THE TRAINING OF THE RADIO OPERATOR*

By

M. E. PACKMAN

In contra-distinction to the advance that has been made by the scientific and commercial development of radio telegraphy, the operator problem stands much as it did in the earliest days. While radio equipment has undergone many improvements, traffic departments have accomplished much in the organization and collection of business, and the number of equipments has greatly increased, little has been done to increase the efficiency of the operating staff. In former days the only question asked of a man applying for a position as wireless operator was, "Are you an operator?" Since the advent of the Government License it has been changed to "Have you a license?" An affirmative answer was and is, in the majority of cases, all that is required to secure the applicant his position. In some cases, this was necessary; and it will undoubtedly continue to be so inasmuch as it is not always possible to obtain a competent man at the particular moment that an operator is needed. It seems, however, that if the question of the training and selection of operators for radio service were handled in a manner more in accord with that followed by railroads, the deplorable condition that exists in some land and ship stations would be greatly improved. As all persons acquainted with the commercial development of radio communication in this country well know, a very chaotic state of affairs existed prior to the time that the Department of Commerce placed certain restrictions on radio equipment, operators, and methods of operating. After the matter of wave length restrictions has been more nearly adjusted to meet present conditions, I think it will be possible to say that as a whole conditions have been much improved.

As far as the operators are concerned, the Government examinations have weeded out many undesirable men from the service and consequently have raised the standard a little higher, but it must be borne in mind that the Department of Com-

* Presented before The Institute of Radio Engineers, New York, October 6th, 1915.

merce looks at the efficiency of the operator from a different point of view than should the commercial company if it is seeking the most suitable men. The requirements of the department are only a part of what good commercial service demands, tho in many cases a first grade license is all that is required or asked for.

As one man of my acquaintance, who employs a great many operators every year has stated in referring to the operators on his ships, "Some of these men cannot send, some of them cannot receive, some of them cannot adjust a detector, and some of them cannot tune." Such men as he refers to, that do little else than ride back and forth on the ships, are common in the radio service everywhere; and the excuse is made that it is difficult to find men who are good telegraphers and at the same time are capable of handling a radio set to the greatest advantage. This condition is the natural result of attempting to get efficiency out of men who have had no telegraphic experience or who have had no training in the use of commercial radio apparatus. I have known men whose highest aim in life was to be so expert a telegrapher that they could sit down and work any telegraph circuit at which they might be placed. On the other hand, there are radio operators who are interested only in the handling of the instruments; and again there are men who have no particular interest in any phase of the business, other than its outside attractions. Obviously none of these classes of men completely fill the requirements of a "good" operator, but this list includes practically all the available men, with few exceptions, who have not been specially trained.

A question then arises: what are the qualifications of a "good" operator. In the first place, he should be capable of transmitting signals clearly, accurately, and rapidly in either American Morse or Continental Morse. He should understand that any communication not only has to be sent but also to be received; and realizing this, he will space his characters and words so that they will be easily understood by the receiving operator. He should know when to repeat and when it is unnecessary, when to send slowly and when he may send faster. In receiving, he should be able to read almost any kind of sending, and to make a neat copy with either pen or typewriter regardless of whether he has interference to contend with or not. If he is capable of getting the most out of his instruments he must thoroly understand the principles which underlie their design. This knowledge must be so perfect and of so practical a nature

that he will know instantly what is needed in case of emergency or disaster. He must have a comprehensive knowledge of telegraphic tariffs, traffic, methods of routing, the location of various radio and telegraphic stations, etc., so that he can quickly determine in what way a message can be handled with the greatest dispatch and least expense. This will not only be an aid to him in procuring business but it will be of benefit to the general public with whom he deals. He must be ready and willing to perform the functions of his office at all times; and in every case he must be a gentleman.

Some of the qualifications enumerated involve inborn personal characteristics that are apart from any training that a school can give. Experience has shown that one phase of the work will appeal more strongly to one man than another and that it is seldom the case that a man of his own initiative becomes proficient in all the things essential to his work. I think it can be said, however, that given a man with average intelligence, willingness, and six months training in a well organized school; a proficient radio operator can be developed.

The object of this paper is briefly to outline the course in "Radio Telegraphy" as given at Dodge's Institute of Telegraphy at Valparaiso in Indiana, and to show some of the methods that are used in an effort to meet the requirements of a comprehensive training for radio operators or other persons interested in the art of radio communication. More than one-third of the students entering the school are enrolled in the Radio Department, and of this number about two-thirds also take the work in the Morse Department, thus familiarizing themselves with both codes. Aside from the special work in each of these departments all students are required to take a half hour's work in penmanship, under a competent instructor, each day. To anyone familiar with telegraphic work, the importance of this is apparent. The school is also equipped with a large number of typewriters so that the student may become proficient in copying directly from the circuits by this means. The greater portion of the students completing the course in Radio Telegraphy enter the service of the Marconi Wireless Telegraph Company with which company we have a working arrangement. Others of these students enter other commercial or government service.

