components of effective resistance, ohmic, dielectric, eddy current, corona, radiation resistance

26—B. *Radiating Systems*—Antennas, grounded, Hertz, half-wave; harmonic operation; tuned feed circuits; current and voltage feed; untuned matched impedance transmission lines, design and calculations; vertical radiators, guyed and self-supporting, mode of operation, field patterns; directional antennas, theory and practice; broadside antenna with reflector

27—B. *Receiving Antennas*—Absorption, skip distance, fading; effect of frequency variation; Kennelly-Heaviside layer; skip distance; refraction and reflection of energy; phase relations of sky and ground waves; types of fading; echo signals; receiving antennas, directional and non-directional, noise reduction types, modern antennas for all-wave reception, transmission lines; automobile antennas

1–C. *Measurement of Antenna Constants*—Effective resistance; fundamental frequency; effective capacity; calculation of distributed inductance; effective height; reactance measurements; typical curves for vertical radiators; field strength measurements, patterns; antenna efficiency calculations

2–C. *The Vacuum Tube, Electron Emission*—Atomic and electron evaporation; physical laws governing emission; advantages and disadvantages of tungsten, oxide-coated and thoriated filaments and emitters; indirect heaters; secondary emission, grid and plate; materials used in plate and grid constructional power requirements for emission; the two-element tube; formation of space charge around emitter; filament and plate saturation curves, causes and limiting factors; AC filament heating, center tap for filament transformer; anode materials, adsorbed gases, radiation emissivity, mechanical properties, electrical conductivity, etc.; water-cooled anode

3–C. *Tube Rectifiers*—Half- and full-wave rectifiers; polyphase rectifiers; high-vacuum high-power rectifier tubes, operating characteristics and circuit requirements; hot cathode mercury vapor rectifiers; effects of gas pressure and temperature on neutralization of space charge; operating voltage and inverse peak voltage; full-wave four-tube bridge rectifier; full-wave three-phase rectifier; filter design; cut-off frequency, wave form, ripple component, load requirements, L and C calculations; complete calculations for three-phase half-wave rectifier and filter-plate supply for broadcast transmitter

4–C. *Theory of the Triode Tube*—Voltage drop between plate and cathode; effects of positive, zero and negative grid on space charge, plate current, internal resistance and grid current; reverse grid current; grid construction; factors determining *u* and plate resistance; static and dynamic Eg-Ip curves; AC components in plate and grid circuits; determination of *u* from characteristic curve; mutual conductance (transconductance), derivation and use; tube input impedance, discussion of equivalent circuit, and effects of load impedance, interelement capacity, circuit adjustment, etc., on input impedance; receiver power supplies, transformer requirements, filter calculations, rectifier tubes; voltage divider circuits, voltage required in receivers and how obtained; study of complex resistance network in broadcast receivers

5—C. *Methods of Obtaining Grid Voltages*—Bias points for Class A, B, AB and C operation; effect of variable *u* construction on required bias; fixed- and self-bias; bias cells; cathode bias resistor calculations; large filter capacity for fixed- or self-bias; grid-leak bias, excitation voltage, IXc, IXL, IR drops; excitation for various types oscillators and amplifiers; calculations

6—C. *The Vacuum Tube as an Amplifier*—Complete analysis of AC components of voltages and currents in the grid and plate circuits; how the various factors, excitation, length of Ip curve, grid bias, plate voltage, load impedance, etc., affect the power output, efficiency and distortion factors; load line analysis of amplifier operation; Class A, B and C amplifiers, characteristics, efficiencies, power ratios, and uses; complete calculations for required load, power output and harmonic distortion

7—C. *The Screen Grid Tube*—Advantages over triode; construction of transmitting and receiving SG tubes; interelement capacities; Eg-Ip characteristic; secondary emission from plate; interstage coupling, both broad and sharply peaked; shielding requirements; use in receivers; the pentode; element arrangement; how suppressor grid reduces effect of secondary emission; load line and power output; power sensitivity comparison; RF and power pentodes

8–C. *Design of Output Circuits for Transmitter Power Amplifiers*—The linear amplifier and advantages from transmitter, controlling audio distortion, permissible limits of radio-frequency harmonics and how controlled by plate tank circuit design, calculation of tube efficiency, KVA/KW ratio limits and what determines the proper ratio, calculation of second and third harmonic components in tank circuit and method of reduction, antenna design to limit harmonic radiation, effect of modulation frequency range and RF operating frequency on permissible KVA/KW ratios, calculations of power output, efficiency, tank circuit design, antenna design, and tube voltage requirements; push-pull operation and circuit calculations; coupling to the antenna, calculations; adjustments for linear output

9–C. *Frequency Multiplying—The Vacuum Tube as a Detector*—Natural and forced harmonics, development of harmonics, the crystal calibrator, use of oscillator harmonics as test frequencies, frequency multipliers for power operation, doublers and triplers; detector action (demodulation), necessity for modulation before detection, types of modulation, small signal-plate detection, grid-leak and condenser detectors, operation, advantages and disadvantages of each, the first detector of a superheterodyne; power effect of high-percentage modulation, operation percentage modulation, practical ratios and values of grid leak and condenser; diode detection, advantages, disadvantages, operation

10—C. *Multi-Element Tubes—Special Tubes*—Receiver developments and their special tube requirements, automatic volume control, superheterodyne mixer requirements, Class B audio amplification, diode detection, AVC and audio amplification, push-pull amplification; advantages of using special tubes, various tube series with respect to emitter power requirements and uses; variable *u* tubes, operation and uses; Class B and audio amplifiers, operation and uses; duplex-diode triode and duplex-diode pentode, operation and curves for each series; metal tubes, characteristics, operation, advantages, tube types

11—C. *Ultra-High Frequency Tubes*—Limitations of conventional tubes at high frequencies; effects of tube capacity; effects of electron transit time; conventional oscillators, limitations, voltage ratings, special tube design; special receiving tubes, 594 and 955, pentode and triode, uses and circuits; Barkhauses-Kurz or positive grid oscillations, modes of oscillation, types of tubes, special construction, frequency ranges, power output and efficiency; Lecher systems for tuning and measurements

12—C. *Complex Notation, Part I*—Introduction; the real number; the imaginary number; the complex number; application of the operator J; impedance in the complex form; addition and subtraction of complex numbers; multiplication and division in the rectangular form; applications to problems

13—C. *Complex Notation, Part II*—Impedance in the polar form; translation from polar to rectangular and rectangular to polar form; multiplication in the polar form; division in the polar form; proof of the equivalence of forms; evolution and involution of complex numbers; the slide rule in coordinate transformation; power determination with complex quantity notation; applications to the series and parallel circuits; exercises

14–C. *The Cathode Ray Tube and Its Applications to Radio*—Oscillographs; origin of cathode-ray tube, and development; theory of operation; deflection of ray, electro-static and magnetic; the fluorescent screen; deflection voltages; sweep voltage and the sweep circuit; uses of the cathode ray oscillograph, voltage and current measurement, wave-form analysis, checking distortion, measuring percentage of modulation; construction of tube, fluorescent screen, electron gun, methods of focusing, deflection mechanism and deflection sensitivity, practical circuits and operation

15–C. *Oscillator and Neutralizing Circuits*—Production of oscillations, zero and negative circuit resistance; Armstrong oscillator, Hartley, fundamental, tuned plate, tuned grid; Colpitt's oscillator, use, calculations of circuit constants, feed-back adjustments; electron-coupled oscillator, circuit, uses, advantages, modifications; oscillator tank circuit design and coupling; excitation and bias voltages; tube capacity, neutralizing circuits, Hazeltine, Rice, Miller, push-pull circuits, theory and operation of each, adjustments, when to use

16–C. *Crystal Control of Radio Frequencies*—Advantages of crystal control; theory of the operation of crystal in controlling frequency; Piezo-electric effect; types of crystals having Piezo-electric properties; axii of crystal; methods of cutting crystal; relation between frequency and dimensions of crystal; circuit to be controlled by crystal; adjustments of circuits; power obtainable in crystal-controlled circuit; method of keying a crystal-controlled transmitter; crystal current and effects of excessive current; care of crystal; crystal holder;

effects of temperature on the frequency of crystals; AT cut crystals

17–C. *Receivers, Radio Frequency, Amplification, General Considerations*—Broadcast receiver-design trends, all-wave, high-fidelity, etc.; factors in design, type of circuit, amount of gain required, sensitivity, calculation of required RF gain, practical limits of sensitivity, noise, thermal-agitation, tube noise, practical typical values, methods of minimizing; superheterodyne circuit, advantages, principal production of beat frequency, methods of mixing, first detector, pentagrid converter, coupling; image frequency suppression, RF gain; IF gain; IF, selectivity, fixed and variable; the coil and circuit arrangements, all-wave circuits; the oscillator circuit, oscillator padding; typical modern receiver circuits

18–C. *Radio Frequency Amplification, Receivers*—Actual gain calculations and factors entering into calculations; tube factors, *u*, Gm, Rp; tuned circuit factors; L, C, R, Q, M, importance of each; calculations of actual RF resistance of coils at various frequencies, accuracy and limitations of calculations, advantages of Litz wire; RF gain with triode, coupling M, actual calculations at various frequencies, gain may exceed *u*, selectivity as determined by M and Q, selectivity of several stages; screen-grid tubes and RF pentodes, extensive calculations, optimum and practical values of M, practical gain and factor affecting, gain at high frequencies; IF gain and selectivity, effects of M and Q, band-pass coupling; iron-core IF transformers, advantages, construction, permeability and Q obtained, comparison with air core

19–C. *Audio Frequency, Amplification*—Amount of gain required, output power level in decibels, negative power levels of input in decibels, extensive calculations, inputs from microphone, broadcast receiver and pickup; determination of amplifier gain, single tube, push-pull; triodes and pentodes; push-pull amplification, advantages, minimize second harmonic distortion, output; Class B audio amplifiers, calculations of output and efficiency, comparison with Class A, types of tubes desired, excitation required, input and output transformers; impedance matching; tone control, frequency compensation, bass control and ABC, circuits and principle of operation; types of audio amplifiers, discussion of characteristics, limitations and frequency response

20—C. *Special Receiver Circuits*—Detailed explanations of the following special receiver circuits: automatic volume control, delayed AVC, automatic noise suppression, volume expander, automatic frequency control

21—C. *Design Features and Adjustments of Transmitter Circuits*—Coupling to the antenna, inductive, capacitive, arrangements, adjustments, advantages, disadvantages of each; minimizing harmonic transfer to antenna; transformer and tank-circuit methods of antenna coupling; use of high and low resistance antennas, coupling adjustments; coupling over wide frequency ranges; use of transmission line, single wire, balanced two-wire, concentric tube line, calculation of surge impedance; coupling transmission line to transmitter and to antenna, harmonic suppression; push-pull operation of power tubes, methods, adjustments, advantages, disadvantages; operating power tubes in parallel; factors in excitation of various tubes and stages, over and under excitation; circuit design to prevent excessive selectivity, L/C ratios, added resistance, ratios of L, C and R

22—C. *Modulation*—Modulation defined; methods of modulation; Heissing system; percentage of modulation; 100 per cent modulation; advantages of high-percentage modulation; modulating the oscillator, advantages and disadvantages; modulating the intermediate amplifier, advantages and disadvantages; modulating power amplifier; high and low level modulation, advantages and disadvantages; maximum undistorted modulated output; adjustments of input level to prevent distortion; sources of distortion; signal level adjustments of remote control operator; line frequency characteristics and their correction

23—C. *Line Terminal and Input Equipment*—Transmission unit, power, voltage and current ratios; impedance matching; attenuation pads, design, and use; H and T type pads; line equalizers; the mixing panel; volume control, design, use, calibration in transmission units.

Final Examination

Audio and Acoustical Engineering

In broadcasting, high-fidelity amplification and proper design of studios is becoming of greater and greater importance. This series of lessons will prepare the engineer to handle practical problems arising in the design and installation of audio and acoustical systems.

