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THE RADIO OPERATOR PROBLEM.*

By

V. Ford Greaves,

Radio Engineer, Department of Commerce.

It has been my good fortune during the past few years to hear some excellent papers read on radio engineering subjects, and the allied arts, by prominent engineers and scientists of a professional standing recognized here and abroad. I have always been particularly interested in the discussions and I am convinced that no matter what the subject, who the author, nor how convincing the conclusions, there is usually to be found in the audience an honest difference of opinion on at least one point and sometimes several. In this lies the value of these meetings. Then, too, in this day and age of trained minds, the specialist often receives valuable hints and suggestions from interested workers in other lines.

This leads to the question, "What is an exact science, and when may one be justified in making a positive statement?" Surely arithmetic may be so classed, altho there may be doubt as to the status of some of the branches of higher mathematics as applied to the arts and sciences. We regret that at present medicine and surgery are not exact sciences.

The art of "Radio Communication" is comparatively new. Convinced by the marked consistency and steady agreements of researches conducted in this field during the past few years, I believe we are all satisfied that a certain portion of radio engineering, at least, may be classified under the heading of an "exact science."

Radio engineering as a whole may not be termed an "exact science" so long as the radio operating element enters as such an important factor. This thought occurred to me repeatedly on hearing eminent radio experts lament operating difficulties.

There are several phases of the operator problem. Three of the most important of these are proficiency in the use of the

* Delivered before The Institute of Radio Engineers, Washington Section; May 20th, 1914.

code, skill in the care and adjustment of the apparatus, and reliability in an emergency.

The requirements of the Naval Radio Service are, of course, most exacting. They include speed in operating, a knowledge of comparatively complicated apparatus, and personal reliability under severe circumstances, including the possibility of disaster in time of peace and of operating under fire in time of war.

Commercial operators are not as a rule required to change their wave lengths nor to make adjustments. A corps of engineers, inspectors and repairmen are maintained at important ports to make necessary adjustments and repairs. However, a certain knowledge of the connections and adjustment is very important and the law requires commercial operators to have this knowledge.

To the extent that "Safety at Sea" depends upon the radio operator, speed is not particularly important, altho it may be desirable under certain circumstances. All operators, of course, can send and receive slowly. To the commercial companies, so far as traffic is concerned, speed is the essential consideration.

The Signal Corps of the Army, the Revenue Cutter Service, and a few other Government departments employing radio operators have certain other special requirements.

Therefore, several phases of the operator problem must be studied. These are operating speed; knowledge of the care and adjustment of the apparatus; and dependability. Possibly we must consider also such a knowledge of the traffic laws and regulations as is essential to reduce interference.

My connection with the Bureau of Navigation has given me an excellent opportunity to study the problem, as I have had several hundred operators' examination papers available from which to draw conclusions and to estimate averages.

OPERATING SPEED.

Let us first consider the question of operating speed.

I am fully satisfied, and I believe experienced inspectors will agree with me, that speed in operating is somewhat of a talent. It is a much more simple engineering problem to force oscillations in a circuit than to force an ungifted individual thru an operator's training school.

We are all more or less familiar with the comparatively simple duties of the "land line operator," which simplicity probably accounts for the excess of average speed of land line transmission as compared to radio transmission.

The land line operator has to deal with very simple apparatus requiring little or no adjustment. He does not have interference to contend with, nor faint and variable signals. The "spark frequency" produced by a "sounder" is the same for all instruments and under all conditions—and, in this country, he uses American Morse code.

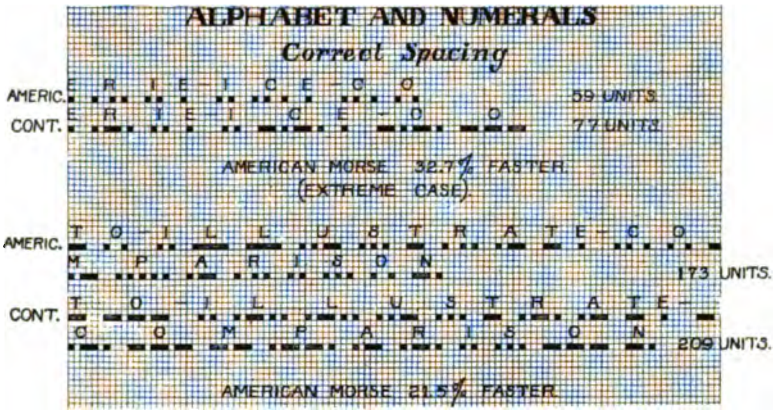

FIGURE 1

As regards the American Morse code, I may state that I am a strong champion of the American Morse code for radio work, altho I am compelled to bow to the overwhelming majority in favor of the Continental Morse. The necessity for a universal radio code is, of course, apparent to all.

However, a few comparisons that I have made between the two codes may be of interest.

TABLE.

CONTINENTAL MORSE.

One dot is the unit of time.
A dash is equal to three dots.
The space between parts of the same letter is equal to one dot.
The space between two letters is equal to three dots.
The space between two words is equal to five dots.

AMERICAN MORSE.

The space in spaced letters is equal to two dots.
The letter L is equal to two dashes.
Zero is equal to three dashes.

Hence, including the letters and numerals only, and allowing three units space between each letter:

American Morse = 394 dots (for the alphabet).

Continental Morse = 460 dots.

Therefore, as a whole, the American Morse is about 16.7 per cent. faster than Continental for the same degree of skill. In ordinary use it is probably about 20 per cent. faster. This is illustrated in Figure 1.

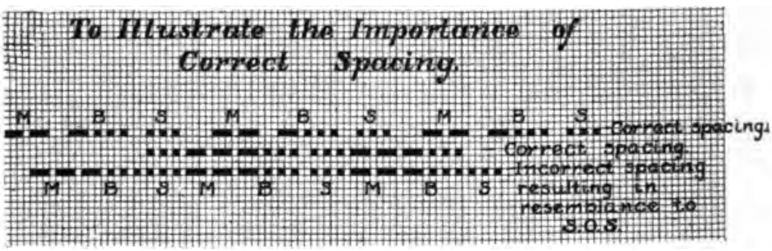

FIGURE 2

I believe the principal objection to the American code for radio purposes is the assumed possibility of confusion in the reception of the "spaced" letters, which may be caused by "static." To this objection, I do not agree. It seems to me that the chances are about equal of static making an "S" out of the American Morse "O"; or an "H" out of the American Morse "C," or an "R" and "S" out of the Continental "I"; etc. The same reasoning applies to static dashes. Compare Figure 2.