As might be expected in an institution of this kind the student body is made up of all classes. The students are of all ages, and they come from all parts of the United States; many of them come even from foreign countries. Some of those who

enroll in the Radio Department, especially, are college graduates; many are high school graduates, while some of them have very meagre education. Altho we have no regular entrance requirements, as far as education is concerned, it is frequently the case that we are compelled to refuse the applicant because of his lack of elementary education. The average student is between eighteen and twenty years of age and has had two years of high school training. This is, of course, a desirable qualification, and I have found that those students who have had amateur experience together with the high school work are the most apt in mastering the radio work. This is due, of course, to their great interest in the radio field. Another class of men that invariably develop into excellent radio operators is drawn from the commercial and railroad fields. There is also a great variance in the ulterior motives of the different students. The majority of them, of course, expect to prepare themselves for service as commercial radio operators. However, we have many special students with entirely different objects in view. Among these are men from the armies and navies of foreign countries as well as some from the United States government service. We have other students who are interested in the subject from a scientific standpoint only, some who expect to teach the subject in other schools and colleges, and so on.

In arranging a course that will meet these varied conditions, numerous points had to be considered. In the first place, it is impossible in most cases for the student to remain in school for a period exceeding six months. This means that all the work relating to the subject must be covered within this time at most. In the second place, owing to the lack of preparatory training in electrical science, it is necessary to begin with the very principles of electricity; and considering the extent of such electrical knowledge that an operator should have, and the complexity of some electrical ideas, it requires a very careful selection of the subject matter in order that the course be made as comprehensive as possible. Many of the theories which underlie the working of radio apparatus, involve the principles of alternating currents, a subject which is usually taken up in the third or fourth year in engineering courses; and altho simple to an electrical engineer is very complex and difficult of explanation to a student who has no foundation for such work. Nevertheless, these ideas have to be covered in order that the student is eventually able to reason out many of the problems and questions that may present themselves sooner or later. In our work the students are not

shown lists of questions, the answers to which can be memorized, and their examinations are the result of actual knowledge of radio apparatus, its uses, merits, and failings. This, it appears, is the only possible manner in which a "good" operator can be trained so far as theory and manipulation of apparatus are concerned.*

In general, the theory, adjustment and operation of radio equipment is given in a series of lectures associated with laboratory work, which occupies three hours each forenoon, five days per week. The beginning class is held between 11 and 12, an intermediate class between 9 and 10, and the advanced class between 8 and 9. The hour between 10 and 11 is devoted to code practice. Other code classes are held from 1.30 to 3 P. M., 4 to 5 P. M., and 7 to 8 P. M. The penmanship class is held between 3.30 and 4 P. M. During the summer months, the evening session is discontinued. In describing the various parts of the course, I shall take up the code work first.

At the time the Department of Radio Telegraphy was established, the American Morse code was used almost exclusively in the radio service in this country, the South Wellfleet station being the only one that used Continental Morse extensively, so far as I am informed. With this condition existing, it was a simple matter to train a Morse operator to receive the same code thru telephone receivers. In the Morse Department of the school, there was and is every facility for training a student in Morse receiving where there are a great variety of speeds. A new student is started on a circuit where an instructor makes the characters of a letter and the student pronounces the letter; and as he becomes familiar with the combinations forming all the letters, he is advanced to a circuit on which short words are sent, which he calls off as he recognizes them. In this way a student is advanced from one circuit to another until he is receiving at a speed of twenty-five to thirty words per minute. On the more advanced circuits in the commercial and railway department, the instruction consists of commercial and railway messages or train orders. Examinations are held from time to

*One method of preparing a man for a government license, which I have been informed is used, is to furnish the student with a list of questions, such as are used by the inspectors in examining applicants for operators' licenses, together with the correct answer to each question. With such a list of questions and answers, it is a simple matter for a telegrapher to pass the examination as given by the Department of Commerce, provided he does not write down answer six for question five. Such a man is of course worthless in actual radio service altho he has nevertheless passed the requirements of the Department of Commerce.

time and the students making the fewest mistakes in their copies, which are marked with care, are advanced to higher circuits.

After a student who had enrolled in the radio course had progressed to the point where he could receive eighteen to twenty words per minute from a sounder, he was transferred to the radio code work. All such students were supplied with practice sets including a single slide tuning coil, detector, fixed condenser, head telephone receiver, and sufficient aluminum wire to construct an indoor antenna, as well as a key and buzzer mounted on a base board. An operator at the radio station in the school sent press matter at a speed of about fifteen words per minute for a period of an hour and a half or so, and at a faster speed for an equal period. Students, supplied with the small receiving sets which they had installed in their rooms, were supposed to spend the afternoon in copying these signals. This method was very good, in some respects, where the total number of students was small and where they were all able to receive ordinary Morse signals at a fair speed. They not only had the benefit of the code practice but they also had some practical experience in the adjustment of detectors and in tuning, which is, of course, a valuable part of an operator's training. On the other hand where students are depended upon to get their own practice in this way, they are very apt to waste a great deal of time and their progress is slow.