1—D. *Audio Frequency Amplifiers*—Analysis of operation and design; classification; distortion in amplifiers, frequency, amplitude, phase; analysis of amplifier operation; resistance-coupled, analysis, equivalent circuits, maximum gain, low-frequency gain, high-frequency gain, practical problems in calculation of gain, design of resistance-coupled amplifiers; curves showing effect of variation of circuit constants, multistage amplifiers

2—D. *Audio Frequency Amplifiers*—Impedance-coupled amplifiers, study of equivalent circuits, maximum gain, low-frequency gain, high-frequency gain, design of impedance-coupled amplifier, advantages and disadvantages; transformer-coupled amplifiers, analysis of operation, general equations and equivalent circuits, calculation of gain at all frequencies, calculations and plotting of gain curve in volts and in decibels, study of factors limiting low, intermediate and high-frequency gain, design of transformer-coupled amplifier; audio-frequency transformers, comparison with power transformers, factors of design, actual characteristics of high-grade transformer, turn ratio

3—D. *Power Amplifiers*—Basic equations, power output calculations, comparison of power amplifiers and voltage amplifiers, calculations of grid bias and excitation voltages for various values of plate voltage and load impedance; calculations for load impedance, undistorted power output, operating efficiency; maximum plate efficiency and relation to load; output vs. input; power tubes; operation of tubes in parallel; impedance matching; push-pull operation, cancelation of even harmonic distortion, plate circuit, input circuit; beam-power amplifiers, tube characteristics, circuit requirements

4—D. *Loudspeakers (Reproducers)*—Sound velocity of transmission, sound waves, characteristics of the ear, loudspeaker requirements, efficiency, types of driving units, moving iron, dynamic field construction for various purposes, voice coil construction, methods of energizing field, the cone; speaker baffles, requirements, calculations of necessary dimensions, types of baffles, horn reproducers, shape, exponential horn, calculation of dimensions for desired low-frequency cut-off, design problem, horn units, tweeters; setting stage horns for proper sound distribution, types of theaters and graphic illustrations of sound distribution, calculation of number of horns needed; multiple speakers, connections, use of impedance matching transformers

5–D. *Microphones*—Types of microphones, factors determining the proper selection of a microphone, sensitivity of various types; single-button carbon, principle of operation, frequency response, sensitivity, circuit; double-button carbon, operation, frequency response, circuit, resistance, operating precautions; similar data on the condenser, moving coil (dynamic), ribbon (velocity), and crystal microphones, advantages and disadvantages of various types, necessary amplifiers and location of amplifiers, matching of impedance, fader circuits, use of directional and non-directional microphones

6–D. *Studio and Auditorium Acoustics*—Studio requirements, location, lighting, air conditioning: design proportions, construction, optimum reverberation time for studios and auditoriums, calculation of reverberation time, echo, dead spots, sound absorption materials, absorption coefficients, selective absorption, effect of audience on reverberation time; proper placement of corrective, materials, effects of noise level, attenuation of walls, doors and observation windows; use of manufacturer's service

Broadcast Transmission Engineering

This important series of lessons will give the student an excellent idea of standard commercial broadcasting practice at both high and low power.

1–E. *General Discussion* of the characteristics of modern transmitters, circuit classifications, trends in design, radiating systems, field patterns, types of radiators; RF circuit arrangements

2–E. *Speech Control Equipment*—A discussion outlining the requirements of such equipment, apparatus necessary, typical installations, etc.

3–E. *Low Power Broadcast Transmitter*—A complete circuit and explanation of the operation of a 100-watt transmitter of a leading manufacturer

4–E. *High Power Broadcast Transmitters*—Special features of high-power (50-kw and up) broadcast transmitters, theory, practice, adjustments of Doherty high-efficiency RF amplifier; general discussion of late model transmitter

5–E. *Power and Control Circuits*—Detailed explanation of typical power rectifier unit and power and safety control circuits of modern high-power transmitter; function of each part of circuit explained

6–E. *A Typical 1-Kw Transmitter*—A detailed discussion of a typical 1-kw transmitter of a leading manufacturer; the discussion includes both power and RF circuits, with each part explained

Aircraft and Navigational Radio

This series of lessons will be invaluable to all students who work with aircraft radio, and marine, aircraft and airways direction finders and radio navigation.

1–F. *Radio Aids to Air Navigation*—A detailed discussion of the "radio range" provided by the Bureau of Air Commerce, U.S. Government; the "aural" range is taken up in great detail

2–F. *No. 1 Continued*—Vertical radiators as used by the airways; a detailed discussion of the "visual" range; artificial lines and their calculations, and the phasing of radiators are discussed in considerable detail

3—F. *Aircraft and Ground Station Transmitters*—A discussion of typical transmitters used for two-way operation with aircraft and for point-to-point work

4—F. *Aircraft Receivers*—Receiving equipment as used on planes and at ground stations; typical installations and apparatus

5—F. *General Discussion* of the problems of installation and maintenance of radio equipment employed in commercial airways service

6—F. *Radio Direction Finders, Part I*—General discussion, RDF systems, directive properties of antenna, loop antenna, theory and equations of loop, deviation, causes and methods of reducing deviation, practical RDF circuits, use of RDF for direction and position finding

7—F. *Radio Direction Finders, Part II*—Bellini-Tosi RDF, principles of operation, advantages and disadvantages, errors and methods of correction; high-frequency direction finders; problems peculiar to high frequency; Adcock system; advantages at high frequencies; aircraft RDF, general discussion; automatic RDF

Advanced Mathematics

1—G. *Solution of Simultaneous Linear Equations with Special Application to Kirchoff's Laws*—The use of determinants; graphs and functions, the graph defined, the function defined; suggestions for drawing graphs, the uses of the graph, finding rates, interpolation, average values, maxima and minima, solving equations; the linear function, general form for the equation of the straight line, writing the equation for the straight-line graph

2–G. *The Exponential Function*—Plotting exponential functions, the logarithmic function, plotting the logarithmic function; log-log and semi-log graphs; empirical formulas, the relation of algebra and geometry, linear, parabolic, hyperbolic and exponential functions discovered from empirical data, trigonometric functions, plotting of combined functions, polar coordinates with emphasis on antenna directivity patterns

3–G. *Differential Calculus*—A study of the practical use of differential calculus, development of formulas, and examples of their use in electrical problems; exercises

4–G. *Integral Calculus*—A study of the practical use of integral calculus, development of formulas, and examples of their use; exercises; where possible the problems apply directly to radio or allied fields

1–H. *Fundamental Ideas*—Relation of television to radio, background of television and facsimile transmission, modern facsimile systems, uses, possibilities, relation between television and facsimile, television image and half-tone print, requirements for good picture, experimental problems, high-frequency transmission, persistence of vision

2–H. *Photoelectric Cell Light*—Photoelectric effect, experimental background, voltages, photoelectric substances; nature of light, frequencies and colors, wave-lengths, sources of light for television, units of light, fundamental calculations, electron emission and relation to light, sensitivity curves with relation to color for various materials, use of light filters, ultra-violet and infra-red light; vacuum and gas-filled types, cell current and output-load voltages, curves for various types of cells with various loads, advantages of gas and vacuum types, photocell equations and calculations compared with radio vacuum-tube work, photo-cell characteristics, construction, types, problems in television photo-cell operation

3–H. *Optical Systems—Mirrors and Prisms*—Control of light, reflection of light, plane mirror, diffused light; spherical mirrors, concave and convex; focal length, calculations, real and virtual images, parabolic mirror; prism, refraction of light, the prism as a reflecting mirror; Nichol prism, polarization of light, construction, use in television; light transmission through quartz rod

4–H. *Optical Systems—Lenses*—Use in light projection and condensing; types, double convex, plano-convex, converging concave-convex, double concave, plano-concave, diverging concave-convex; center of curvature, principal axis, principal focus; spherical aberration; formation of image, combinations of lenses, uses, care, handling, condenser and projection combinations; lens requirements for television cameras

5–H. *Cathode Ray Tubes*—Principle of operation, development, fluorescent screen, duration of spot, electron gun, production of ray, methods of deflection, magnetic and electric, velocity of deflection, saw-tooth scanning and reasons for, focusing of beam by proportioning of fields, deflection calculations, minimizing flicker, RCA Kinescope, sizes of tubes, power and voltage requirements; projection type tubes

6–H. *Scanning in Television*—Necessity for scanning, mechanical scanning, Nipkow disc, need for synchronism, disadvantages of mechanical scanning, direct and indirect scanning methods, speed, lens requirements; electronic scanning, advantage of cathode-ray tubes; RCA Iconoscope, principle of operation, construction, outstanding advantages, diagrams; Farnsworth "image dissector," diagram, principle of operation, "electron multiplier"

7—H. *Synchronization*—Picture aspect ratio, number of lines and pictures per second, synchronism of mechanical scanning systems, circuits; synchronism with cathode-ray systems, vertical and horizontal synchronizing voltages and frequencies; Iconoscope synchronization, return of ray during "dark" period, RCA experimental systems, square-top signals, signal filters, amplification of synchronizing signals, relaxation oscillator, saw-tooth amplifier, circuit of complete system with explanation

8—H. *Studio Control Circuits*—General circuit arrangement, including video preamplifier; voltage amplifier and line amplifier, shading panel, Iconoscope blanking voltage generator, pedestal generator, synchronizing impulse generator, horizontal and vertical deflection voltage generators, monitors, synchronizing generator, multivibrator chains and circuits of individual units

9—H. *Video Amplifiers*—Problems in video amplification, wide frequency response, gain, tube types, impedance matching, design calculations; coaxial cable and its use in video transmission

10—H. *Special Characteristics of Television Receivers and Transmitters*—A discussion of the present-day experimental types considering necessary band width, separation of video and audio signals, modulation methods, transmitter problems at frequencies involved, and other related factors

International Correspondence Schools

This institution offers a home-study course involving three features which make it possible for a student to become proficient in the subject or subjects in which he is interested. First, each lesson of the course is prepared with the thought that it combines the functions of a text and of an instructor. Second, as many lessons as are needed for the mastery of a given subject are included in the course and arranged in such a way that the student can proceed with the next lesson when he masters the one before it. Third, the student's knowledge of each lesson is determined by means of an examination, and helpful corrections and suggestions are given to keep him on the right track.

The study texts of these courses are prepared by experts in the field—men with good technical training and a lot of practical experience in the particular subject which they cover. The material received from the experts is carefully edited by men trained in I.C.S. work in order to make it suitable for home-study purposes. Each text is further clarified by a liberal use of illustrations.

The checking of students' work is done by specially trained instructors under the supervision of a principal to whom all special problems are referred. The work submitted by the student is carefully corrected and properly graded. A passing grade (A, B, or C) warrants the student to proceed with the next lesson. Inferior work makes it necessary for the student to review a portion or all of his lesson and submit additional work on questions selected by the instructor. The student's previous training and experience as well as his work on his course all form part of his record, which is at all times available to those who are responsible for his training.

When the student completes his course and does satisfactory work on the final examination, he is awarded a diploma. Investigation shows that an I.C.S. diploma has helped many graduates to gain promotion in their chosen line of work. It has also helped many to enter fields which without the training would have been closed to them.

The Educational Department of the International Correspondence Schools consists of a number of schools each of which is under the supervision of a director. The faculty of the I.C.S, which includes all directors, principals, and assistant principals, is headed by the dean of the faculty, who with the aid of the deans of the schools of technology and business determines the educational policies of the schools.

The Radio School of the International Correspondence Schools is responsible for the preparation of texts pertaining to radio as well as for all educational service to students enrolled in radio courses. A brief description and the list of lessons of each course follows.

General Radio Course—This covers the entire radio field and in particular such branches as radio operating, radio servicing, sound work, facsimile, and television. The fundamental instruction—mathematics, electric theory, radio principles—is more advanced than is generally the case in a home-study course. The practical instruction has been selected with the thought of rendering the greatest service in the branches most prominent in the radio industry. An important part of the course is the section on drawing—17 lessons—which is a valuable asset to every radio technician. The General Radio course is recommended to the student who wants all that there is to be had in a home-study course and who is earnest and ambitious enough to undertake the task of building a radio career.