I have said that I believe good operating is something of a talent. If this be true, I may then be permitted to state my belief in the superior attractiveness of American Morse. To my mind, the American Morse code is more *artistic* than the Continental. It has more rhythm and seems to be more graceful and better balanced. However, I shall not press this point. The law provides for the use of the Continental code, and we are law abiding citizens.

Experience has shown that skilled land line operators make the best radio operators even when compelled to use the Continental code. Operators of shore stations are usually required to be familiar with both codes so as to operate both the radio apparatus and the land line connection. It is found that the land line operator acquires skill in the use of the Continental code as used in radiotelegraphy much more readily than the radio operator can pick up the use of the sounder, altho the difficulty of the differences between the two codes are about equal, only eleven of the letters being different. This may be accounted for by the fact that a long "buzz" is a much clearer representation of a dash than the double click of a sounder.

It may appear at first thought that the examination of operators to determine their speed in receiving is a very simple matter and this is so if certain precautions are taken. We have often heard that skilled operators recognize each other by their "style" of sending (or "fist," which, I believe, is the operator's term). Some expert operators have told me that there is almost as much individuality to the "style" of sending as to handwriting. This can be shown in a few moments by means of the Omnigraph.

Such individual differences being existent, the examination of operators in code should not be conducted by means of hand sending if consistency and uniformity are important.

Some claim that an operator, to be entitled to a license, should be able to receive the sort of erratic sending which he may encounter in practice and that the test should be conducted by hand. But such a rule is too flexible. An operator may time himself to send twenty words in one minute, but part of the time he may have sent at the rate of twenty-five words per minute and part at fifteen. With a view to uniformity and consistency at the several examining offices, the Bureau of Navigation adopted an automatic machine sender called the Omnigraph. The signals are cut on dials and the spacing is theoretically correct. The clock works are provided with a governor so that the speed may be maintained uniformly at the desired number of words per minute. Another adjustment is also provided which permits of a certain variation in the "style" of sending. We can thus supply the difference between the "short dot, jerky style" of the amateur and the "long dot, paralytic style" of the practised professional.

Some operators have objected to being examined by means of the Omnigraph; stating that whereas they could receive twenty words a minute if the sending were by hand, they could not copy signals from the Omnigraph at that speed. In one case it was found that the reason the operator could not read the Omnigraph signals was because of the confusing echoes, due to reverberation in the room of the sounds set up by the buzzer. The instrument was taken out of doors and the difficulty disappeared. This difficulty is easily obviated indoors by shunting a pair of telephones and condenser about a small resistance in the "buzzer circuit" as shown in Figure 3.

It seems to be advantageous to let the buzzer operate continuously, and to connect the Omnigraph in series with the telephone circuit.

Other complaints against the Omnigraph have been found to be due to more or less psychological reasons, such as nervousness and prejudice. Several experiments have been conducted with a view to eliminating complaints of this nature. The Omnigraph and a key have been mounted in one room and the telephone circuit extended into another. An expert operator has been employed to send by hand. By a switching device the

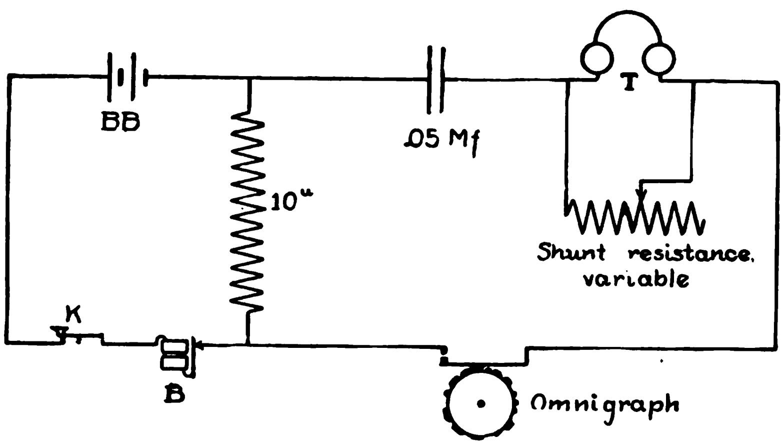

FIGURE 3

telephone circuit could be alternated between the Omnigraph and the hand key. In these experiments more than half of the operators who had previously objected to the Omnigraph stated that the Omnigraph was the better sender. The rest agreed that they could not tell the difference, and not in a single instance did an operator select the hand sending as the better. This experiment has been repeated several times in different parts of the country by different persons with practically the same results.

The Bureau of Navigation is therefore satisfied that the Omnigraph, or a similar machine, is very satisfactory and is fair to all as a means of conducting the code test.

The Bureau of Navigation General Letter No. 69, of April 10, 1914, provides:

"CONTINENTAL MORSE CODE TEST."

"The test shall consist of messages with call letters and regular preambles; conventional signals and abbreviations and odd phrases; and shall in no case consist of simple, connected reading matter. The test will be conducted by means of the omnigraph or other automatic instrument wherever possible.

"The test shall continue for five minutes at the speed of 20 words, 12 words and 5 words per minute, respectively, for commercial first, second, and lower grades, and to qualify, the applicant must receive correctly, 20, 12, or 5 words in consecutive order."

At 20 words per minute this is equivalent to giving an applicant five trials to make 100 per cent. in any one trial.

We will now pass on to a consideration of the technical knowledge desirable in a radio operator.

TECHNICAL KNOWLEDGE.

Examinations at best are unsatisfactory in many particulars. The desired aim may be accomplished on the average, but the injustice or excessive leniency sometimes shown are frequently very discouraging. Furthermore, the examiner usually feels that the examination he has prepared is too easy, and the operator usually complains that it is too hard.

In connection with the system of examinations of commercial radio operators for licenses, the Bureau of Navigation has received many compliments, complaints, criticisms and suggestions, all of which have been valuable. Some have suggested the elimination of any written examination; and advised depending upon oral questions and a practical demonstration to determine an applicant's qualifications.