In the spring of 1913, the Department of Commerce regulations went into effect, calling for Continental code and examinations for licenses. It was evident that numerous changes would have to be made in the course of instruction in order that the students might receive the necessary and proper training. As a result a complete reorganization of the department was inaugurated. The Continental code is now taught exclusively in the Radio Department and the system used for many years in the Morse work is followed with the exception, of course, that all receiving is done with telephone receivers instead of by means of a sounder.

Ten code circuits, operated at various speeds, are used at the present time. On circuits 8, 9, and 10, which are the beginners' circuits open buzzers are used. An instructor sends letters singly on the lowest of these, and the student calls out the letter as he recognizes it. The student is not permitted to copy on paper at the start as it is found that he then invariably loses interest before he has accomplished anything. There is always

a little rivalry among the members of a group of new students as to which one will be the first to call off the letters as they are sent; and this urges them to use increased energy in mastering the first few days' work. As they become familiar with all the letters, figures, and characters prescribed for radio signaling the students are advanced to a higher circuit where they pronounce words. Inside of a few weeks or less, they are able to receive words sent at a rate of four or five per minute. The length of time required, of course, depends upon the natural aptitude of the student, and his application.

Figure 1 shows the general arrangement of the code and lecture room; the photograph, being taken from the instructor's desk does not, however, include the switch board and instruments

FIGURE 1

used in controlling the circuits. On circuits 1 to 7, all receiving is done thru double head telephone receivers similar to those used in commercial working. The transmitter or signal producing device used on all of these circuits consists of a buzzer, controlled by a telegraph key, having line wires connected to the terminals of the interrupter, a condenser being interposed in one or both of these. On circuits 3 to 7, there is one transmitter on each circuit, with telephone terminals bridged across the line wires for seven students. Circuits 1 and 2 are arranged in long

lines along the side of the code room, and each is divided into eight stations all of which are equipped with a buzzer transmitter, condenser and transfer switch for changing from sending to receiving. All of these circuits are connected with a Western Union switch board at the instructor's desk by means of which any one of the circuits may be connected with any other or any transmitter on the instructor's desk can be instantly connected, by means of a loop pin with any circuit. Or, in the same manner, a telephone transmitter may be connected with any circuit. The code speeds on circuits 7 to 1 are gradual variations from five or six words per minute on 7 to the highest speeds on circuits 1 and 2 which usually are connected together. Each of the buzzers on these circuits is separately adjusted so as to give out as good a note as possible, and it always happens that there are as many different tones as there are buzzers inasmuch as it is difficult to obtain a perfect tone from all. This I consider to be an extreme advantage, however, over the system used in some schools where one master vibrator or other audio frequency generating device is used as a source of power to supply all circuits. It is possible for a student to become so familiar with one spark frequency, especially if it is absolutely regular, that he will have great difficulty in copying commercial stations which have sparks varying in a more or less degree from the perfect tone. With the individual buzzer method, however, an experienced operator, when listening in on our faster circuits to the interchange of radio messages will not fail to recognize its true ring. Some of these student stations emit a high musical spark resembling the 500-cycle stations, while there are others of varying pitch down to the rough irregular spark such as is emitted by the old low frequency sets of the Shoemaker type. In fact nearly every condition of arcing or other irregularity in a commercial transmitter is automatically met.

To some this may appear to be a deplorable way in which to teach a student to copy telegraph code, but on further consideration it is evident that the student not having had a perfect spark to copy from at all times, has accustomed himself to just the conditions of regular commercial service. Altho the tendency is toward a universal use of musical sparks and apparatus with which such sparks can be readily and easily maintained, it will undoubtedly be a long time before the difficulties of tone adjustment will be done away with. Again, the moral effect of an irregular or rough spark is impressed upon the mind of the student. Some students of their own accord endeavor to get and

maintain a clear tone, while others are more or less indifferent. In any case, the advantages of the good tone are evident and a certain pride is ordinarily taken in maintaining such tones. (I have been told by old operators that our students can be recognized by the adjustment of their test buzzers.)