Subjects:

- Arithmetic
- Elements of Algebra
- Trigonometry and Graphs
- Logarithms
- The Slide Rule
- Mechanics and Machine Elements
- Diagnosis of Receiver Troubles
- Voltage and Current Tests
- Point-to-Point Resistance Tests
- Alinement of Tuned Circuits
- Cathode-Ray Oscillograph in Radio Service

- Elementary Chemistry
- Electricity and Magnetism
- DC Calculations
- Alternating Currents
  - Complex Quantities in AC Calculations
- Sound and Acoustics
- Principles of Radio Communication
- Radio Tubes (with Tube Tables)
- Theory of Radio Receivers
- Vacuum-Tube Amplifiers
- Vacuum-Tube Oscillators
- Methods of Testing Vacuum Tubes
- Batteries and Power Converters
- Audio Voltage and Power Amplifiers
- Microphones and Loud-speakers
- Public-Address and Centralized Radio Systems
- Sound-Picture Recording
- Sound-Picture Projection
- Tuned R-F Receivers
- Superheterodyne Receivers
- Short-Wave and Long-Wave Receivers
- Antenna and Receiver Installations
- Automobile Radio Installation and Service
- Electrical Measurements in Radio Servicing
- Elimination of Radio Interference
- Theory and Construction of DC Motors and Generators
- Alternators
- Transformers
- Alternating-Current Motors
- Synchronous Converters and AC Rectifiers
- Electrical Meas. Instruments
- Storage Batteries
- Design of Magnets and Electro-magnets
- Design of Transformers
- Codes and Code Practice
- Radio Antennas
- Undamped-Wave Radio Communication
- Radio Telegraph Transmitters
- Radio Telephone Transmitters
- Facsimile Transmission and Reception
- Principles of Television (in preparation—)
- Police and Aviation Ground Station Transmitters
- Broadcast Transmitters
- Radio Transmitters for Telephone and Telegraph
- Wavemeters and Frequency Monitoring Units
- Point-to-Point Communication
- Geometrical Drawing
- Elements of Projection Drawing
- Mechanical Drawing

Radio Operating Course—The Radio Operating course differs from the General Radio course in that the practical instruction is confined only to subjects which are of interest to the student desirous of obtaining an operator's license. The course will be found helpful to those who wish to become commercial or broadcast operators and for those operating radio equipment in aviation or in police departments.

Subjects:

- Arithmetic
- Formulas
- Trigonometry and Graphs
- Logarithms
- Mechanics and Machine Elements
- Electricity and Magnetism
- The Slide Rule
- DC Calculations
- Alternating Currents
- Sound and Acoustics
- Principles of Radio Communication
- Radio Tubes (with Tube Tables)
- Theory of Radio Receivers
- Vacuum-Tube Amplifiers
- Vacuum-Tube Oscillators
- Methods of Testing Vacuum Tubes
- Batteries and Power Converters
- Audio and Power Amplifiers
- Microphones and Loudspeakers
- Tuned R-F Receivers
- Superheterodyne Receivers
- S-W and Code Practice
- Radio Antennas

Radio Operating—18 *lessons, as follows*:

- Review of Elementary Electricity
- Motors, Generators, Storage Batteries
- Electron Tubes in Transmitters
- Amplifiers in Transmitters
- Oscillators in Transmitters
- Modulation Systems
- Studio and Control-Room Apparatus
- Frequency Measurements
- Antenna Measurements
- Broadcast Transmitters
- Marine-Radio Telegraph Transmitters
- Aircraft and Police Radio
- Marine-Radio Direction Finders
- Radio in Aircraft
- U.S. Auto Alarms
- General Radio Regulations
- FCC Rules and Regulations
- Aeronautical Procedure
- Facsimile Transmission Reception
- Principles of Television (in preparation—3 lessons)
- Radio Along the Airways
- The Airplane—A Mobile Radio Station
- The Duties of Aviation Radio Men
- Aviation Radio Communication
- Aviation Radio Power Equipment
- Bonding the Airplane
- Shielding the Ignition System
- Installation of Aviation Radio

Sound Technician's Course—The Sound Technician's course includes all the lessons of the General Radio course which are of interest to the student of sound-reproducing equipment. This includes broadcast and short-wave receivers, sound amplifiers, and electric phonographs. Instruction on television and facsimile is also included.

Subjects:

- Arithmetic
- Elements of Algebra
- Trigonometry and Graphs
- Logarithms
- The Slide Rule
- Mechanics and Machine Elements
- Elementary Chemistry
- Electricity and Magnetism
- DC Calculations
- Alternating Currents
  - Complex Quantities in AC Calculations
- Sound and Acoustics
- Principles of Radio Communication
- Radio Tubes (with Tube Tables)
- Theory of Radio Receivers
- Vacuum-Tube Amplifiers
- Vacuum-Tube Oscillators
- Methods of Testing Vacuum Tubes
- Batteries and Power Converters
- Audio and Power Amplifiers
- Microphones and Loudspeakers
- Public-Address and Centralized Radio Systems
- Sound-Picture Recording
- Sound-Picture Projection
- Tuned R-F Receivers
- Superheterodyne Receivers
- Short-Wave and Long-Wave Receivers
- Antenna and Receiver Installations
- Automobile Radio Installation and Service
- Electrical Measurements in Radio Servicing
- Diagnosis of Receiver Troubles
- Voltage and Current Tests
- Point-to-Point Resistance Tests
- Alinement of Tuned Circuits
- Cathode-Ray Oscillograph in Radio Service
- Principles of Television (in preparation—3 lessons)
- Elimination of Radio Interference

Sound-Picture Projectionist's Course—This course is made up of lessons which are of special interest to the projectionist who wants a better knowledge of sound-amplifying equipment. Its purpose is to provide practical instruction on the amplifying equipment and its components as used in motion-picture theaters.

Subjects:

- Arithmetic
- Formulas
- Trigonometry and Graphs
- Logarithms
- Mechanics and Machine Elements
- Elementary Chemistry
- Electricity and Magnetism (2)
- Sound and Acoustics
- Radio Tubes (with Tube Tables)
- Vacuum-Tube Amplifiers
- Methods of Testing Vacuum Tubes
- Batteries and Power Converters
- Audio and Power Amplifiers
- Microphones and Loudspeakers
- Public-Address and Centralized Radio Systems
- Sound-Picture Projection
- Sound-Picture Recording

Practical Radio Servicing Course—This course is recommended to the student who wants to be a good service technician. With its practical lessons, job sheets, service instruction, and Trouble Shooter's Manual, the course will enable one to do efficient work in a comparatively short time. Many use their servicing knowledge and experience as a start in a radio business.

Subjects:

- Direct-Current and Ohm's Law
- Direct-Current Networks
- Magnetism and Electromagnetism
- Radio Job Sheet
- Theory of Alternating Currents
- Inductance and Capacity
- Resonant Electrical Circuits
- Radio Job Sheet
- Transformers in Radio Receivers
- Motors and Generators
- Sound and Acoustics
- Radio Job Sheet
- Principles of Radio Transmission
- Theory of Radio Tubes (and Charts)
- Radio Receiving Systems
- Radio Job Sheet
- Superheterodyne Receivers
- Short-Wave and Long-Wave Receivers
- Antenna and Receiver Installations
- Practical Electrical Wiring
- Automobile Radio Installation and Service
- Electrical Measurements in Radio Servicing
- Diagnosis of Receiver Troubles
- Voltage and Current Tests
- Point-to-Point Resistance Tests
- Alinement of Tuned Circuits
- Perpetual Trouble Shooter's Manual
- Cathode-Ray Oscillograph in Radio Service
- Radio Sales and Advertising
- Principles of Television

- Batteries and Power Converters
- Audio Voltage and Power Amplifiers
- Microphones and Loudspeakers
- Tuned Radio-Frequency Receivers
- Public-Address and Centralized Radio Systems
- Elimination of Radio Interference
- Facsimile Transmission and Reception

Chapter XII

COLLEGE TRAINING

Engineering

There are more than 150 colleges in the United States and Canada which offer complete courses in engineering leading toward a degree. These are listed at the conclusion of this chapter to facilitate ready reference.

The problem of choosing a college is difficult in most cases, and should not be attempted without the proper counsel. Many young men may choose a particular college solely because of the popularity of the name associated with it. This may prove erroneous, since there are many colleges with relatively obscure names which offer splendid curricula leading to a degree in electrical engineering. Here once more it is important to consult competent educators and men actively engaged in the engineering profession for constructive information. Be sure to weigh their advice thoroughly, but take care not to jump to any quick conclusions. Some engineers would be very apt to recommend their own alma mater for traditional reasons only, without regard to the particulars involved. The school in question may have a very high academic ranking, but this does not mean that it will supply the information required for electrical or radio engineering. True, any recognized college or polytechnic institute will give a thorough mental training in preparation for the engineering profession, but it may not have a suitable curriculum for the specialized branch of radio engineering. Many factors may enter into the picture of proper choice far beyond the ability of this author to outline.

There are, however, some important considerations with which the author has had experience. In some twenty-five years as an instructor and practical engineer many engineering and educational contacts have been formed. These associations have enabled a rather practical deduction of the problems involved, and they may serve as some aid in the final solution of the young man's problem.

The most important of these is the reputation of the college or the institute in the engineering profession. How does it rate in the mind of the employer? This most emphatically does not imply any inferior standard of learning, but it does have an important bearing on the final choice. Of course, there are many engineering employers who are interested only in the training, regardless of the college in which it was received. This is as it should be, since many prominent engineers have obtained their knowledge in the smaller institutions.

Another important consideration is the broad opinion of the engineering profession as to which of the colleges have the highest ranking in this particular branch of engineering. The author has consulted many educators and engineers on this question for a number of years. The majority of these men, it was observed, listed certain colleges as their Class A choices, even though they themselves were graduates of other institutions. Their choice was based upon broad experience, engineering and educational contacts.

Another important consideration for the young man is the college outlet. To what industrial or research organizations do some of the colleges send their graduate students? Do certain large industrial organizations have a leaning toward certain colleges? The former question can be answered by the college that the young man has elected. The latter is substantially true and depends upon two primary factors: (1) the employer's preference, due to traditional affiliations; (2) the employer's preference, due to past employment experience.

In some cases the choice of a specific college by an industrial organization may be due to endowment affiliations. In any event, these factors are of some importance and may be taken for what they are worth.

Before the young man plans his college career it is of course necessary that he complete his preliminary education—high school or preparatory school. This also is a very important choice, since it is the molding pot for good engineers. If the young man is definitely assured that he intends to make the engineering profession his life work, and if he is in the financial position to do so, then a reputable preparatory school is recommended. If, on the other hand, he must attend the high or secondary school system to complete his preparatory education, he should exercise great care in the choice of his program, so that the proper subjects for a good engineering groundwork are obtained.

Some Recommended Engineering Colleges

Pursuant to the suggestions made in the earlier portions of this chapter relative to the proper choice of college, a number of Class A engineering colleges and their curricula will be outlined. It must, however, be understood that the specific mention of Class A colleges does not imply that these are the only ones in this class. Many other large and small universities are similarly classified. Those outlined are chosen only because of popular opinion expressed by educators and engineers with whom the author has had contact; the opinion here given does not pretend to be based on a national survey.

The object is merely to acquaint prospective engineering students and vocational counselors with the type of knowledge required for a successful career in the radio engineering field. This outline should serve as an effective guide for training personnel in the primary, secondary, and preparatory schools. In all cases, the schools and courses are chosen primarily with this objective in view as well as with specific direction toward the field of radio engineering.

1. Armour Institute of Technology
2. California Institute of Technology
3. Carnegie Institute of Technology
4. Case School of Applied Science
5. Cooper Union
6. Cornell University
7. Georgia School of Technology
8. Massachusetts Institute of Technology
9. Rensselaer Polytechnic Institute
10. Purdue University
11. Washington University
12. Yale University, Sheffield Scientific School

The Cooper Union Institute of Technology

Admission to the First Year—The engineering courses of the Cooper Union are in great demand. Limited facilities permit of admitting less than one-sixth of those who apply. Consequently, it has been found advisable to limit the number of persons taking the entrance examinations to those whose secondary-school records are of sufficiently high caliber to indicate that they have some reasonable prospect of success in these examinations, in which the competition is severe. To be admitted, an applicant must fulfil the following three conditions:

(a) Satisfy the secondary school requirements
(b) Qualify in the Cooper Union entrance examinations, viz., mathematics, English, scientific aptitude, and engineering aptitude

(c) Pass an examination to determine his physical fitness to carry on the work of the course

Secondary School Requirements—Not only must a qualified applicant have graduated from a four-year course in an accredited American high school or the equivalent, but in addition he must show satisfactory credentials of work in 16 units as indicated below.

A form on which his high school can transmit a certified copy of his record will be sent to each candidate when his application for admission has been received at the Admissions Office.

This form should be delivered by the applicant to the office of his high-school principal. When the form has been returned, it will be examined by the Admissions Committee. If the applicant's record meets the entrance requirements with respect to prescribed and elective units and shows evidence of graduation, and also indicates high scholarship acceptable to the Admissions Committee, he will be considered qualified to take the entrance examinations and will be so notified.