This might be very successful if only one or two persons could conduct all the examinations, but where there are twenty or thirty persons conducting the examinations the personal element and individuality are found to vary to such a large extent as to render the suggested scheme impracticable even tho the desired results might be obtained by the two methods proposed. Furthermore, it is difficult to keep a record of oral and practical examinations and an exact record is valuable and necessary for later reference, in case of investigation or court proceedings.

Some have suggested that an applicant for commercial operator's license should be over 21 years of age; should have had a certain amount of practical experience at sea; should be examined physically as to hearing, etc.; should be considered as to his morals and submit evidence of good character; and should be examined to determine "coolheadedness" and dependability in time of disaster or peril.

Some of these points are of course very difficult to determine, but granting that by some skilful method a man is found who qualifies in each, he is no longer a radio operator. He has been promoted from the operating rank to the position of installer, repair man, inspector, engineer or superintendent (commanding a salary anywhere from $1,000 to $5,000 per annum). We must bear in mind that the position of radio operator is the starting place in the practical field of radiotelegraphy.

The question of age I will discuss a little later. As to practical experience at sea, it is very difficult to see how the many hundred operators required can obtain it. A few schoolboys, of course, can arrange to take trips during the summer, on certain classes of vessels which are only required to have one first or second grade operator, but the young man who expects to depend upon operating for his living can hardly afford to make such trips on little or no pay.

As to dependability in time of disaster or peril, I do not believe this can be determined by any examination nor should the judgment of a keen observer of human character be relied upon; as personality enters to such an extent as to preclude even a fair degree of consistency.

In the Department of Commerce Regulations made pursuant to the radio laws, the stand is taken that so far as the law is concerned the qualifications of an operator can be determined by a code test and a written examination without oral questions or demonstration of adjustment of apparatus.

A company or individual employing a radio operator may be reasonably expected to determine special qualifications desired in an employee such as personal habits, morals, and whether or not he is subject to seasickness.

The present system of examination recently instituted at all the commercial radio operators' examining offices is based upon two years' experience with the problem. Many valuable suggestions from officers and experts of other Government Departments and Bureaus are incorporated. Lieutenant Commander Hepburn of the Navy Department and Mr. F. A. Kolster of the Bureau of Standards have been particularly interested in the problem. Their advice has proven extremely sound.

The examination is conducted under the following headings and values:—

		Points Maximum value.
1.	Experience	20
2.	Diagram of Receiving and Transmitting Apparatus	10
3.	Knowledge of Transmitting Apparatus	20
4.	Knowledge of Receiving Apparatus	20
5.	Knowledge of Operation and Care of Storage Batteries	10
6.	Knowledge of Motors and Generators	10
7.	Knowledge of International Regulations Governing Radio Communication, and the United States Radio Laws and Regulations	10
	Total	100

75 constitutes a passing mark for first-grade commercial.
65 constitutes a passing mark for second-grade commercial.

Experience operating either amateur apparatus or the apparatus provided in good operator training schools, or experience as apprentice at commercial shore stations and in ship stations is given an appropriate value.

The questions concerning the adjustments and functioning of the apparatus are intended to be so worded as to preclude the possibility of an undesirable applicant being especially primed for the examination. It is believed that the total number of questions so completely cover the whole field, so far as the operator is concerned, that there is little danger of applicants becoming familiar with the specific questions thru their frequent repetition. The questions are divided into several groups and an applicant cannot, of course, be especially primed for any one group.

I have heard complaints that some of the questions can be answered in a few words without developing the meaning of the answer if the applicant really understands his own answer. To a certain extent this cannot be helped. A question is more or less of a hint and an applicant is expected to state clearly his full knowledge of the subject. There is the further danger of long questions containing the answer.

(Some of the answers to questions which have come to my attention are amusing. For instance:—

Question: What is the effect of increasing the coupling? Answer. The coils are closer together.

Question: What are the advantages of the quenched spark gap? Answer. It is better. Etc.)

The theoretically ideal examination consists of one question, "What do you know about radio apparatus?", but such a question is, of course, not practicable.

The questions will, however, be revised from time to time. Applicants who fail to qualify will not be re-examined within three months. As there is no fee attached to the examination, it has been found that many incompetent operators try the examination frequently to see if they can accidentally pass. Others desire to become familiar with the system and questions. It is believed that the three months' clause in the regulations will thus eliminate a great deal of unnecessary work on the part of examining officers and result in applicants being more thoroly prepared before attempting the examination. The records show that under the old system only one applicant out of nine qualified. That is counting each examination of those who made several attempts to pass, many of whom finally procured licenses.

All examination papers, whether the applicant qualifies or not, are filed in the Bureau of Navigation in an individual record of the operator.

AGE.

Several persons have suggested that the law should specify a minimum age limit for commercial radio operators, especially for shipboard work. Such a law might have certain advantages but would be difficult to enforce.

If, for instance, a minimum age of 18 were fixed, we all know that a great many excellent operators would be disqualified, and many undesirable candidates would not hesitate to overstate their age, even under oath. This latter statement is known to be a regrettable fact and is substantiated by statistics of services in which a minimum age is specified, even tho a severe penalty for false statement of age is provided. It is not practicable to search out birth certificates of several thousand men per year.

After all, so far as existing conditions are concerned, the question of age seems to have adjusted itself quite satisfactorily, and in this, as before, the person employing an operator may be expected to employ older men for the more responsible positions.

There are a few boys 15 years of age holding commercial first-grade licenses, but from a search of inspection records on file in the Bureau of Navigation it does not appear that any of these are employed at commercial stations or on ships as senior operators.

We give herewith a chart and a curve showing the ages of licensed operators, commercial first and second grades.

Figure 4

DEPARTMENT OF COMMERCE,

Bureau of Navigation, Radio Service.

Washington, February 28, 1914.

COMMERCIAL WIRELESS OPERATORS.

The following tables show the number of commercial radio operators and their ages at the time licenses were issued by the Secretary of Commerce.

Of the first-grade operators 57 per cent. were 21 years of age or older, while 83 per cent. were 18 or older.

Of the second-grade operators 49 per cent. were 21 years of age or older, while 75 per cent. were 18 or older.

Of both grades 82 per cent. were 18 years of age or older.