Another advantage of the individual buzzer arrangement is that the loudness of the different stations can be readily adjusted to any fixed value, assuming that the frequency of interruption is constant. As previously mentioned, a condenser is interposed between either one or both sides of the line and the buzzer, and by constructing these condensers so that they have different capacities, their impedences are different and hence different stations can be made to send out signals of different strengths. Some of the stations have adjustable condensers and hence have a ready means of "varying their power." At the instructor's desk, variable condensers are used so that the signal strength can be varied from just audibility to any desired value. Other methods of varying the signal strength in such circuits readily present themselves, but the method outlined above has proven to be the most satisfactory of any that I have tested. In any case it is exceedingly important that the practice signals be not too loud and it is desirable to have them of different strengths. It has been my experience that a student may become so proficient in the code work on the circuits, that he can copy the most complicated code and cipher messages from the fastest senders, but when placed in the radio receiving room he will be able to get but little of what is being sent. This is partly due to the fact that he may be practicing with too loud signals. Ability to read very faint signals from distant stations is largely a matter of ear training and for this reason it is desirable to have the practice signals quite weak. On the other hand, an operator who is accustomed to receiving such signals may become so confused by very loud signals that he will be unable to copy them.

Each station on circuits 1 and 2 is provided with four calls; that is, it represents four different ship or land stations and the operator at each of these places is expected to answer any one of these calls. Inasmuch as the international call letters assigned to commercial stations in this country, into the service of which most of our students go, are combinations beginning with W or K, each of the student stations has one call beginning with each of these letters. The two remaining calls are selected from those used in the United States Naval service or foreign stations, thus

giving a wide variety of combinations. Some of these calls are selected on account of the difficulty encountered in transmitting them, or again there may be two that are easily confused or wrongly interpreted by a receiving operator. Others admit of a rhythmical swing which experienced operators develop. Among the different stations and ships represented on these circuits are those at the principal ports on our sea coasts and on the Great Lakes and the vessels which are likely to be in communication with them. The instructor's desk answers to or uses any call not assigned to one of the student stations. Occasionally the entire system of calls is changed. It is thought that such a system as this trains the student to be quick to recognize as well as to send difficult or uncommon calls.

Practically all the code work on these faster circuits consists of message work, and such other communications as are actually carried between ships and radio stations. Everything is carried over these circuits in accordance with the provisions of the London Convention, the Marconi traffic regulations, and good judgment. Students are not permitted to converse over the circuit nor to carry on any conversation except where the exigency of the case demands it. Messages are sent from one station to another with proper prefixes and service instructions, being relayed where necessary and filed for future reference. As might be expected, a student is often tempted to give an O. K. on a message addressed to his station when a goodly portion of it is missing rather than to ask for a repetition or to say that he had not received it, and in order to circumvent this, nearly all the messages sent out from the instructor's desk are messages that call for answers or must be relayed. This proves to be a very satisfactory method of insuring that the communication has been actually received and soon the student ceases to commit such offenses. Sometimes a wrong check is purposely affixed to determine if the student will note this. The various ship stations send in their "T R" reports and positions which must conform to the practice of commercial stations; in fact, everything is handled as nearly in conformity with actual conditions as possible. Very little press is sent over these circuits as it not only gives the student a fictitious idea of his ability, but really furnishes little practice. In fact, I am convinced that it has a tendency to make him "guess" more than anything else, which is, of course, one of the worst habits that an operator can acquire. In case such material is sent over the circuits, it is generally an article having in it many uncommon words. In some instances

subjects in French, German or Spanish, or long lists of code or cipher words are sent in an endeavor to train the student to write down just what he receives, by sending such material that he is unable to form any advanced ideas.

Another failing common to many operators, which we have endeavored to overcome in our men, is the inability to read signals thru interference. There always has been more or less of this to contend with, but now that all commercial work is ordinarily carried on at the same wave length, or at best at a few wave lengths the confusion has become greater; and when severe atmospheric disturbances exist in addition, it taxes the ability of the operator to the utmost. The acquiring of ability or skill in reading signals under these conditions is a matter of patience and concentration of the mind on one particular tone; a faculty which can be developed by training. In order, in a measure, to duplicate the condition of interference and to bring out this faculty of copying under adverse conditions, I make it a practice at times to have an interfering transmitter, or possibly several, working on the same circuit at the same time the regular code practice is being carried on over this circuit. This is done an hour or so each day and the results are exceptional. Ordinarily an omnigraph or other automatic transmitter is used to operate the interfering buzzer, the strength of the signals being variable. However, at times two groups of students will be carrying on communication simultaneously on the same circuit.

For the regular code practice, no automatic transmitters or sending machines of any kind are used, altho we have a number of varieties; except that a day or two before the government inspector visits the school, the omnigraph is used in order that the applicant shall not be confused by its mechanical accuracy. Hand sending by expert radio operators is depended upon entirely. All students receive such instruction either one and a half or two hours per day depending upon which circuit they happen to be working and the state of their advancement. During such periods of the day as there is no instruction on the circuit the students send among themselves, each being assigned a certain part of an hour, the schedules being rigidly maintained.