Required Units

English (4 years)	4
Algebra (Elementary and Intermediate)	1½
Plane Geometry	1
Trigonometry	½
Physics	1
Chemistry	1
Social Sciences or History	1

Elective Units

Advanced Algebra	½	Botany	½
Solid Geometry	½	Physical Geography	1
Surveying	½	Astronomy	½
Mechanical Drawing	1	Physiology	½
General Science	1	Vocational or Industrial Subjects	1 to 4
Languages	1 to 4	Social Sciences or History	3
Biology	1		
Zoology	½		

A unit, as noted in the foregoing lists, represents a year's study in any subject in a secondary school, and constitutes approximately a quarter of a full year's work in the Institute.

Entrance Examinations—Entrance examinations for the current term will be held on four consecutive afternoons, beginning August 28, as mentioned in the calendar of each year.

The examinations consist of four tests, as follows:

Mathematics—The applicant will be tested on his aptitude for mathematics. The examination will test his facility in arithmetic, in fundamental operations of algebra, and in the theorems of plane geometry and formulas of plane trigonometry. A candidate preparing for this examination would do well to review elementary and intermediate algebra, plane geometry, and plane trigonometry.

English—The applicant will be tested on his ability to read rapidly, and with adequate comprehension, scientific prose of the type encountered in school and college texts in chemistry, physics, mathematics, and other technical subjects. The applicant will be tested on his general and technical vocabulary. Applicants failing to show reading ability in English adequate for college work will not be admitted.

Scientific Aptitude—The applicant will be tested on his ability to visualize and manipulate the third dimension when represented in a plane, and otherwise to show promise of ability successfully to pursue that part of the engineering curriculum represented in the drafting room and laboratory.

Engineering Knowledge—The applicant will be tested on his general engineering knowledge and common sense in simple engineering matters. He also will be tested on his knowledge of what kind of things are included in the field of civil engineering, electrical engineering, mechanical

Curriculum for Electrical Engineering

First Year

First Semester

	Periods per week C*	L*	P*	E*
Descriptive Geometry	2	0	3	5
Engineering Drawing	0	3	1	4
English Composition and Rhetoric	1	0	1	2
General Chemistry	4	3	5	12
Mathematics I	6	0	3	9
Physics	4	3	8	15
Western Civilization	4	0	4	8
Total	21	9	25	55

Second Semester

	Periods per week C*	L*	P*	E*
Descriptive Geometry	1	3	4	8
English Composition and Rhetoric	1	0	1	2
General Chemistry	4	3	5	12
Mathematics II	5	0	4	9
Physics	4	3	8	15
Western Civilization	4	0	4	8
Total	19	9	26	54

Second Year

First Semester

	C*	L*	P*	E*
Calculus	3	0	6	9
Fuels and Combustion	2	0	3	5
Humanities—American Literature or American Government	2	0	2	4
Kinematics of Machines I	2	3	4	9
Physics (Electricity and Magnetism)	3	3	9	15
Principles of Mechanics	3	0	5	8
Total	15	6	29	50

Second Semester

	C*	L*	P*	E*
Calculus	3	0	6	9
Electrical Measurements I	0	3	4	7
Electricity and Magnetism I	3	0	3	6
Humanities—Contemporary Literature or Social and Industrial History of United States	2	0	2	4
Hydraulics	2	0	3	5
Kinematics of Machines II	1	3	2	6
Principles of Mechanics	3	0	5	8
Technical Analysis	0	3	2	5
Total	14	9	27	50

*C—Class.
L—Laboratory or drawing.
P—Normal preparation time.
E—Effort time, measuring scope of course.

THIRD YEAR

First Semester

	Periods per week C	L	P	E
Alternating Current I	2	0	5	7
Direct Current Machines I	2	0	4	6
Economics	2	0	2	4
Electrical Machine Laboratory I	0	3	4	7
Electrical Measurements II	0	3	4	7
Electricity and Magnetism II	2	0	4	6
Heat Power I	2	0	4	6
Mechanics of Materials	2	0	4	6
Total	12	6	31	49

Second Semester

	Periods per week C	L	P	E
Alternating Current Machines I	2	0	4	6
Differential Equations of Electricity	3	0	6	9
Direct Current Machines II	1	0	2	3
Economics	2	0	2	4
Electrical Machine Laboratory II	0	3	4	7
Heat Power	2	0	4	6
Machine Design I	2	1	3	6
Materials and Hydraulic Laboratory	0	3	3	6
Mechanics of Materials	2	0	4	6
Resuscitation	†	0	0	0
Total	14	7	32	53

FOURTH YEAR

First Semester

	C	L	P	E
Alternating Current II	1	0	2	3
Alternating Current IV	1	0	2	3
Alternating Current Machines II	3	0	5	8
Direct Current Machines III	2	0	3	5
Economics–Engineering Applications	2	0	4	6
Electrical Machine Laboratory III	0	4	6	10
Machine Design II	1	3	2	6
Mechanical Engineering Laboratory	0	3	3	6
Social Philosophy Colloquium	2	0	2	4
Total	12	10	29	51

Second Semester

	C	L	P	E
Alternating Current III	3	0	2	5
Alternating Current IV	1	0	2	3
Alternating Current Machines III	2	0	4	6
Economics–Engineering Applications	2	0	4	6
Electrical Machine Laboratory IV	0	4	6	10
Electrical Measurements IV	0	3	5	8
Mechanical Engineering Laboratory	0	3	3	6
Power Plants	2	0	3	5
Resuscitation	†	0	0	0
Social Philosophy Colloquium	2	0	2	4
Total	12	10	31	53

† One period per term.

engineering, and chemical engineering. The tests will be based largely on *Building an Engineering Career*, by C. C. Williams, published by McGraw-Hill Book Co., and *Engineering—a Career and a Culture*, published by the Engineering Foundation, 29 West 39th Street, New York City. Every applicant should carefully study both of these books.

These examinations are designed to indicate intrinsic ability rather than the possession of acquired facts. For this reason it is not possible to prepare for them in the conventional sense of the word.

However, a few months spent in reviewing the necessary mathematics in any good textbook of high-school grade, will be of material assistance to an applicant.

Purdue University

FRESHMAN YEAR

Hours	*First Semester*	*Hours*	*Second Semester*
4	Chemistry	4 or 3	Chemistry Chem. Engr.
3	English	3	English or Speech
2	Engr. Drawing Engr. Lectures	2	Engr. Drawing Engr. Lectures
5	Mathematics	5	Mathematics
1⅔	Military Training	1⅔	Military Training
2	Shop-Surveying	2	Surveying or Shop
17⅔		17⅔ or 16⅔	

SOPHOMORE YEAR

Hours	*First Semester*	*Hours*	*Second Semester*
3	Economics	4	Elem. Elect. Engr.
4	Mathematics	4	Mathematics
1⅔	Military Training	1⅔	Military Training
5	Physics	5	Physics
2	Shop or Descriptive Geom.	2	Descriptive Geom. or Shop
3	Elective	3	English or Speech
18⅔		19⅔	

JUNIOR YEAR

Hours	First Semester	Hours	Second Semester
4	Applied Mechanics	4	Applied Mechanics
5	Elem. AC Theory	3	Electronics
3	Elect. and Mag. Fields	3	Elect. Machinery
3	Thermodynamics	3	Elect. Measurements
3	Elective	3	Heat Engr.
		3	English or Speech
18		19	

SENIOR YEAR

Hours	First Semester	Hours	Second Semester
4	AC Machinery	5	AC Machinery
2	Elect. Meas.	3	Elect. Design
3	Engr. Adm. and Seminar	3	Engr. Adm.
1	Mechanical Lab.	3	Elective
3	Technical Elective	3	Thesis or Elective
6	Elective		
19		17	

Choice should be made of the appropriate number of electives from one of the following groups, although selection from as many groups as desired is permitted.

POWER AND LIGHT

Hours		Hours	
3	Power Trans. and Dist.	3	Power Trans. and Dist.
3	Illuminating Engr.	3	Unbalanced Circuits
3	Thermionic Tubes	4	Hydraulics
3	Transport. Systems	3	Power Plant Engr.
3	Power Plant Engr.	3	Adv. Elec. Machinery
3	Elec. Transients	3	Elec. Ry. Engr.
3	Elec. Power Plants		
3	Electricity Meters		

COMMUNICATION

3	Power Trans. and Dist.	3	Telephone Engr.
3	Telephone Engr.	3	Radio Engr.
3	Radio Engr.	3	Theory of Comm. Ckts.
3	Theory of Comm. Ckts.	3	Thermionic Tube Ckts.
3	Thermionic Tubes		

INDUSTRIAL

3	Automotive Engr.	3	Advanced Automotive Lab.
3	Gas and Gasoline Engines		

3	Power Trans. and Dist.
3	Illuminating Engr.
3	Thermionic Tubes
3	Elements of Acct.
3	Elec. Power Plants
3	Analytic Elec. Engr.
3	Electrical Design
3	Oil Engines
3	Thermionic Tube Ckts.
3	Industrial Engr.
3	Adv. Elec. Machinery

California Institute of Technology

FIRST YEAR, ALL THREE TERMS

	Units per Term
English	6
Physics	12
Chemistry	12
Mathematics	12
History	5
Drawing	3

SECOND YEAR

	Units per Term		
	1st	*2nd*	*3rd*
Mathematics	12	12	8
Physics	12	12	8
Mathematics Review			4
Physics Review			4
History	6	6	6
Surveying		11 or	11
Mechanism	9 or	9 or	9
Materials and Processes		11 or	11
Geology	9		
Descriptive Geometry	3 or	3	
Descriptive Geometry		3 or	3
Engineering Drawing	6 or	6	
Engineering Drawing		6 or	6

THIRD YEAR

English	8	8	8
Applied Mechanics	14	14	14
Engineering Chemistry	9		
Accounting	9		
Direct Currents		9	

Direct Current Laboratory		6	
Alternating Currents			9
Alternating Current Laboratory			6
Differential Equations		9	
Heat Engineering	12		
Hydraulics			12
Mathematical Physics	12	12	12

FOURTH YEAR

	Units per Term		
	1st	*2nd*	*3rd*
Humanities Electives	9	9	9
Current Topics	2	2	2
U.S. Constitution			2
Economics		10	
Business Law	6		
Electrical Machinery		6	9
Electrical Engineering Laboratory			9
Electric Circuits	12		
Engineering Conferences	2	2	2
Electricity and Magnetism	6	6	6
Electrical Measurements	4	4	
Vacuum Tubes		12	
Mechanical Laboratory	9		
Heat Engineering			10
Heat Engineering	12		
Hydraulics			12

Georgia School of Technology

The course of study is planned to give comprehensive training in the fundamental sciences of chemistry, physics, mathematics and applied mechanics. Adequate training is given also in the scientific and applied aspects of important branches of engineering other than electrical, such as constructive materials, steam engineering, hydraulics and hydraulic machinery.

Parallel with the theoretical work are carefully planned laboratory courses, beginning with the first year in chemistry and continuing throughout the four years in the various sciences and engineering branches studied. The laboratory work is so conducted as to enable the student to verify theory by performing fundamental experiments.

The curriculum includes courses in English, economics, the humanities, and public speaking. Every engineer should be able to use effectively both oral and written English. He should also have such training as to give him a sense of social responsibility and make him more useful as a citizen and industrial leader.

In the majority of cases students can complete the electrical engineering course in five years, provided they plan their work with the departments concerned, beginning with the junior year.

FRESHMAN YEAR

First Term

	Credit
Inorganic Chemistry	4
Engineering Drawing	2
Composition and Rhetoric	3
Elementary Functions	5
French, Spanish, or German or Social Science	3
Military or Naval Instruction	1.5
Orientation	—
	18.5

Second Term

	Credit
Inorganic Chemistry	4
Engineering Drawing	2
Composition and Rhetoric	3
Introduction to Engineering	1

Analytic Geometry	5
French, Spanish or German or Social Science	3
Military or Naval Instruction	1.5
	19.5

SOPHOMORE YEAR

First Term

	Credit
Economics	1
Humanities	3
Calculus	5
Physics	6
Military or Naval Instruction	1.5
	18.5

Second Term

	Credit
Accounting	3
Humanities	3
Calculus	5
Physics	6
Military or Naval Instruction	1.5
	18.5

JUNIOR YEAR

First Term

	Credit
Principles of Electrical Engineering	5
Differential Equations	3
Heat Treating Laboratory	1.3
Thermodynamics	2
Industrial Relations	2
Applied Mechanics	3
Mechanics of Materials	2
	18.3

Second Term

	Credit
Hydraulics	3
Laboratory	2.7
Alternating Current Circuits	5
Machine Shop	1
Instruments and Fuels Laboratory	1.3
Power Plant Engineering	3
Applied Mechanics	2
	18

SENIOR YEAR

First Term

	Credit
Seminar	1
Telephony	2
E. E. Laboratory	2.7
Transmission	3
Radio Engineering	3
AC Machinery	5
Power Plant Auxiliaries Laboratory	1.3
	18

Second Term

	Credit
Metallurgy	2
Seminar	1
E. E. Laboratory	2.7
AC Machinery	3
Public Speaking	3
Heat Power Laboratory	1.3
Electives	—
	18

Electives

	Credit
Radio Engineering	3
Radio Laboratory	2
Finance	3
Marketing	3
Business Law	3
Technical English	3

Electrical Engineering—Typical Entrance Requirements

Mathematics

Radio engineering is basically electrical engineering, as we have said before, and all those aspiring to make radio engineering a career *must* have a thorough knowledge of electrical engineering principles.