First-grade Operators.

Ages	Graphic	Number
21 or older		1,197
20		244
19		293
18		197
17		119
16		36
15 or under		13
Total		2,099

Second-grade Operators.

Ages	Graphic	Number
21 or older		120
20		29
19		38
18		23
17		18
16		13
15 or under		6
Total		247
Grand total both grades		2,346

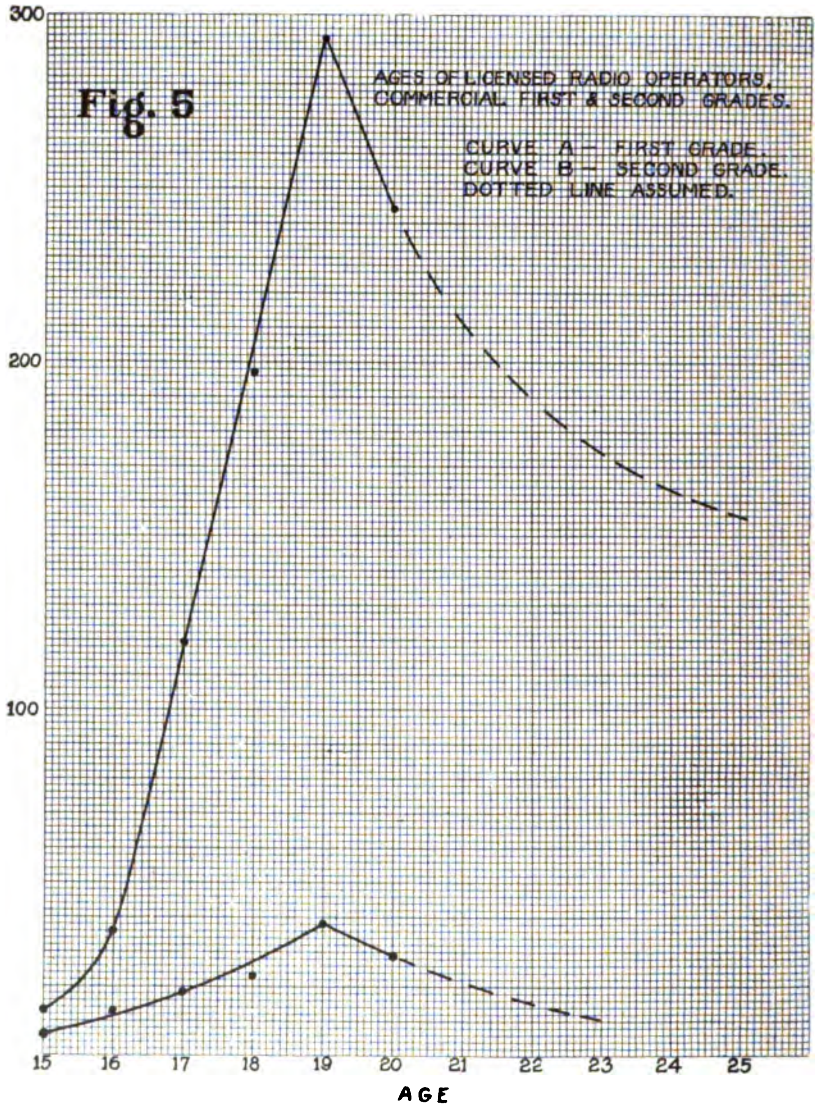

Fig. 5
AGES OF LICENSED RADIO OPERATORS,
COMMERCIAL FIRST & SECOND GRADES.
CURVE A — FIRST GRADE.
CURVE B — SECOND GRADE.
DOTTED LINE ASSUMED.
300
200
100
15
16
17
18
19
20
21
22
23
24
25
AGE

It is interesting to note that most of the operators are 19 years of age. This is true of both the first and second grades. It is assumed that if the number 21 years of age and above were shown, the curve would drop down from 19 as indicated at 20.

The maximum at 19 may be accounted for if we assume that "wild oats" are usually ripe at about that age. I think that most young men who are suddenly imbued with a desire to leave home for a career at sea as radio operators are about 19 years of age. (Such was my own personal experience and while I do not advocate or approve of young men leaving school at this age, unless necessary, I believe the radio operating field offers such young men much better opportunities than many other lines of work that they might follow.) There may be other interesting psychological reasons accounting for this age maximum.

CONCLUSION.

We all know that there are good operators and some bad operators holding first-grade licenses who all passed the prescribed examination. There are also good physicians and some decidedly inefficient physicians practicing under licenses. I do not believe any examination can be devised which will bring out certain points as well as experience and practice.

As a recognition of experience, trustworthiness and efficient service the Department of Commerce now issues a special license known as "Commercial Extra First Grade" which is explained in Bureau of Navigation General Letter No. 69.

It is true that the successful operation of a radio station and to a large extent the range, depends a great deal upon the skill and experience of the operator. It is regretted that more experienced operators are not available. The dearth of experienced men as operators, especially for shipboard service may be due largely to the fact that the radio field is comparatively new and rapidly growing, and experienced men are often promoted to the higher positions mentioned previously. It is true that in the United States there are more than twice as many operators holding commercial first-grade licenses as there are operators employed as such. A cursory glance at the record seems to indicate that many radio employees holding higher positions maintain their operator's licenses for use in case of necessity, or as a matter of personal interest. Also a number of skilled and experienced amateurs not seeking employment have obtained commercial operators' licenses in connection with their small stations.

As I have mentioned before, the position of radio operator is the starting position in the radio field. Considering the rapidly increasing demand for radio operators I think it is really quite remarkable, on the whole, that the present standard of efficiency has been attained.

I believe operators are frequently held accountable for troubles and difficulties, the causes of which were entirely beyond their control, or the remedies for which requires a knowledge not warranted by the remuneration. It is a tedious and tiresome task to sit with telephones over one's ears by the hour, especially when there is no traffic, always on the alert for an emergency. Such service may mean long hours without sleep and even the loss of life.

Operators should be given opportunity to study, and special arrangements should be made to instruct them in the care, adjustment, and theory of the apparatus under actual service conditions.

They should be taught and required to comply strictly with all the rules and regulations, but this should be accomplished in a skilful manner without creating antagonism.