It is generally considered that not all men can become expert senders, this being a natural qualification with some; but it has been our experience that nearly any person can become a good sender if he is taught the full arm "pump handle" movement and rigorously practices it. Slow sending, if heavy, distinct, and properly spaced is always better than light rapid

sending in the case of a new man. After he has once become a good sender, he easily acquires the speed which is essential in many cases. Taking operators as they are ordinarily found, better speed can generally be made and more business transacted in the same time, by sending good distinct characters at a speed of twenty or twenty-two words per minute than can be done by transmitting at a speed of twenty-eight or thirty words per minute. There is always a tendency for new men to endeavor to "burn up" some other operator by rapid sending and if he is a poor sender at best, a great deal of time is lost as a result. Our code circuits are fitted with good telegraph keys, some Western Union keys, and some heavier keys similar to those frequently found in radio stations; and students are urged to practice a correct method of sending on these during all their spare moments. In cases where a man is especially stiffened in the muscles of his forearm from manual labor, or in other cases, we insist on an hour or so of continuous sending every day. After a student has practiced a correct method of sending until he has become sufficiently competent to transmit signals clearly, accurately and without "breaking," he is allowed to operate the school station on field days. Students are always anxious to do this but good sending on the practice circuits is pre-requisite. In most cases a good sender is the result.

In the technical or theoretical phase of the work the first part of the course consists of a study of the elements of electricity and magnetism, emphasizing such points as relate directly to radio apparatus and abbreviating such matters as are not of first-hand importance. Following these more elementary subjects, the course is extended into a study of dynamo electric machinery, going only briefly into the theory of such apparatus, but giving special attention to the actual principles of the generation of current, the factors influencing the output, the function of the various parts, as well as the use, and care of such machines and methods of making tests and repairs. In connection with the study of alternating current machines the student is familiarized with terms common to alternating current operation (frequency, wave form, power factor, etc.), so that when the study of capacity and inductance has been taken up, the elements of alternating current problems will be less difficult. To facilitate the study of dynamo-electric machinery, the laboratory is equipped with a number of types of motor-generator sets used in radio service as well as various other A. C. and D. C. motors and generators of different capacities, together with starters, rheo-

stats and other auxiliary apparatus. Figure 2 is a view of the general laboratory which shows some of this equipment. In the foreground is a direct current generator, belted to a three-phase

FIGURE 2

induction motor, the set being used to supply direct current for operating the motor-generators and other direct current apparatus. The generator of this set is of very open construction and the terminals of all windings are brought to a connection block, making it a very convenient machine for demonstration work. Along the right hand side of the picture can be seen several radio transmitters, of different types, used for instruction and demonstration work. Along the wall to the left, not visible in the photograph, are cabinets containing various kinds of physical and electrical instruments, tuning devices, measuring instruments, and other apparatus useful in experimental work in radio telegraphy.

After completing that part of the work covering dynamo-electric machinery, a study of electro-magnetic induction is taken up, theoretically and experimentally. This is one subject upon which too much time cannot be spent and every effort is made to present the phenomena of inductance and self and mutual induction in such a manner that the student will get a clear conception of principles involved. The effects of self inductance

are discussed in their relation to the primary circuits of induction coils and transformers. In the explanation of mutual induction I have found the use of audio frequency currents, generated by a buzzer, very helpful, using induction coils or coupling coils in which one of the coils can be rotated with respect to the other. Use is also made of coupling transformers of all types common to radio service, the result of which is that the student looks at the principle rather than any one form of construction. Many other schemes used by instructors in physics can be used to advantage. This part of the course is concluded with a study of the practical construction of commercial induction coils and transformers such as are used in radio installations, here as elsewhere, attention being drawn to methods of testing and making temporary or permanent repairs.

Following this work the next part of the radio set that is studied is the condenser, it being considered in its various forms and constructions. An effort is made to give the student a clear insight into the principles which are involved in certain important phenomena. Methods of calculating the approximate capacities of different types are shown, and then the means of obtaining any desired value of capacity, with definite dielectric strength, by the combination of standard units is demonstrated. Emphasis in this case is laid on the methods by which the proper capacity in the condenser of a radio set can be obtained by re-arranging the separate units of the condenser which has been injured, thru breakdown or puncture, and the precautions which must be taken in thus using it. Methods of charging condensers as used in the closed circuit of transmitters and the necessity for and function of the spark gap are demonstrated; which leads to a study of oscillatory discharges.

It has been my experience that unless the theoretical work is varied or made attractive by the interposition of actual radio telegraphing, thus giving an actual demonstration of some of these theories, it often happens that the student will lose interest, with the result that he fails to grasp the very things which are most essential. At this point, then, a horizontal aerial is strung up a short distance from the ground thus constituting a very apparent air condenser, and an induction coil is connected thereto forming a plain aerial transmitter. With this arrangement signals or messages are sent to portable stations. Altho this type of transmitter is generally known to the student, the experiment proves an interesting diversion in which many of the practical difficulties encountered in the operation of such sets

with large induction coils, and their remedies, can be easily demonstrated and in a forcible manner.