In order to acquaint young men now preparing for college entrance in this field, a typical entrance examination given in one of the local colleges, together with a first-year examination, is herewith presented.

The author believes that it will serve as a splendid guide and also give a fairly good idea as to the individual's ability of mastering engineering subjects. A careful examination of the entrance questions will indicate the type of mathematical background required *before* entering engineering college.

GEOMETRY

(1) (a) Walking along a straight road a traveler noticed at one milestone that a house was 30° off to the right. At the next milestone the house was 45° off to the right. How far was the house from the road? (b) It requires 41 1/7 rods of fence to inclose a semicircular field. Find the area of the field. Take pi = 3 1/7.

(2) Construct, explaining the method, but without

proof; (a) $x = \sqrt{2ab}$, where a and b represent given lengths. (b) A circle passing through three given points.

(3) A point P is 17 inches from the center of a circle. A tangent from P to the circle is 8 inches long. What is the radius of the circle? (b) The area of an equilateral triangle is 3 sq. units. Find the area of the inscribed circle.

(4) (a) What is the locus of points equidistant from two given intersecting lines? (b) Two circles are tangent internally at a point A. The diameter AB of the large circle cuts the small circle at D. Another diameter, $FMNG$, of the large circle, is perpendicular to AB and cuts the small circle at M and N. If BD is 9 inches and FM is 5 inches, what are the diameters of the two circles?

(5) (a) Find the central angle of a sector whose area is equal to the square of the radius. (b) In a circle of diameter 20, find the area of a segment whose chord is 10.

(6) (a) The angles of a triangle are in the ratio 3:4:11. Find the number of degrees in each. (b) In triangle ABC, angle A is 60°, AB is 7, and angle C is a right angle. If CD is the altitude on AB, find the length of DB.

(7) (a) The base of a triangle is 20 ft.; the other sides are 16 ft. and 10 ft. A line parallel to the base cuts off 2 feet from the lower end of the shorter side. Find the segments of the other side and the length of the parallel. (b) If the side of one equilateral triangle is equal to the altitude of another, what is the ratio of their areas?

(8) (a) Prove that the line joining 6 and 9 on the clock face is perpendicular to the line joining 2 and 7 o'clock. (b) Complete the following statements: The area of a trapezoid is equal to .... The area of a regular polygon is equal to .... An angle between a tangent to a circle and a chord drawn from the point of contact is measured by .... The angle at a vertex of a regular polygon of n sides is equal to ....

(9) (a) A swimming pool is 60 feet long, 20 feet wide, 3 feet deep at one end and 8 feet deep at the other; find the area of the bottom of the pool. (b) A right triangle

has sides 20 and 21. Find the length of the median on the hypotenuse.

(10) (a) A village has two standpipes of the same height, one 10 feet in diameter and the other 16 feet in diameter. What should be the diameter of a new standpipe of the same height which can replace the two original ones? (b) Two tangents to a circle are perpendicular to each other. A point on the circumference, included between the tangents, is 8 inches from one tangent and 9 inches from the other. Find the radius of the circle.

ALGEBRA

(1) Factor (a) $3x^2 + 5x - 12$ (b) $(a^2 - ab^2)^2 - (ab - b^2)^2$ (c) $x^2 + y^2 + abx - (2x + ab)y$

Find the l.c.m. of

$$2m^2 + mn - 10n^2,\ 4m^2 - 25n^2, \text{ and } m^3 - 8n^3.$$

(2) Simplify:

(a) $\left(a^2 + \dfrac{b^4}{a^2 - b^2}\right)(a^2 + b^2) \div \left(\dfrac{a}{a+b} - \dfrac{b}{b-a}\right)$

(b) $\dfrac{\dfrac{x}{y} + \dfrac{y}{x}}{\dfrac{x}{y} - \dfrac{y}{x}} - 1$ (c) $\dfrac{a^2}{3\,(b - a)} + \dfrac{3\,b^2}{4\,(a - b)} - \dfrac{2a - b}{6}$

(3) (a) Given the formulas $v^2 = 2gh$ and $v = gt$, eliminate v and solve the resulting equation for h. (b) Take $g = 32$ and find the value of t when $h = 100$.

(c) Simplify $5x - [-3x - (-x + y) - (2x - y)]$.

(4) If $x = 4$, find the value of each of the following expressions:

(a) $\sqrt[2]{\dfrac{9}{x}}$ (b) $\sqrt[3]{\dfrac{-2}{x^3}}$ (c) $x^{-3/2}$ (d) $(2x)^{-2/3}$ (e) $(2x^{3/2})^0$.

(5) (a) Solve for x and y: $\left\{\begin{array}{l} ax + by = n \\ 2ax + 3by = n \end{array}\right\}$

(b) Solve for x: $\dfrac{4\,(x+3)}{9} = \dfrac{8x + 37}{18} - \dfrac{7x - 29}{5x - 12}$

(6) (a) Simplify $\sqrt{4/5} + 3\,(5)^{-\frac{1}{2}} - \frac{2}{\sqrt{6}}$ and find the value of your answer to the nearest tenth.

(b) Simplify

$(5\sqrt{8} + 3\sqrt{7} - 6\sqrt{5})\ (6\sqrt{2} - 4\sqrt{7} + 6\sqrt{5})$.

(7) (a) The sides of a rectangle are in the ratio 5:2. If 2 inches are added to each side, the ratio is 4:3. Find the sides. (b) The perimeter of an isosceles triangle is $\frac{2a + 3}{a^2 - 4}$; one of the equal sides is $\frac{1}{8a + 16}$. What is the length of the third side?

(8) (a) Solve and check $\frac{20}{\sqrt{15 + x}} - \sqrt{x} = \sqrt{15+x}$ (b) In the formula $s = \frac{a}{1 - r}$, $a = 1 + \sqrt{5}$, and $r = 3 - \sqrt{5}$, find the value of S as a fraction with a rational denominator.

(9) An auto makes a trip of 150 miles at a constant speed. Returning, it travels 2 1/2 miles an hour faster and returns in 40 minutes less time than it took to go out. Find the speed of the car on the outward trip.

(10) (a) Solve for x and y: $x + y - m = 0$; $y^2 = 2\,mx + m^2$

(b) For what values of m will the roots of the equation $x^2 - (m - 3)x + 2m - 9 = 0$ be equal?

FIVE-YEAR COURSE IN ELECTRICAL ENGINEERING

Elementary Electrical Measurements (First Year)

(1) Give examples of the practical application of the four principal phenomena which may accompany a flow of an electric current.

(2) A tangent galvanometer of ten turns gives a deflection of 65° when measuring a current of 3.18 amperes. What deflection would be produced by a current of 9.55 amperes? What is the constant of the galvanometer?

$$H = 0.20$$

$$\text{Tangent } 65° = 2.14$$

(3) Describe briefly the Wheatstone Bridge. Give a diagrammatic illustration of the bridge and prove the relation of the several resistances when the bridge is balanced.

(4) The resistance of a millivolt meter and its connecting leads is 2 ohms, and its full-scale deflection is 200 millivolts when used with the leads. What resistance must be placed in series with the instrument to give it a full-scale deflection of 750 volts?

(5) (a) What is meant by resistances in series, resistances in multiple and equivalent resistance? (b) Derive the formula for obtaining the equivalent resistance of several conductors connected in multiple.

(6) The resistance of aluminum at 20° C is 2.828 microhm centimeters. What is the resistance of 15 miles of aluminum wire (diameter 204 mils.), at 20° C?

(7) Define specific resistance, difference of potential, magnetic line of force, electromotive force, free north pole.

(8) Across the terminals of a storage battery which has an e.m.f. of 8.8 volts and an internal resistance of 0.3 ohm, there is permanently connected a resistance of 7 ohms. If another resistance of unknown value is connected in parallel with the 7-ohm coil, the potential difference at the battery terminals is 7.9 volts. What power is the unknown resistance taking?

(9) What is the purpose of an electroscope, and what are its essential parts?

(10) A conductor is made up of two resistances in series. The resistance of the first is 15 ohms and of the second 25 ohms. This conductor is connected in multiple with a uniform conductor which is 8 feet long. Locate the point on the uniform conductor which will have the same potential as the point between the two resistances.

Problems on Tangent Galvanometers

(1) The diameter of the coil of a tangent galvanometer is 101.53 cm. How many turns are required so that a cur-

rent of 2 amperes shall produce a deflection of 45°? (H = 0.25 Tan 45° = 1.)

(2) If it be required to measure a current of 100 amperes, how large a coil of 1 turn would be required? The allowable (maximum) deflection being 65°. (H = 0.2202 Tan 65° = 2.14.)

(3) A tangent galvanometer of 20 turns has a diameter of 20cm. If the needle deflects 35°, what is the current in amperes? (H = .2244 Tan 35° = .70.)

(4) A tangent galvanometer of 10 turns gives a deflection of 65° when measuring a current of 3.18 amperes. What deflection would be produced by a current of 9.55 amperes? What is the constant of the galvanometer? (H = 0.20.)

(5) A galvanometer of 10 turns and 10-centimeter radius gives a deflection of 30 when measuring a current of 2 amperes. If the number of turns had been 5, what would the deflection have been? (H = 0.17 Tan 30° = .577.)

(6) The deflection of a tangent galvanometer when 1 ampere passes through the coil is 15; another current passing through the same galvanometer gives a deflection of 30. What is the value of the second current in amperes? (H = 0.18 Tan 15° = .268.)

(7) Where H = 0.17, what is the constant of a tangent galvanometer having a coil of 10 turns and a diameter of 50 centimeters?

(8) A tangent galvanometer has two coils, one 80 cm. in diameter with 4 turns; the other 100 cm. in diameter with 10 turns. Currents measured by the two coils produce the same deflection. What is the relation between the currents?

(9) A tangent galvanometer of 10 turns and 5 centimeters radius gives a deflection of 55°. If H = 0.20, what is the current in amperes? (Tan 55° = 1.43.)

(10) A tangent galvanometer has two coils, one 50 centimeters and 10 turns; the other coil, 100 centimeters in

diameter. A current of 2 amperes produces the same deflection on both coils. How many turns are in the second coil? ($H = 0.25$.)

(11) What must be the diameter of the coil of a tangent galvanometer of 5 turns so that a current of 4 amperes shall produce a deflection of 45°? ($H = 0.1885$.)

(12) A galvanometer of 5 turns and 10-centimeter radius gives a deflection of 30° when measuring a certain current. If $H = 0.1815$, what is the value of the current in amperes?

Problems on Ohm's Law

(1) Current is to be furnished to a heating coil from a 120-volt source. What must be the resistance of the coil so that it will use 200 watts?

(2) Current is to be furnished to a heating coil from a 120-volt source. What must be the resistance of the coil so that it will use 400 watts?

(3) The potential difference across a heating device is 120 volts. If the resistance is 10 ohms, what is the current consumption? How many coulombs pass in 10 seconds?

(4) An electric flatiron consumes 600 watts when connected to a supply of 120 volts. What is the resistance of the iron and how much current does it take?

(5) The capacity of a body is 0.05 microfarad. A certain quantity of electricity is added to the body, and the potential difference is found to be 50 volts. What is the quantity?

(6) A heating device consumes 550 watts when connected to a 110-volt circuit. What is its resistance? What is the quantity of flow per second?

(7) The power consumed by a toaster is 600 watts when connected to a 120-volt supply. What is the current consumed? What is the resistance of the toaster?

(8) The power consumed by a toaster is 600 watts. If the current is 5 amperes, what is the resistance of the toaster?

(9) An electric soldering iron is connected to a 110-volt circuit. If the power consumed is 550 watts, what is the resistance of the iron? What is the current?