As the art advances improvements in the design of apparatus are being disclosed with a view to reducing and simplifying the adjustments which must necessarily be made by the operator. In connection with such improvements, I take this opportunity to protest against the term "fool-proof" which is too frequently used by radio engineers. I know from personal experience and it has come to my attention from other sources, that even *good* operators feel that the term as used is a personal affront. The terms, "rugged, automatic and self-adjusting" are suggested in lieu thereof.

I have received a number of personal inquiries from prospective radio operators as to the prospects and future possibilities for a young man entering the field as a ship operator. The field is new and rapidly growing. The public demand for radio communication renders the field permanent. My experience and observations convince me that the opportunities for advancement are far superior to those in many of the older trades or professions.

Below is given a table showing the rates of compensation for radio operators of the Navy, the American Marconi Company and the Tropical Radio Telegraph Company (United Fruit Co.), and the graded scales of promotion.

Subsistence is gratis for shipboard service and at some shore stations in the Naval, Marconi and United Fruit Services.

U. S. Navy	American Marconi Company	United Fruit Company (Tropical Radio Telegraph Co.)
Per Month		Per Month
3rd class $33.00	1st six months at $25.00 per month.	Juniors, $40.00
2nd class $44.00	2nd six months at $30.00 per month.	Juniors, $50.00
1st class $55.00	Increase of $2.50 per month, each half year, to $40.00 per month.	Seniors, $60.00
Chief $66.00	Increase of $5.00 per month, each year, to $60.00 per month.	Seniors, $75.00
	At shore stations increase of $5.00 per month, each year, to $90.00 per month.	Shore stations, $75.00 to $175.00
	At trans-oceanic shore stations increase of $5.00 per month, each year, to $120.00 per month.	

PROMOTIONS.

Naval Service.

On 1st re-enlistment the pay of each man is increased $6.99 per month.

On 2nd and subsequent re-enlistments the pay of each man is increased $4.79 per month.

If a man re-enlists for four years within four months after an honorable discharge, he receives four months' pay at the rate he was paid upon discharge.

There are other allowances and privileges, such as medical and dental attention, hospital privileges, retirement privileges after thirty years, on three-fourths pay with light and fuel allowance; six months' pay to beneficiary on decease; $1.00 a day for subsistence on shore at certain stations. Increased pay for permanent appointment as Chief Petty Officer, Seaman Gunner. Good conduct medals, etc.

Marconi Service.

Promotions indicated in foregoing table.

Gratuities in the nature of bonuses on messages are added to ship operators pay.

Operators stationed at trans-oceanic stations will be furnished board and lodging at the company's hotel at $35.00 per month.

United Fruit Service.

The first promotion from $40.00 to $50.00 is made at the end of two or three months, depending upon ability and aptitude shown.

The promotions from $60.00 to $75.00 at the end of about six months' service as senior depends upon aptitude shown and ability to "copy" direct on the typewriter in either the American Morse or Continental codes.

The promotions to shore stations and salaries paid depend upon vacancies, location of station and other conditions.

If I have shown the necessity for more hearty coöperation between the radio operators and their employers and their superior officers, so that the radio laws and regulations, and the unwritten laws of good judgment may be intelligently complied with in the interest of safety to life at sea, I shall be satisfied.

SUMMARY: The most important characteristics of the good radio operator are proficiency in the use of the code, skill in the care and adjustment of the apparatus, and reliability in an emergency. The requirements of the commercial companies of the Navy in these directions are considered. The American Morse code is compared with the Continental critically, and is adjudged superior. The use of the "Omnigraph" for test sending is favorably discussed. The requirements for an operator's license of any grade are given, and the problem of appropriate and searching examinations therefor is handled. The age distribution of radio operators is given graphically and numerically. The salaries and conditions of promotion of operators in the United States Navy, the American Marconi Company, and the United Fruit Company are compared.

DISCUSSION.

E. T. Chamberlain: Mr. Greaves' paper impresses me as an admirable statement from the administrative point of view, and is correct so far as I am familiar with the radio operator problem. Of course, I am not in a position to discuss the relative merits of the two telegraphic codes, but so far as the examination of operators for federal licenses is concerned, Mr. Greaves has expressed my own opinion. The examination system will be improved from time to time as experience and suggestions from those interested may prompt.

Questions of ages and wages will no doubt be automatically adjusted by the law of supply and demand, and in accord with the tendencies of the times.

R. B. Woolverton: I have found Mr. Greaves' paper very interesting, and many of his statements are corroborated by my own experience. I enthusiastically agree with him in his opinion that the American Morse code is far superior to the Continental code, especially with respect to speed; and as for accuracy thru static disturbances, my experience at the San Juan, P. R. station, which received almost entirely on long wave lengths, did not indicate that the Continental code was superior to the American Morse. It has always been my experience that even an expert operator receives good Morse by words, and Continental by letters; and besides there is an easy rhythmic swing to Morse which offsets any possible advantage which Continental might have.

Mr. Greaves' data regarding the number of operators at different ages is very interesting. There is one point in this connection, however, which I may point out. In the examination of 700 commercial operators I have been surprised to note that it is not the older, experienced group of operators which obtains the highest percentages. The keen, 19-year-old group of high school boys nearly always shows the higher percentages. Their knowledge of radio subjects, altho obtained largely from text books, is minute and very thoro. Their lack of experience causes lack of self-confidence, and the result is that they prepare themselves much more thoroly than the old experienced operators.

I heartily agree with all Mr. Greaves' statements regarding the Omnigraph. After long experience with the instrument I have found that in every case where the operator can really receive 20 words per minute with reasonable ease, he is always *pleased* with the Omnigraph's characteristic sending.

David Sarnoff: I heartily agree with Mr. Greaves in his opinion that the radio operator is a very important factor in the art of radio communication, and as such should receive careful consideration and study. The importance of the human element in the art of radio communication cannot be overestimated.

It seems to be an open question, as to which of the following combinations is preferable: An older and within reasonable limits, less efficient type of equipment in the hands of a skilled radio operator, or, a modern and more efficient set in the hands of a poor operator.

My own observations and experience in connection with the above problem leads me to answer the question in favor of the skilled operator. However, I fully appreciate the necessity and desirability of having the ideal condition, viz.: The good operator and the good set.