Just at this point, when the student has in mind the oscillations of the current in this plain aerial transmitter and the radiation of electric waves, I have found it to be a very opportune time to go ahead with the explanation of the terms period and frequency, and their relation to wave length. With an aerial 100 feet long, all of which is visible, the student can be made almost to see the oscillation running out to the end of that wire and returning in a given time, and if the wire is longer that it will take a greater length of time for the complete oscillation.

After concluding the study of plain aerial transmitters, with stress laid on the limiting quantity of charge that can be converted into radio frequency energy in consequence of the small capacity of the aerial, the work naturally leads into the study of coupled transmitters wherein much larger capacities can be used. With an understanding of oscillatory currents already acquired, the effects of the constants of the closed circuit on the wave length are quite apparent. I have found that a study of wave lengths in a circuit which does not radiate waves, leads to much confusion and lack of understanding hence the reason for a consideration of wave length in connection with the plain aerial transmitter first.

During that part of the work covering closed circuits of the transmitter, I assume a circuit having a condenser of a certain capacity about which is shunted an inductance of some twenty turns. It is stated that the wave length using say two turns is 300 meters. The inductance of the helix per turn is then calculated, and the results tabulated. The student then calculates the wave length with the movable clip on each of the twenty turns and enters this data in his tabulation after which attention is invited to the fact that the wave length varies as the square of the number of turns. From this it is apparent that in case he was working on a ship and for any reason was required to change his wave length say from 300 to 600 meters the position of the clips would be instantly known, with fair approximation, without the use of a wave meter or other device. In like manner, the effect of the condenser capacity on the wave length is demonstrated; and cases are assumed wherein a portion of the condenser is damaged and the use of half of the condenser with a definite increase in the inductance will give the wave length required, this to be obtained without the use of measuring instruments. It is a well known fact that the majority of operators,

after having once located a 600-meter adjustment on their receiving tuners, actually do very little tuning, and in case of accident to a ship or its radio equipment, it is very necessary that the operator on such a ship should be able to maintain his apparatus in such a condition that he can send on a wave very nearly 600 meters in length. In cases where the distance is great, this may be of extreme importance. Close coupling will not answer in all cases and hence an endeavor is made to give the student a knowledge of the best and quickest way in which to meet such conditions (to say nothing of the value which such information is to him at all other times). In order to verify the calculations and to bring the facts more emphatically to mind, the wave length at each adjustment is measured in the laboratory by means of a wave meter and the results are tabulated along with the calculated values in the note book which every student keeps. The results of such measurement are also reproduced in curves.

Following this work, means for transferring the oscillating energy to the radiating circuit and the conditions under which the greatest current is produced in the antenna are taken up and explained. Various methods are demonstrated in the laboratory for indicating the maximum antenna current, so that an operator will have some way of determining if his antenna is radiating the maximum amount of energy whether he has an approved hot wire ammeter or not. In the study of resonance between an oscillating circuit and an oscillating E. M. F., no attempt is made to avoid the actual alternating current principles which determine the strength of current that will flow in a circuit containing resistance, inductance and capacity. Once this idea is formed in the mind of a student a great many questions such as resonance phenomena in the audio frequency circuits, the use and proper capacity of telephone condensers in receivers, etc., are readily understood. In any case of this kind, the general theory is explained and then demonstrated by experiment. After demonstrating the tuning of the open and closed circuits in different ways the effects of re-transference of energy between them and the production of two wave lengths are brought out. Here, as in many other cases, it is necessary to exaggerate the fact in order to make the desired impression, and for this purpose we have some special apparatus with which it is possible to produce two wave lengths differing from each other by several hundred meters, with the two circuits tuned to an intermediate value.

At this point we take up the study of spark gaps especially

the quenched gap which, when placed in the primary circuit of the above coupled system, serves to demonstrate the quenching action in a forcible manner. I have constructed a small quenched gap having ten sections which quenches perfectly operating on 60-cycle current in connection with a one-fourth kilowatt leakage transformer. An attempt to measure the wave length of the circuit in which it is contained shows a very flat wave having a decrement that is difficult to determine. This is shown mounted on a small panel set (Figure 2) which was built for some experimental work in transmitting on low antennas.

The work in transmitting sets is concluded with a study of several standard sets that are in commercial use, showing the inter-relation of the various parts and auxiliary apparatus such as meters, circuit breakers, antenna switches, etc. One of the sets that we have permanently installed in the school is a Marconi 2-kilowatt, 240-cycle set which was loaned to us thru the courtesy of Mr. John Bottomley. This set is complete with storage battery-induction coil auxiliary set, and receiver. Several other complete sets of composite type are also installed. Figure 3 is a view of the radio station showing the Marconi

FIGURE 3

2-kilowatt, 240-cycle transmitter, the storage battery auxiliary transmitter, switch boards, and various types of receiving apparatus.