(10) The power consumed by a toaster is 600 watts. If the resistance of the toaster is 20 ohms, what is the current?

(11) A tangent galvanometer is used to measure the current taken by a flatiron. If the resistance of the iron is 20 ohms and the PD across the terminals is 110 volts, what will the galvanometer read? K of galvanometer = 2. H = 0.18.

(12) An electric toaster has a resistance of 22 ohms. What current does it take when connected to a 110-volt circuit? What is the power consumed?

(13) Tangent galvanometer is used to measure the current taken by a toaster. If the resistance of the toaster is 25 ohms and the watts consumption is 600, what will be the deflection of the galvanometer? K of galvanometer = 2. H = 0.20.

Problems on Ohm's Law (Batteries, etc.)

(1) A storage battery whose emf. is 25 volts and internal resistance 0.5 ohm is connected to a circuit whose resistance is 4 ohms. What current does the battery supply? What is the voltage impressed on the circuit?

(2) A battery whose emf. is 6 volts delivers 2 amperes to a resistance of 2.7 ohms connected across its terminals. What is the battery resistance?

(3) A battery whose internal resistance is 0.5 ohm supplies 3 amperes to a circuit consisting of two coils of 1 ohm and 2 ohms resistance in parallel. What would the potential difference at the battery terminals be if an additional coil of 5 ohms resistance were placed in parallel with the other two?

(4) A storage battery whose emf. is 18 volts will maintain a current of 8.8 amperes through a resistance of 1.95 ohms connected across its terminals. What current will it

supply if this circuit is replaced by one having a resistance of 1.14 ohms?

(5) Each cell of a storage battery has an emf. of 2.1 volts and a resistance of 0.12 ohm. Will the battery supply more current to a circuit whose resistance is 0.09 ohm when the cells are connected in series or in parallel?

(6) A battery whose emf. is 10 volts and internal resistance 1 ohm has connected across its terminals two coils in parallel of 5 and 10 ohms resistance. What is the potential difference at the battery terminals?

(7) Two batteries whose emfs. are 6.3 and 10.5 volts and whose internal resistances are 0.15 ohm and 0.2 ohm respectively are connected in series with a circuit of 2 ohms resistance. What will be the value of the current?

(8) A battery is supplying 1.15 amperes at 5.75 volts to a coil having a resistance of 5 ohms. What current would flow through a coil of 10 ohms placed in parallel with the first? The emf. of the battery is 6.3 volts.

(9) A battery whose emf. is 17 volts and internal resistance 0.21 ohm is supplying 8 amperes to a circuit consisting of a coil of 2.4 ohms in parallel with an unknown resistance. What is the value of the unknown resistance?

(10) What resistance must be connected in series with a storage battery whose emf. is 21 volts and internal resistance 0.24, so that a charging current of 5 amperes will be established through the battery when connected across 110-volt mains?

Problems on Voltmeters and Ammeters

(1) The resistance of a millivoltmeter and its connecting leads is 1 ohm; and its full scale deflection is 50 millivolts when used with the leads. What is the resistance of a multiplier with which the instrument will give a full-scale deflection of 150 volts?

(2) Derive the formulas for obtaining the resistance of a multiplier in terms of the voltmeter resistance.

(3) Two voltmeters having full-scale deflections of 150

and 50 volts and resistances of 17,136 ohms and 5364 ohms are connected in series with a coil of 7500 ohms resistance across 220 volts. What will each instrument read?

(4) The resistance of a millivoltmeter and its connecting leads is 1 ohm, and its full-scale deflection is 50 millivolts when used with the leads. What shunt resistance should be used when the instrument is to be used as an ammeter to give a full-scale deflection of 100 amperes?

(5) The resistance of a millivoltmeter and its connecting leads is 1 ohm, and its full-scale deflection is 50 millivolts when used with the leads. What is the resistance of a multiplier with which the instrument will give a full-scale deflection of 50 volts?

(6) A 150-scale voltmeter whose resistance is 17,527 ohms is connected in series with an unknown high resistance across a 220-volt circuit. If the voltmeter reads 138.5 volts, what is the value of the unknown resistance?

(7) Ten coils having each a resistance of 10,000 ohms are joined in series to two points whose PD is maintained at 100 volts. What will be the PD between the terminals of each coil? What will be the reading of a voltmeter of 20,000 ohms when connected in multiple with one of the coils? If connected across the whole set of coils?

(8) An unknown resistance is connected between the trolley wire and the rail of an electric road. The potential difference between the rail and the wire is 550 volts. If the midpoint of the resistance is connected to the rail by a 20-ohm coil there will be a current of 5 amperes through the latter. What is the unknown resistance?

(9) Two voltmeters whose resistances are 17,238 ohms and 5212 ohms are connected in series across 180 volts. What will each instrument read?

(10) The resistance of a millivoltmeter and its connecting leads is 1 ohm, and its full-scale deflection is 50 millivolts when used with the leads. What shunt resistance should be used when the instrument is to be used as an ammeter to give a full-scale deflection of 50 amperes?

Problems on Resistivity

(1) If the cross section of a bar of metal is 1 square inch, its length 1 foot, and its resistance 0.0008 ohm, what is its resistivity?

(2) A rod of aluminum 100 cm. long and 0.4 cm. sq. in cross section has a resistance of 0.0007 ohm. If the resistivity of copper is 0.00000172 ohm-cm., what is the specific resistance of aluminum?

(3) The resistance of a copper rod 1 inch in diameter and 10 feet long is 0.000102 ohm. What will be its resistance when drawn into a wire 0.1 inch in diameter?

(4) A copper bar 0.512 inch square and 3.674 feet long has a resistance of 0.0001122 ohm. What is the resistivity of copper in ohms per mil-foot?

(5) If the cross section of a conductor 100 meters long is 2 square millimeters and its resistance is 1 ohm, what is the resistivity of the material?

(6) A copper rod, 12.5 inches long and having a diameter of 0.5 inch, has a resistance of 43.1 microhms; what is the resistivity of copper?

(7) If the resistance of copper is 1.72 microhm-cm., what is the resistance of a copper bar 0.5 inch square and 4 feet long?

(8) If the resistivity of copper is 0.67879 microhm-inches, what is the resistivity in microhm-cm.?

(9) If the resistivity of copper is 1.62 microhms per cm. cube at 0 C, what is its resistivity at this temperature in microhms per mil-foot?

(10) If the resistivity of copper is 1.72 microhm-cm. at 20 C, what is its resistance per inch cube at the same temperature?

Chapter XIII

NON-ENGINEERING

Young men and women who are thinking of training themselves for work in the field of radio broadcasting should also bear in mind the fact that all together there are about 20,000 employees in the radio broadcasting stations and network operations throughout the United States. This figure does not include artists, meaning actors and actresses, singers, comedians, etc., but it does include technical employees. Inasmuch as this chapter is being devoted to non-engineering opportunities, the figure of 20,000 must therefore be considerably reduced.

It is not likely that the number of employable opportunities will increase. There could hardly be more radio stations in operation than there are today. The eventual development of television may have a marked effect on the whole employment situation—it may open a huge field —but there is no way at present to figure when this will take place.

However, besides the jobs to be found in non-engineering departments of radio stations, there are associated fields with which all stations are closely related, particularly advertising agencies, talent-booking agencies, and all lines of entertainment. All together they employ quite a large number of men and women.

Employing a smaller number, but presenting opportunities for well-trained and experienced workers, are firms specializing in radio research, making field surveys; also cooperative organizations such as the National Association of Broadcasters and the governmental commission known as the Federal Communications Commission.

The important work in a radio broadcasting station, other than the engineering work, may be divided as follows:

Program

Radio stations, radio networks, advertising agencies and booking or artist-management services all take part in the building of a radio program.

Needed are production directors, orchestra conductors, announcers, sound-effects operators in addition to the participating artists. All these are creative workers, all need to be especially trained for their jobs. Each program involves a considerable amount of creative work, often a good deal of research, all of which is subject to management and skilful direction.

Talent

Since the advent of radio, especially since network radio came on the scene in 1927, it has become one of the largest branches in the whole field of entertainment. Orchestras, bands, musical and dramatic artists of every kind, comedians, commentators—all of these are being used continually. A search for new talent and new kinds of talent is always going on. Related to all this is a large management field. The networks and many of the individually owned radio stations have what they call booking departments or artists' service; also there are many independent organizations not owned or in any way tied to the stations. These management services act as business representatives for the artists, collecting a percentage of their earnings as compensation.

Publicity

Because radio is both commercial and cultural, publicity or public relations plays an important part in its development. All radio stations have publicity workers, whose work varies from direct contact with listeners to indirect contact through newspapers, magazines and all sorts of different media. Whenever you read an item about a radio personality you may be sure that a publicity man or woman saw to it that the item was conceived, written, and published.

Sales

Radio broadcasting makes its money by selling time on the air, just as publications sell space and circulation. The sales staff of a single station or a radio network is a highly organized, experienced, and hard-working department. It provides the sinews of commerce, it brings in the money to pay for the operation of the enterprise; all that the artists earn and all everyone else in the organization earns is provided by the work of the sales staff. This involves actual selling, servicing, market research, statistical analysis, sales promotion . . . in fact, all the selling effort that characterizes any typical business enterprise.

Miscellaneous

All of the various departments which have been outlined need the support of clerks, auditors, bookkeepers, secretarial help, legal counsel, and such various other services as are typical of any business. These do not require special training in any particular; rather, the usual training along the lines of general business.

Organization

In considering training oneself for a job in radio broadcasting, it is well to get a mental picture of the way the broadcasting industry is organized today.

There are approximately 800 commercial broadcasting stations. Of these approximately one half are linked with the three major national networks; i.e., National Broadcasting Company, Columbia Broadcasting System, Mutual Broadcasting System. However, most of the stations linked with the networks also operate as local businesses in their home communities.

The headquarters of each of the three main national networks are located in New York City. They also maintain regional offices and fairly large staffs at other points. Outside of New York, the largest business and program activity of the networks is in Chicago, Washington and Hollywood; Chicago by reasons of its commercial importance; Washington on account of its political importance, and Hollywood because of the close artistic cooperation between radio and the movies.

Most of the stations which cooperate with the networks are private business enterprises and are not owned by the networks. For instance, National Broadcasting Company, through its two networks, the Red and the Blue, has the cooperation of more than 160 radio stations. The N.B.C. programs are fed to these stations. The arrangements, however, are by contract, not by ownership. National Broadcasting owns, manages, operates and programs only seven stations. It owns but does not operate or program three others. In a few additional instances it manages and programs or merely programs, but does not own the station. Similar conditions obtain with C.B.S. and M.B.S.

So, you see, its actual network ownership of stations which carry its programs is quite limited. These other stations cooperating with N.B.C. have a good deal of time for sale, and they sell it locally; that is, for their own circulation in their own community.

Nevertheless, National Broadcasting Company needs close to 2000 workers to carry on its activities. Of these, about 1200 are employed in New York City; the others are in its various offices throughout the country and abroad. Of these 2000 employees, about 300 are women and the majority of them are clerks or secretaries, although there are a few highly specialized positions held by women who have had long experience with the company or who have had specialized experience which N.B.C. found profitable to hire.

It should be noted that of these 2000 employees, a goodly number are engineeringly trained for technical positions; the number hirable for work being considered in this chapter is therefore lower by about 15 per cent.

Employment Policy

The viewpoint of the National Broadcasting Company's employment policy is being here presented. While it does not absolutely parallel the practice of the other networks, it is close enough for all practical purposes to be taken as typical.

With very few exceptions, everyone at National Broadcasting Company starts at the bottom. It is a long and hard grind thereafter. Those who stand the gaff have a good chance to go up. The starting level is usually a college education, though it is not always an absolute prerequisite.

There are three places where a newcomer may be placed: the page and guide staff, the mail room, and the duplicating room. The last is where letters are duplicated in large quantities. In whichever division the newcomer starts, he is in effect an office boy. His pay is $15. And he should be a college graduate; that is, he then will have a better chance of getting the job. His background, choice of college majors, what he did in spare time or during vacations—these, too, will be influential considerations. Participation in college dramatics will be an asset, likewise work in summer dramatic stock companies, musical training, whatever is helpful and contributory to the show business.

The networks are not eager to employ youngsters, even in these opening positions, until they are about twenty years old or even older. That is one reason why they prefer college men and women. By the time young folks come out of college they are certain to have reached the desired age.