I note he says that "so far as safety at sea depends upon the radio operator, speed is not particularly important, altho it may be desirable under certain circumstances," and I do not think I can quite agree to the above. Speed in radio when speed can be utilized is perhaps more desirable and more important than in any other means of communication, for the reason that nearly all commercial ship and shore stations operate on 600 meters, and therefore make it necessary, particularly in crowded waters, to wait for the next fellow to "get thru." As a radio operator of a number of years of experience, I can now recall those painful moments of waiting. This is true not only in cases of ordinary commercial work, but also in cases of distress, to wit: the recent case of the steamship "Empress of Ireland," which only had six or seven minutes available in which to communicate During this time, the radio operator gave the Father Point station full particulars of his distress and received from that station the information and assurance of the assistance that would come to him in time.

We all know the number of sad cases, even to-day, where it takes a radio operator considerably more than six or seven minutes to despatch a single message, even if static and other interference are absent. As a general rule, an operator who is capable of telegraphing with speed, will utilize this ability when it is possible to do so, and as it is admitted that under certain conditions, speed is not only desirable but imperative, it must follow that an operator should have speed; and this applies not only in the case of commercial operators but to all operators engaged in radio work. It must be considered, however that speed alone does not constitute the "good" radio operator. It is speed, plus stability, that is most effective.

With regard to the use of the Omnigraph as a means for testing operators' skill, I believe that there should be no objection to this instrument. I have personally used the Omnigraph and found no cause for complaint. Absolutely perfect sending is sometimes objected to by operators for the reason that they are not accustomed to it. I know that when the Marconi Company discontinued the use of manual transmission at Cape Cod and substituted the automatic, several ship operators complained of the sending the first two or three nights, but thereafter expressed their preference for the automatic. However, there is a difference between the automatic used at Cape Cod and the Omnigraph utilized by the Department of Commerce which, as explained, affords means for adjusting the character of sending.

American Morse vs. Continental.

I have used both American and Continental Morse in radio work, and believe with equal efficiency. Experience compels me to disagree with Mr. Greaves' opinion concerning the advantages of American Morse. Continental has proved itself to be by far the safer code in cable work and particularly so in radiotelegraphy. In my opinion, American Morse in radio can only be used by expert senders if any degree of accuracy is expected. Amateur sending can be interpreted to make all sorts of combinations, even by an expert receiver. In Continental this is not probable; and even indifferent sending is not so liable to be erroneously interpreted by the receiving operator, this being due to the absolute regularity of the Continental signals. Such regularity is a tremendous advantage in receiving radio signals thru static. The possible confusion which arises over poorly sent American Morse is best understood by a double code operator.

At this time when the advantages of the Continental code over the American Morse are so universally acknowledged and recommended for adoption by the American land wire companies, it may be interesting to quote an expression of opinion on the subject by so eminent a telegraph man as Mr. George G. Ward, Vice-President and General Manager of the Commercial Cable and Postal Telegraph System:

"I have read many articles in the past for and against the substitution of the Continental, or what might more appropriately be called the Universal telegraph alphabet, for the American telegraph alphabet, and, in my opinion and opinions of many with whom I have discussed this question, including the eminent authority on all questions pertaining to telegraphy, the late Lord Kelvin, the Continental alphabet is by far the safer, and is also the quicker method of transmitting code messages by sound.

"In fact Lord Kelvin in a discussion I had the honor of having with him on this question stated to me that he could prove mathematically that the Continental code is faster than the American code, and altho I regret that I never pressed Lord Kelvin to make this demonstration, I fully believe that his statement was correct."

V. Ford Greaves: In cases of distress speed in operating is desirable if all the operators concerned are efficient, but in most cases it is not essential. It must be remembered that during the transmission of messages relating to distress the law requires a cessation of commercial traffic, thereby eliminating interference.

There appears to be some difference of opinion concerning the relative merits of the two codes, and as I said, we must bow to the overwhelming majority internationally in favor of the Continental.

I have had two years' experience as a two-code operator and my conclusions are all in favor of the American Morse.

It is my understanding that the Tropical Radio Telegraph Company have made exhaustive comparative tests employing expert operators in both codes working thru most trying conditions of static and interference and have found the American Morse several per cent. more efficient, based on net profits.

We regret that Lord Kelvin did not give us his calculations on the subject.

John L. Hogan, Jr.: It is indeed a pleasure to encounter a paper written in the spirit shown by this of Mr. Greaves'. While my opinion differs from his on a few of the subordinate matters expressed, my endorsement of his desire for a closer coöperation between executive, designing and operating forces than has been the rule in the past cannot be made too emphatic. The usual designer of radio apparatus seems to proceed upon the assumption of a hazy personal set of ideal operating conditions, and to lay out and build instruments which he believes will operate well when these ideal conditions are met. In the past this error has been made by every firm constructing radio apparatus of which I have knowledge, but it is gratifying to find that recently (at least in certain quarters) the matter of meeting actual present-day operating conditions has been closely studied and made use of.

The rivalry between exponents of the "American" and Continental Morse codes is always interesting. In the past five years I have made many trials of actual radio transmission of code and plain English dispatches, and in some cases have carried the tests along continuously for months. In every instance the Continental code has given better speed for equal accuracy or better accuracy at equal average speed, and I am therefore convinced by experience of its superiority. Accuracy must always be the element which determines the value of any telegraphic or telephonic communication.

Federal examination and licensing of operators is proving to be of great use to commercial radio corporations in spite of the fact that (as Mr. Greaves points out also) qualification for first-grade license does not in itself guarantee an operator to be entirely suitable for service. The examination is at least a big step in eliminating incompetent and useless men who have in the past harassed employers, as is attested by the fact that only one examination in nine results in a grant of first-grade rating. The operating companies owe the Department of Commerce a vote of thanks for this service.

I hope that the Institute will hear many more papers of such practical importance as this on "The Radio Operator Problem."

THE OPERATING CHARACTERISTICS OF A THREE PHASE 500 CYCLE QUENCHED SPARK TRANSMITTER.[1]

By

Emil J. Simon and Lester L. Israel.