During the course, about one week's time is spent on storage battery work in which are set forth the details of types common in radio service, their care, methods of charging, etc. Some circuits applicable to emergency ship lighting are also shown.

In taking up the study of receiving circuits and receiving apparatus, we begin with a review of the principles of resonance, again emphasizing the factors which determine the impedance; wherein it is seen that the alternating E. M. F. produced in the antenna by the passage of a wave train can only produce a maximum current in the antenna to earth circuit when the inductance and capacity of that circuit bear a definite relation to each other. Therefore, in order that this circuit shall be adjusted so as to have a low impedance, its capacity and inductance must be made variable by the insertion of a variable condenser and a tuning coil at its earthed end. Before progressing farther into the theory of tuning, it is necessary to consider the action of some detector, such as a crystal rectifier, stating its function and the actual reason for its use. After this has been done, a detector can be included in our antenna circuit and we have the elements of the simplest form of receiving circuit. It is shown experimentally and theoretically how this circuit can be so adjusted that it will respond to waves of widely differing length; and then how it can be further adjusted so that it will respond only to frequencies which are very near to that to which it is tuned. Such a receiver is then compared with a standard receiver as to selectivity and strength of signals, which readily demonstrates its disadvantages. The next improvement on this simple outfit, the close coupled tuner is taken up in the same manner, theoretically and experimentally. In connection with this type of receiver, reference is made to commercial tuners embodying this principle, such as the Type "D" tuner of the United Wireless Telegraph Company, many of which are still in use. Every student, tho generally much to his displeasure at first, is required to use one of these tuners in the radio receiving room until he becomes familiar with its use and possibilities.

After the study of closely coupled receiving sets, and the various methods involving a direct coupling, their advantages and disadvantages, loose or inductively coupled receivers are taken up; first in an elementary way, and then in connection with regular receiving sets. Our laboratory is well equipped with tuning apparatus of various kinds so that quite an opportunity is offered for setting up any standard circuit, or most special circuits. Specific instructions in the use of commercial tuners,

such as are used by the commercial companies, follow the theoretical circuits. A great many operators in commercial service are incapable of getting the most out of their receiving sets; and especially is this true in the case of some of the more complicated receivers involving intermediate circuits or special tuning apparatus. In order to train the student to make the most of the facilities at hand and to give him an actual knowledge of the use of such apparatus, I have used the following scheme with success. The tuner or receiving circuit under test is connected to an antenna in the usual manner or to a dummy antenna in which are induced sharply tuned oscillations from a wave meter excited by a buzzer operated by an omnigraph. With the wave meter in operation, the student adjusts the receiver as broadly as possible, thus picking up the signals; after which he tunes for selectivity, and readjusts for the optimum results. After he has become familiar with the various adjustments several wave meter transmitters differing more or less in wave length are simultaneously operated, all being inductively related to the antenna or dummy antenna. A student will send with one of these transmitters while the one manipulating the receiver will endeavor to separate his signals from the interfering signals. In a short time the student becomes quite adept in tuning, and is able to meet many of the difficulties encountered in practice.

In the study of detectors, many of the common types are included, tho the most emphasis is laid on those of the crystal rectifying type inasmuch as they are the ones most used in commercial service at the present time. A great deal of stress is laid on the use of carborundum, which is probably more used and more reliable than any other detector. In much the same manner that a student becomes apathetic toward the Type "D" tuner, he becomes averse to the use of carborundum for reasons which are well known, but if he is supplied with a suitable potentiometer and a large collection of these crystals, he can generally be convinced that this form of detector has some merits. Every student, during the course, spends several hours testing crystals. The laboratory is equipped with a large number of detector stands, potentiometers, and tuners fitted for the use of these crystals, and in using these he gains an idea of the correct method of using such detectors, and eventually has more confidence in them.

One forenoon each week, a special class is held at which all students in the radio work are in attendance. This period is devoted to the discussion and study of radio law, the international

regulations, traffic rates, method of computing charges, and similar matters. On some occasions, classes in geography are held at this hour, and maps of the radio districts are studied, steamship lines and routes pointed out, location of radio stations noted, and so on. Each student is required to learn the name of every passenger steamship line on the Great Lakes, the names of their vessels, their runs, call letters, and stations with which they are likely to be in communication. This information is of great value to a new operator, and requires very little time to learn. Some students take a great interest in this work.