This beginner's job is at the very best a mere chance. It is the young fellow's opportunity to prove that he has what it takes; nothing more. There is a possibility for a slight increase in wage. At National Broadcasting Company beginners can hold on for two years. During these two years the most likely looking go up to $20 weekly from the starting wage of $15. Half get one wage, the other half the slightly higher wage. At the end of two years the workers will be promoted to a department or let out. When promoted to a department, such as program, publicity, music or any one of a number of different departments, they are still office boys. The only difference is that they have what might be called a toehold. But only one in ten gets these toehold jobs. The others have to seek employment elsewhere.

After getting such a toehold job in a department, the worker has an opportunity to show what he's got. He is in a group that is limited to a specialty. If he has what it takes, he ought to be able to go places.

The beginner who hangs on to his first network job and then starts his slow climb up, or the beginner in the unassociated station operating on its own without network affiliation, sooner or later has to specialize. Let us consider what form his work may take.

Announcers

Everyone knows what an announcer is. How do you get to be an announcer? What do you have to start with?

At the beginning of radio broadcasting, most announcers came from the ranks of vocalists. Graham McNamee, for instance, was a singer. The reason why singers became announcers was simple. They had had voice training. You might set that down as No. 1 qualification. You have to have a pleasing voice, good diction.

Another quality required today, one which was not required at the beginning, is a sure command of your own English language. There is a tendency nowadays to be sure of this first, and of the voice next. A number of announcers were trained to teach English.

It is idle, of course, to say that all who intend to become announcers must start as office boys. However, it is true that a number who did start as office boys graduated as announcers. Probably there is no regular road to the position of announcer. If you get taken on as an office boy, the chances are that you will be favored when there is such an opening. Except for that, you might not be around when the opening came. Even the existence of the opening would not do you much good if you lacked the training and the qualifications. The most important of these is a knowledge of good English, and all that this implies. The next is a pleasing voice and knowing how to use it.

What do announcers make? Well, it varies. According to a survey made by the Federal Communications Commission in 1938, the average weekly pay of announcers for stations throughout the country was $34.40. Among the leading stations in big cities it is considerably higher. It may range from $37.50 up to $85. This, you must remember, is for staff announcers. There are other opportunities for announcers. They may be so outstanding that sponsors are willing to pay extra for their use. Instead of accepting a staff announcer, sponsors may designate a man of their choice. They pay for this, probably at the rate of $50 per program up, depending on whom they so designate.

An announcer who captures the popular fancy, and thus becomes in demand by sponsors, may run his earnings up to several hundred dollars a week. There are not many such, but they do exist. Announcers have the opportunity of identifying themselves by name; the audience gets to know them, and this adds to their earning value.

Besides working for the stations and free-lancing by themselves, announcers also work for the larger advertising agencies. When they do this, they may or may not hold salaried jobs. They may continue to work as free-lances, getting paid according to the number of programs the advertising agency uses them on; or they may accept a straight salary. The figure is quite variable, though it is apt to be slightly higher than if they were on the payroll of the radio station.

Writers

We are now talking about script writers, not fact writers. Script writing is creative work just as much as is playwriting. The FCC survey previously referred to stated that the average pay among radio stations in 1938 was $35.68 a week. However, it is definitely the fact that by and large the best script writers are not on a station's payroll or on any payroll. The cream of the crop are free-lances, usually established in their own offices with a business manager to attend to their interests. Doubtless they learned the technique of their trade in a station's writing department; then, when they learned how to click, they got out for themselves. In New York, Chicago and Hollywood, writers who are on station payrolls, or in script-writing departments of advertising agencies, knock out from $50 to $90 a week. The big money in writing, however, is made by the free-lances who have set up in business for themselves. They work up a character or a story, market it themselves by peddling it, either to a station or a network or an advertising agency or the sponsor direct. It may be a serial story with one or two, or even five or six, performances a week. That kind of chore spells real work, but the rewards are large. The scripts may bring as little as $25 or as much as $200. Some serial writers make $1000 a week; not many of them, but it happens frequently enough to take it out of the class of the unusual.

No one sets any standards for men and women who can afford to go into business for themselves. They make their own standards. If they can create and fashion material that rings the bell from the viewpoint of the buyers of radio-script material, it does not matter what kind of education or background they may have. It stands to reason, however, that they must have the technical ability that usually comes from training.

Most of these successful radio writers are college men and women, who specialized in dramatics and dramatic writing at college, then got experience and training either on the stage or in the script department of a radio station or advertising agency. They had a little success while on salaried jobs; enough for them to take their own measure before they cut out for themselves.

The foregoing goes also for the gag writers, the trick announcement writers, such as those who create the humor in certain commercials where the comedians jam up with the straight announcer. Such writers are quite as distinctive in their work as the comedian himself. They usually work closely with the comedian and get paid by him rather than by the buyer or buying agent.

Producers

This is a technical term, doubtless borrowed by radio from the stage and screen, though its exact counterpart is not found either in stage or screen. The producer is in complete charge of the show. He ties it together. Strictly speaking, he is supposed to have the authority to direct the orchestral leader, the actor and actress, the technician, the announcer, the writer, and all others who cooperate in putting a show on the air. For the purposes of the program and for the time it takes in rehearsal and actual performance, his word is supposed to be (and usually is) supreme. This requires a high level of ability and personality, and the radio producer usually has it.

The producer may be working for the station or for the advertising agency in charge of the program, if it is a sponsored program. When a sponsored program is produced for a network, the advertising agency's producer is usually allowed full sway. Nevertheless, the network producer stands by. Should a conflict arise, the network producer outranks all others.

The FCC survey estimated that in 1938 the average weekly rate of pay to producers up and down the land was $45.72. In New York and producing centers it is much higher. The range is probably between $75 and $200. In some advertising agencies it may be even more.

The producer, because his is the supreme authority, can make and break a show. On him rests the selection of talent, selection of script or script writers; he integrates all the work that goes into production. On his knowledge, good taste, understanding of objective and knowledge of how to achieve it, rests whatever success the program will win. Naturally, this takes experience.

A successful producer may have gotten his experience in a variety of ways. Quite likely he started away back in high school by taking part in school dramatics—writing, acting, directing. He continued this interest at college. He worked in the theater after college, either as an actor or behind the scenes. He may have been a radio writer or radio announcer or both. He undoubtedly was an assistant producer. In brief, he must have gone all through the mill, because he has to know a good deal about everything that is done—including a good deal about music.

Publicity

Publicity workers are extremely important in a radio station's success. They work with the sales department in its advertising and sales-promotion work; they also work with the program department in furnishing information to the press and in generally using every possible worthwhile method to bring the station's programs to the attention of the listening public.

The work is quite as exacting in its preparatory requirements as that of the other departments. In its work with the sales department, it follows the same methods of modern advertising as those used by manufacturers, distributors and retailers everywhere. In its work with the program department it employs the modern practice of publicity and public relations to the *n*th degree. For the former, the training given in business administration in colleges and experience in business are essential. For the latter, college training is desirable; experience on metropolitan newspapers almost essential, at least in New York and other big cities. In smaller cities, newspaper experience on papers such as serve the community is equally valuable.

Salaries range widely; anywhere from $30 weekly to $400. Naturally, there are not many who reach the latter figure; possibly one or two. A salary of $75 is apt to be close to the rule in New York; the pay is somewhat less in other cities. There is not the opportunity in this division of radio work to make the large sums that creative writers frequently obtain. Advertising agencies also hire publicity men and women; they are apt to pay slightly higher wages than do the stations.

Music

Musicians of all sorts, leaders, singers, instrumentalists, are apt to make larger sums than any other workers in the radio field. However, this is a field more properly belonging to music and music study than radio and its opportunities. Musical artists in the radio field, even though they devote all their time to radio, come up through the music ranks, not the radio ranks.

Value of Showmanship

We have been discussing the writer, the announcer, the producer. It is quite possible, in many stations outside the very largest ones, that all these functions might be expected of a single individual. Even in the middle-sized station, where the staff is large enough to include one or two of each variety, the radio chap is likely to be a writer and producer and announcer all in one. And also be able to attend to the publicity!

It is fair to make a comparison here with the newspaper in the average-sized city. The editor of such a newspaper may also be expected to be a reporter, a makeup man, an editorial writer, and a good deal else, all wrapped in the single human package. When a staff is small, specialization is a luxury not to be afforded.

There is room for an apt comparison between the type of man radio needs in its program work, in so far as production, announcing and writing are concerned, and the type of man who does editorial work on a newspaper. There are a good many qualities which these two have in common, though not as many as you might think. A better comparison is with the kind of personality that makes a success in show business.

For it is extremely important for any youngster who wants to get into radio and become successful . . . it is extremely important that he realize at the start and never forget that radio is show business.

Yes, radio is show business, and a good radio man, whatever the department of his employment and whatever his contribution to the art, must have a flair for showmanship. This is true of the producer, the writer, the announcer, the publicity man, as well as every radio worker.

Radio is show business, and the workers in it must be showmen.

In itself that would not be so extremely difficult. All successful circus people, show folks on Broadway, concert managers, have always been showmen. But in radio you have the combination of having to be a showman and in addition having to apply your showmanship to the field of orthodox business.

Ordinary showmanship merely means putting on an exhibition that will make people spend money at the box office to see your show. But radio showmanship means putting on a show that will make people *tune in your show* against an enormous amount of competition. All they need to do is to turn the dial; but you have to make them tune in your show and then make them go out and spend money at the drug store or grocery store or gasoline station for the product your show is advertising.

That takes Showmanship with a capital S.

If you can learn to do that, you'll be a big Success in radio; Success with a capital S, too. Nobody can teach it to you. You have to learn it for yourself. It cannot be taught in school. Some of the tools it uses can be acquired in school, however, and the sooner you make up your mind to master them, the better off you will be.

In school and in college you can make yourself as proficient as possible in the use of the English language. This is fundamental, the basis, the bedrock of the equipment you later will be called on to use. To speak English as it ought to be spoken; to write it so that it sings!

You cannot possibly put in too much time increasing your proficiency in English.

Take every opportunity offered by school to learn about dramatics. Take part in things as an actor or actress, as a writer, as a behind-the-scenes participant. You learn by doing.

At your public library, get acquainted with some of the radio magazines in the trade-paper division. Not the fan magazines telling of the stars' love affairs and what they eat for Sunday breakfast; that won't teach you anything. But the trade journals telling what the trade practices are, what's going on in radio business circles, what the new programs are advertising, and why. Reading the trade magazines will give you a real "feel" of the business. Two good ones to read are *Broadcasting*, published in Washington, D. C., appearing twice a month, and carrying all the news of the radio industry; and *Variety*, published in New York every week. The former is essentially a business paper; the latter is decidedly a showman's paper.

Almost every young fellow has the opportunity to learn about music. If he does not take private lessons on the piano or any other instrument, he has the chance in school to learn. If he wants to go ahead in radio, he would be well advised to embrace the opportunity in school to learn as much as possible about music. Because, in radio, music figures largely, even in the out-and-out dramatic programs.

There's this, too, to bear in mind about radio: All knowledge is valuable. Whatever you know about anything can be grist in your mill later on. Radio programs, like the movies, seek a common denominator of understanding; they seek to reach huge audiences. Common knowledge is especially valuable, but all knowledge is applicable.

Summary

Summing up: As regards the opportunities in radio broadcasting to work in the non-engineering fields, the advisable preparation is pretty much the same for writing, production, announcing, even publicity. Get all the formal education you can. Develop all possible traits of showmanship. Get acquainted with the inside of radio show business by reading one or several of the trade papers. In school, pay first and particular attention to learning the use of your own language, English. Participate in school and college dramatic and musical activities; also in debating and similar activities. They all are exercises in the good use of English; furthermore, they all are exercises in the development of the much-prized and much-to-be-desired quality of showmanship. You've got to have showmanship, or else radio has nothing for you and you have nothing for radio.

If there is a radio station in your town, hang around occasionally. Get an after-school job there if you can, or a summer job. You know, you learn by doing. Be of willing service, and they won't mind having you around. Even if you don't earn anything, you'll be learning. If it's radio publicity you are shaping yourself for, hang around the newspaper in your town. Get a job there if you can. Be a school reporter for the paper; anything to create these editorial contacts. We must get newspaper experience sooner or later to be acceptable in a radio publicity department.

In the last analysis, eagerness for doing the work will develop the insistence that eventually will get you a job. But if you make the desired acquaintances while you still are in school, you will find a job ready for you when you're ready for it. The time to be thinking about a job is while you're in school. Then you can walk into it when you get out of school; you'll have been preparing for it all the while.