The use of a polyphase alternating current source to energize the oscillating circuits of a radio transmitter is not new in the art. Eisenstein in his patents[2] has clearly shown how this may be accomplished. For example, in his United States Patent Number 991,837, filed in August 1905, he shows (Figure 1) a three phase transmitting arrangement in which each phase energizes thru corresponding transformers three separate oscillating circuits having a common inductance directly connected in the aerial circuit. By this arrangement, Eisenstein hoped to accomplish several important results. First of all by greatly increasing the number of discharges per cycle in each phase, he desired to obtain a continuous or nearly continuous excitation of the antenna. (Figure 2.) This, he said, would enable him to use the arrangement for telephony. The greatly increased spark frequency meant a greatly increased total energy in the radiating circuit without an increase of the potential to which it would be charged. Eisenstein furthermore appreciated the many advantages to be obtained thru a satisfactory secrecy system. He claimed that he could produce this by using different wave lengths in the several discharge circuits, and that because of the high spark frequency (perhaps entirely beyond the limit of audition) the signals would be inaudible in a telephone.

Eisenstein unquestionably had the correct idea. At that time, however, shock excitation methods had not been disclosed to the art. The open spark-gaps which Eisenstein of necessity had to employ made the success of his much cherished plan impossible. The cause of the failure of his system is best described by quoting from Ernst Ruhmer's, "Drahtlose Telephonie:"[3]

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[1] Delivered before the Institute of Radio Engineers, New York, May 13, 1914.

[2] German Patent No. 176, 011; issued September 3, 1906.
German Patent No. 175,438; issued August 28, 1906.
U. S. Patent No. 991,837; issued May 9, 1911.

[3] "Drahtlose Telephonie," by Ernst Ruhmer, Berlin, 1907, page 88.

"Altho in the previously described sending system of Eisenstein no large intervals of time elapsed between the successive combinations of partial discharges and a continuous excitation of the transmitter takes place, a lack of constancy of time interval exists between the successive discharges; which, as we have seen, follow one another with increasing rapidity as the supply voltage is raised.

"Clearly this objectionable feature can be avoided only thru the use of high tension direct current applied to the spark gap."

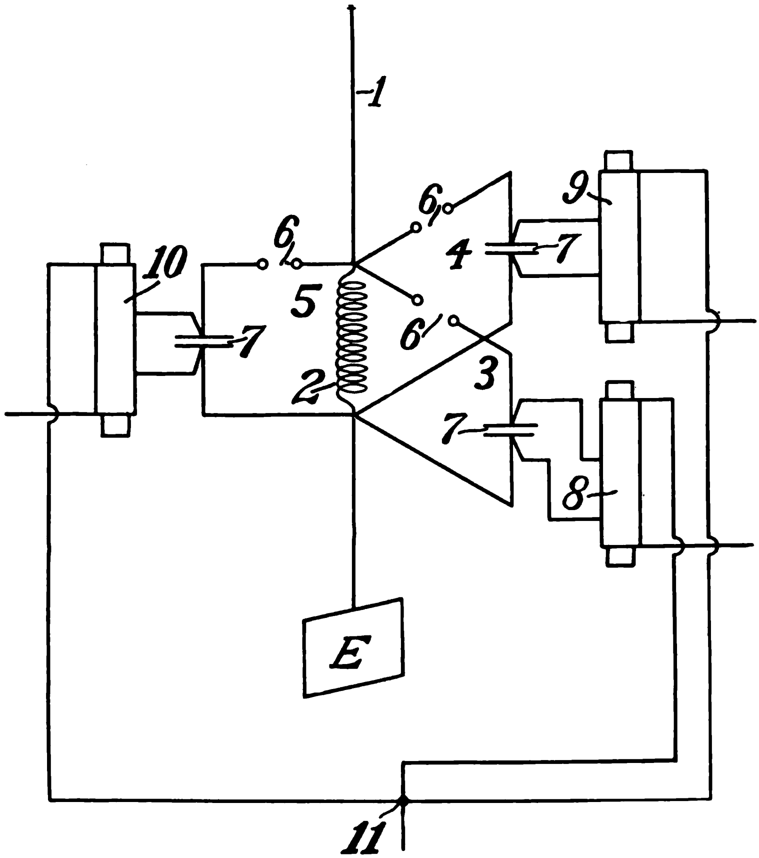

FIGURE 1

It was in the beginning of 1910 that the idea was first conceived of employing quenching spark-gaps in place of the open gaps of Eisenstein. In view of the state of the art at that time, such a substitution must have been obvious and surely required no great mental conception. However, it was felt, that this difference in degree, would be sufficient to distinguish success from failure. The prevention of interaction between the antenna circuit and the closed oscillating circuits would enable a more rapid and at the same time uniform succession of spark discharges to be obtained. Again it was not long before those familiar with practical quenched spark operation recognized the limitations of power which such gap construction imposes. Here then appeared a method by which the power of a quenched spark transmitting set could be multiplied by as many times as the number of phases used.

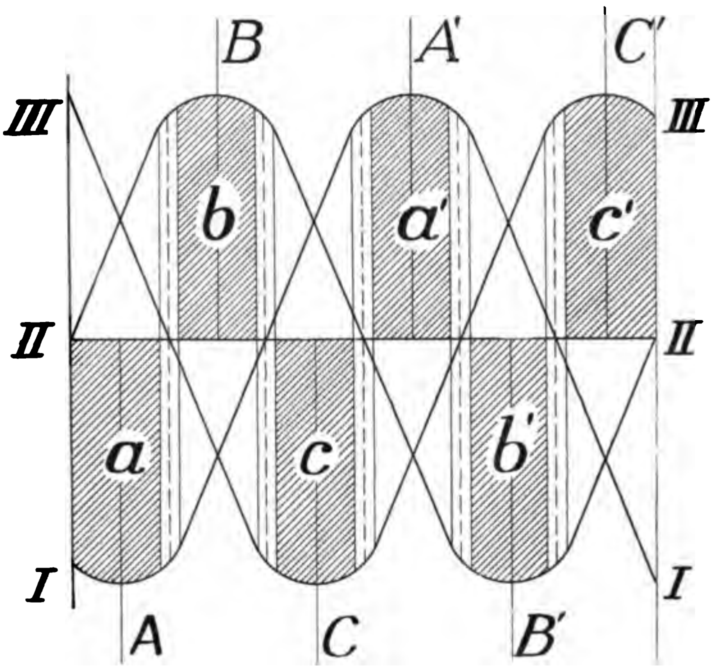

FIGURE 2

Seibt early recognized the great possibilities of a polyphase quenched spark transmitter. In his United States Patent application filed December 27, 1909 for: "Improvements in Apparatus for Producing Powerful Electrical Oscillations," claim 27 reads:

"In an apparatus for producing slowly damped electrical oscillations, the combination with coupled electrically oscillating circuits, of a three phase alternating current source for supplying energy to one of said circuits, said excited circuit having means for quickly snapping off the spark discharge in and opening said circuit consisting of spark gaps corresponding in number and relative connections to the three phases of alternating source, the coupling of said inter-related oscillating circuits being sufficiently strong and adjusted to cause such opening of the said oscillating circuit substantially as described."