Altho our station license is an experimental license and calls for no specific hours of service, we have certain hours during which we always have one or more men on duty in the receiving room, where they get a great deal of practical experience. The requirements as to the matter of maintaining a continuous watch during the time that is assigned to a student are strict, the result of which is that the man acquires a sense of duty so that he is much more apt to realize the importance of his position after he is actually in the service. A complete log is kept of everything that transpires, and all messages are copied and filed. These later are sorted out and entered on report blanks such as are used by the commercial companies and which are furnished by them for this purpose. In fact, the business of the station, in every particular, is handled by the students in a manner as nearly in conformity with commercial practice as is possible. In rating students for positions their record in the receiving room, and number and completeness of the messages copied are taken into consideration.

The receiving room is well equipped with commercial tuners and some special receivers and other receiving apparatus. In the laboratory we have apparatus for receiving undamped, continuous wave stations as well as spark stations, and tuning apparatus for waves as long as 14,000 meters. Most of the equipment in the receiving room is commercial apparatus, while the experimental apparatus is used in the laboratory station. Figure 4 is a photograph in the laboratory receiving room, showing some special receiving apparatus used in research work. At the right is seen a long wave receiving coupling and on the left is a continuous wave generator which was built for testing receivers for undamped waves. It can also be used as a generator for heterodyne receiving. A radio-telephone, with which some experimental work has been done, can be seen in the foreground

on the left. Any transmitter in the laboratory can be controlled from this room.

For the regular station work, we have a standard six wire aerial, supported on a 100-foot (31 meter) steel tower, brought down to a mast on the building. In connection with the labo-

FIGURE 4

ratory apparatus, we have a smaller four wire aerial and a long single wire antenna, used principally for long wave reception. With the arrangement of these different aerials and certain apparatus, it is possible to have several groups of students receiving simultaneously without mutual interference. Ordinarily we have two well-advanced operators on duty in the station from 8 A. M. until midnight; however, in case of severe storms over the lake region, a continuous watch is maintained.

Another interesting feature of the work in the radio course is the so-called "field work." One afternoon each week, when the weather conditions permit, the students are divided up into parties of four to eight and supplied with portable receiving sets or complete field sets which are taken out into the surrounding country and set up. Aerials are erected on poles provided for the purpose or put up on high trees. Occasionally a kite will be used to elevate an aluminum wire or a small boat on one of the nearby lakes will be equipped with a small sending and receiving

set. Figure 5 shows a field station, in the charge of a group of students, with which they are in communication with the station at the school. As will be seen this set includes both transmitter and receiver, and when the aerial is elevated to a suitable height,

FIGURE 5

it has a range of several miles. It can be used either as a "plain aerial" set or directly coupled, radiating about half an ampere either way when properly tuned.

Communication is established between these field stations and the school, where an operator is maintained. During the course of such work aerial construction, methods of quickly putting up an emergency aerial, and the importance of good earth connections are demonstrated in an interesting and forcible manner. I have also found this to be an excellent manner in which to combine practical detector adjustment, tuning and wiring up of apparatus. Many interesting experiments that can be performed in the open country readily present themselves, all of which are of advantage in an operator's training. The effects of broad and sharp waves, necessity of tuning, and the

advantages of high spark frequencies and so on are readily set forth in an interesting manner.

For the benefit of special students or those who are particularly interested, we have a somewhat more advanced course in electrical and radio engineering subjects including radio telegraphic measurements and theories. The extent of this work, at the present time, is limited owing to a lack of necessary equipment, but at the same time it offers some advantages to those students who are ambitious and desirous of extending their knowledge of the art of radio communication.

During the coming fall it is our plan to erect a second steel tower 175 feet (54 meters) high at a distance of 400 feet (123 meters) from our present tower. It is also expected that we will add considerably to our electrical equipment at that time.

SUMMARY: The qualifications of a "good" operator are divided into inborn and acquired or teachable characteristics. A course of training for radio operators is then discussed in detail. The entrance requirements and objects of the students are considered, and the subject matter of the course is given.

1. **OPERATING DIVISION.** Students are taught to receive on buzzer-excited circuits, using head band telephone receivers. A number of circuits of gradually increasing speed and difficulty are provided. Different tones and intensities of signals are provided to accustom the student to actual conditions. All messages sent between student stations are in accordance with the radio laws and commercial practice. Messages must generally be checked and relayed by the student. Artificial interference is provided to teach reading of desired message thru such interference.

2. **TECHNICAL DIVISION.** The elementary principles of electricity and magnetism and the study of dynamo-electric machinery are given. Inductance, mutual inductance, capacity, wave length and frequency are studied, together with methods for their predetermination by calculation. Resonance phenomena are shown. Different types of commercial receivers and crystal detectors are tested. Field work is done with portable transmitting and receiving sets. Some facilities for research work are provided.

3. **TRAFFIC DIVISION.** The radio law, international regulations, geography and other material of value to operators are taught by lecture. Work in penmanship is obligatory.