APPENDIX

ENGINEERING SCHOOLS

Listed by the United States Office of Education in the Educational Directory, 1935

ALABAMA

Alabama Polytechnic Institute, Auburn
Alabama, University of, University

ALASKA

Alaska, University of, College

ARIZONA

Arizona, University of, Tucson

ARKANSAS

Arkansas, University of, Fayetteville

CALIFORNIA

California Institute of Technology, Pasadena
California, University of, Berkeley
Santa Clara, University of, Santa Clara
Southern California, University of, Los Angeles
Stanford University, Stanford University

COLORADO

Colorado State College of Agriculture and Mechanic Arts, Fort Collins
Colorado College, Colorado Springs
Colorado School of Mines, Golden
Colorado, University of, Boulder
Denver, University of, Denver

CONNECTICUT

Connecticut State College, Storrs
Yale University (Sheffield Scientific School; Yale Engineering School), New Haven

DELAWARE

Delaware, University of, Newark

DISTRICT OF COLUMBIA

Catholic University of America, Washington
George Washington University, Washington
Howard University, Washington

FLORIDA

Florida, University of, Gainesville
John B. Stetson University, De Land

GEORGIA

Georgia School of Technology, Atlanta
Georgia, University of, Athens

HAWAII

Hawaii, University of, Honolulu

IDAHO

Idaho, University of, Moscow

ILLINOIS

Armour Institute of Technology, Chicago
Illinois, University of, Urbana
James Millikin University, Decatur
Lewis Institute, Chicago
Northwestern University, Evanston

INDIANA

Evansville College, Evansville
Notre Dame, University of, Notre Dame
Purdue University, Lafayette
Rose Polytechnic Institute, Terre Haute
Valparaiso University, Valparaiso

IOWA

Iowa State College of Agriculture and Mechanical Arts, Ames
Iowa, State University of, Iowa City

KANSAS

Kansas State College of Agriculture and Applied Science, Manhattan
Kansas, University of, Lawrence

KENTUCKY

Kentucky, University of, Lexington
Louisville, University of, Louisville

LOUISIANA

Louisiana Polytechnic Institute, Ruston
Louisiana State University and Agricultural and Mechanical College, Baton Rouge
Tulane University, New Orleans

MAINE

Maine, University of, Orono

MARYLAND

Johns Hopkins University, Baltimore
Maryland, University of, College Park
United States Naval Academy, Annapolis

MASSACHUSETTS

Harvard University, Cambridge
Lowell Textile Institute, Lowell
Massachusetts Institute of Technology, Cambridge
Northeastern University, Boston
Tufts College, Medford
Worcester Polytechnic Institute, Worcester

MICHIGAN

Detroit, University of, Detroit
Michigan College of Mining and Technology, Houghton
Michigan State College of Agriculture and Applied Science, East Lansing
Michigan, University of, Ann Arbor

MINNESOTA

Minnesota, University of, Minneapolis

MISSISSIPPI

Mississippi State College, State College
Mississippi, University of, University

MISSOURI

Missouri, University of, Columbia
Missouri, University of, School of Mines, Rolla
Washington University, St. Louis

MONTANA

Montana State College, Bozeman
Montana State School of Mines, Butte

NEBRASKA

Nebraska, University of, Lincoln

NEVADA

Nevada, University of, Reno

NEW HAMPSHIRE

Dartmouth College, Hanover
New Hampshire, University of, Durham

NEW JERSEY

Newark College of Engineering, Newark
Princeton University, Princeton
Rutgers University, New Brunswick
Stevens Institute of Technology, Hoboken

NEW MEXICO

New Mexico College of Agriculture and Mechanic Arts, State College
New Mexico School of Mines, Socorro
New Mexico, University of, Albuquerque

NEW YORK

Alfred University, Alfred
Brooklyn, Polytechnic Institute of, Brooklyn
City of New York, College of the, New York
Clarkson College of Technology, Potsdam
Columbia University, New York
Cooper Union, New York
Cornell University, Ithaca
Manhattan College, New York
New York University, New York
Rensselaer Polytechnic Institute, Troy
Rochester, University of, Rochester
Syracuse University, Syracuse
Union University, Schenectady
United States Military Academy, West Point

NORTH CAROLINA

Duke University, Durham
North Carolina State College of Agriculture and Engineering, Raleigh
North Carolina, University of, Chapel Hill

NORTH DAKOTA

North Dakota Agricultural College, Fargo
North Dakota, University of, Grand Forks

OHIO

Akron, University of, Akron
Antioch College, Yellow Springs
Case School of Applied Science, Cleveland
Cincinnati, University of, Cincinnati
Dayton, University of, Dayton
Ohio Northern University, Ada
Ohio State University, Columbus
Ohio University, Athens
Toledo, University of, Toledo

OKLAHOMA

Oklahoma Agricultural and Mechanical College, Stillwater
Oklahoma School of Mines, Wilburton
Oklahoma, University of, Norman
Tulsa, University of, Tulsa

OREGON

Oregon State Agricultural College, Corvallis

PENNSYLVANIA

Bucknell University, Lewisburg
Carnegie Institute of Technology, Pittsburgh
Drexel Institute, Philadelphia
Gettysburg College, Gettysburg
Haverford College, Haverford
Lafayette College, Easton
Lehigh University, Bethlehem
Pennsylvania Military College, Chester
Pennsylvania State College, State College
Pennsylvania, University of, Philadelphia
Pittsburgh, University of, Pittsburgh
Swarthmore College, Swarthmore
Villanova College, Villanova

PHILIPPINE ISLANDS

Philippines, University of the, Manila

PUERTO RICO

Puerto Rico, University of, Rio Piedras

RHODE ISLAND

Brown University, Providence
Rhode Island State College, Kingston

SOUTH CAROLINA

The Citadel, Charleston
Clemson Agricultural College, Clemson College
South Carolina, University of, Columbia

SOUTH DAKOTA

South Dakota State College of Agriculture and Mechanic Arts, Brookings
South Dakota State School of Mines, Rapid City

TENNESSEE

Tennessee, University of, Knoxville
Vanderbilt University, Nashville

TEXAS

Rice Institute, Houston
Southern Methodist University, Dallas
Texas Agricultural College, Arlington
Texas, Agricultural and Mechanical College of, College Station
Texas Technological College, Lubbock
Texas, University of, Austin

UTAH

Utah State Agricultural College, Logan
Utah, University of, Salt Lake City

VERMONT

Norwich University, Northfield
Vermont, University of, Burlington

VIRGINIA

Virginia Military Institute, Lexington
Virginia Polytechnic Institute, Blacksburg
Virginia, University of, Charlottesville
Washington and Lee University, Lexington

WASHINGTON

Washington, State College of, Pullman
Washington, University of, Seattle

WEST VIRGINIA

West Virginia University, Morgantown

WISCONSIN

Marquette University, Milwaukee
Wisconsin, University of, Madison

WYOMING

Wyoming, University of, Laramie

PUBLIC SCHOOLS OFFERING RESIDENT INSTRUCTION IN RADIO

Mechanics, Operation, Repair, Servicing, Sound

ALABAMA

Birmingham—Paul Hayne School

ARIZONA

Phoenix—Arizona Vocational School

CALIFORNIA

Oakland—Central Trade High School (Service)
San Francisco—Gompers Trade Senior High School
San José—San José Technical High School
Santa Monica—Santa Monica Technical High School (and Sound)

DELAWARE

Wilmington—H. Fletcher Brown Vocational School

FLORIDA

Miami—Northside Technical School (Service and Operation)
Tampa—Brewster Vocational School (Service and Operation)

MARYLAND

Baltimore—Boys Vocational School

MASSACHUSETTS

Boston—Boston Trade School for Boys

MISSOURI

St. Louis—Hadley Vocational School

NEW JERSEY

Bloomfield—Essex County Boys Vocational School (Servicing)

Merchantville—Camden County Vocational School (Mechanics)

NEW YORK

New York City—Brooklyn High School for Specialty Trades (Mechanics)

New York City—Chelsea Vocational High School (Mechanics)

New York City—East New York Vocational School

New York City—Jamaica Vocational High School (Mechanics)

New York City—Metropolitan Vocational High School (Mechanics)

New York City—New York Vocational High School for Boys (Mechanics)

New York City—Queens Vocational High School (Mechanics)

NORTH DAKOTA

Wahpeton—State School of Science

OREGON

Eugene—Eugene Vocational School (Repair)

PENNSYLVANIA

Pittsburgh—Connelley Vocational School

PUERTO RICO

Ponce—Roosevelt Vocational School (Mechanics)

Rio Piedras—University of Puerto Rico, School of Arts and Trades (Mechanics)

San Juan—J. Gomez Brioso Trade School (Mechanics)

TEXAS

Houston—Houston Vocational School

San Antonio—San Antonio Vocational and Technical School

UTAH

Logan—Utah State Agricultural College

WASHINGTON

Seattle—Edison Vocational School (Service)

These courses are recommended under the requirements of the Smith-Hughes Act.

PRIVATE SCHOOLS OFFERING RESIDENT COURSES IN RADIO

Radio Engineering

Capitol Radio Engineering Institute,
3224 16th Street N. W., Washington, D. C.
Dodge's Institute,
Valparaiso, Indiana
R.C.A. Institutes,
75 Varick Street, New York, N. Y.
1154 Merchandise Mart, Chicago, Ill.

Radio Operating, Servicing, Television

Dodge's Institute,
Valparaiso, Indiana.
Gulf Radio School,
New Orleans, La.
Massachusetts Radio School,
18 Boylston Street, Boston, Mass.
Port Arthur College,
Port Arthur, Texas.
R.C.A. Institutes,
75 Varick Street, New York, N. Y.
1154 Merchandise Mart, Chicago, Ill.
Y.M.C.A. Trade and Technical Schools,
5 West 63rd Street, New York, N. Y.

TEXTBOOKS RECOMMENDED

For the Various Branches of Radio

AMATEUR

How to Become a Radio Amateur, American Radio Relay League, Hartford, Conn.

Radio Amateur's Handbook, American Radio Relay League, Hartford, Conn.

Radio Handbook, Radio Limited, Santa Barbara, California

Radio Amateur Course, Popular Book Corporation, New York, N. Y.

RADIO OPERATING

Fundamentals of Radio, Terman; McGraw-Hill Book Co., New York, N. Y.

Practical Radio Communication, Nilson and Hornung; McGraw-Hill Book Co., New York, N. Y.

Radio Manual, Sterling; D. Van Nostrand & Co., New York, N. Y.

Radio Telegraphy and Telephony, Duncan and Drew; John Wiley & Sons, New York, N. Y.

RADIO SERVICING

Alternating Current in Radio Receivers, Rider; John F. Rider Publications, N. Y.

DC Voltage Distribution, Rider; John F. Rider Publications, N. Y.

Resonance and Alignment, Rider; John F. Rider Publications, N. Y.

Oscillators at Work, Rider; John F. Rider Publications, N. Y.

Servicing by Signal Tracing, Rider; John F. Rider Publications, N. Y.

Servicing Superheterodynes, Rider; John F. Rider Publications, N. Y.

The Cathode-Ray Tube at Work, Rider; John F. Rider Publications, N. Y.

Radio Physics Course, Ghirardi; Radio Publications, N. Y.

Modern Radio Servicing, Ghirardi; Radio Publications, N. Y.

Radio Servicing, Hicks; McGraw-Hill Book Co., N. Y.

Television in America, Batcher and Rider; John F. Rider Publications, N. Y.

Trouble-Shooter's Handbook, Ghirardi; Radio Publications, N. Y.

RADIO THEORY AND RADIO ENGINEERING

Elements of Radio Communication, Morecroft; John Wiley & Sons, New York, N. Y.

Principles of Radio Communication, Morecroft; John Wiley & Sons, New York, N. Y.

Communication Engineering, Everitt; McGraw-Hill Book Co., New York, N. Y.

Fundamentals of Radio, Terman; McGraw-Hill Book Co., New York, N. Y.

Fundamentals of Radio, Ramsey; May be purchased through American Radio Relay League, Hartford, Conn.

Radio Engineering, Glasgow; McGraw-Hill Book Co., New York.

Radio Engineering, Terman; McGraw-Hill Book Co., New York.

Principles of Radio, Henney; McGraw-Hill Book Co., New York.

Principles of Television Engineering, Fink; McGraw-Hill Book Co., New York.

The radio engineering texts are primarily recommended for advanced students and teachers.

RADIO AS A CAREER

Kitson CAREERS Series

By

JULIUS L. HORNUNG