His method for accomplishing this result is shown in Figure 20 of his patent application (Figure 3). A recent exhaustive test has demonstrated beyond the question of a doubt that this arrangement of Seibt's is inoperative, because no appreciable

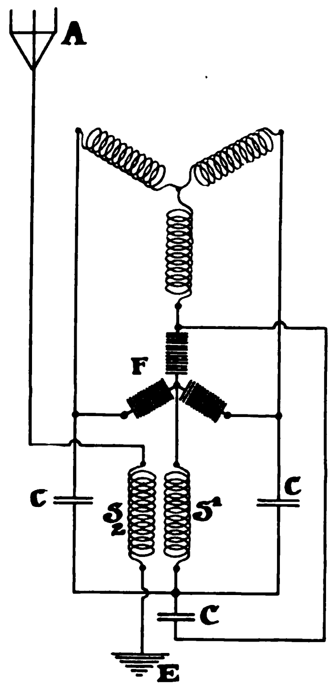

FIGURE 3

amount of current will flow thru the primary coil, S′, of the inductively coupled oscillation transformer.

It was not until the year 1913 that an opportunity presented itself of thoroly demonstrating the practicability of employing a polyphase alternating current. Stirred on by a patent situation which apparently gave to one radio company the sole right to use a high spark frequency in the transmitter, in conjunction with practical methods of reception used to-day, a three phase, 500 cycle generator of 7.5 kilowatt capacity was constructed. Preliminary tests made in the laboratory with the use of a dummy aerial showed sufficient promise to warrant the making of further tests on a more extensive scale and in connection with a radiating antenna.

Thru the courtesy of the Navy Department, a series of tests were conducted last November, using the New York Navy Yard antenna. The apparatus consisted of three 2 kilowatt panel radio transmitters each individually energized by the separate phases of the 7.5 kilowatt 500 cycle three phase generator. The primaries of the low frequency or power transformers were connected in delta for convenience. The secondary of each oscillation transformer was connected in series with the antenna and ground. In order that the type of apparatus used may be clearly kept in mind, photographs (Figures 4 and 5) setting forth the essential features and diagrams of connections (Figure 6) are shown herewith.

As in almost every test of this kind there was some speculation as to the results that would be obtained. A casual inspection suggests at once that the effect of allowing these three practically independent quenched primaries to act on a single secondary oscillating circuit, will be to produce a 3,000 sparks per second tone in the telephone. As shown in Figure 7 the primaries would be expected to discharge 1–3000th second apart, and as the energy in all the primaries is immediately transferred to the common antenna circuit, there should be produced three sets of 1,000 spark wave trains evenly inter-spaced. It was expected that the maximum voltage produced by the three phases in the antenna circuit would be the same as that produced by one phase acting alone; and that the power input would be tripled, thus increasing by the $\sqrt{3}$* current produced by a single phase in the antenna circuit; and similarly for two phases that the tone would be 2,000 per second and the current increased by the $\sqrt{2}$.*

The real difficulty feared was that some change in the constants of the low frequency circuits would result which would alter their resonance condition. For example, if the phases were delta connected as shown in Figure 6, the transformers T_2 and T_3 would be connected in series across the transformer T_1, apparently changing the constants of this phase.

But as is usual in experiments of this kind, the preliminary speculations as to results and difficulties to be met were quite in error.

The first test made was to determine the effect of having the three phases act simultaneously on the antenna circuit. Each

* Power input varies directly as the square of the current.

Figure 4

Figure 5

phase was separately adjusted to obtain a clear tone and maximum radiation at the common wave length to which the antenna circuit was tuned. Caution was exercised to have the quenched spark gaps of the phases A, B and C properly adjusted to a common generator voltage, because of the difficulty in attempting to vary this voltage separately for each phase. Thus approximately equal power was supplied by each phase. The readings for the three separate phases operating singly were:

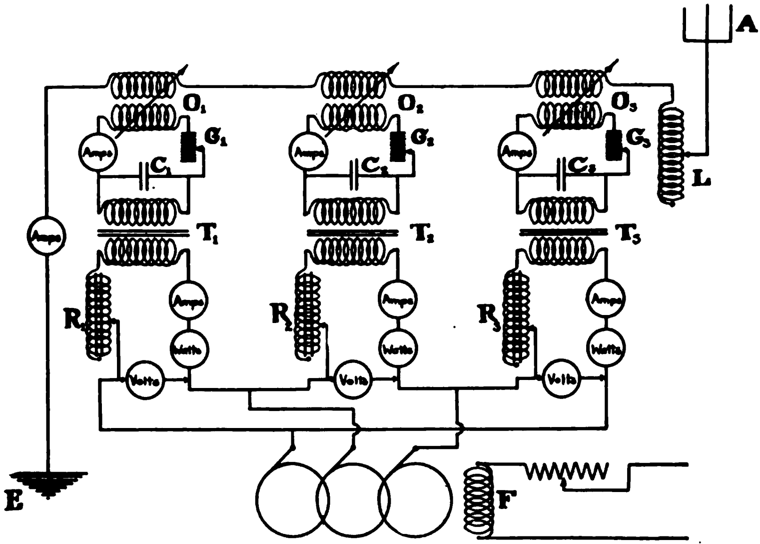

FIGURE 6

Phase	Gen. Output	Gen. Current	Closed Circuit Current	Antenna Circuit Current	Gen. to Antenna Efficiency	Mean Efficiency
A	1.95	32	8	13	53.5%	
B	2.12	25	8.5	15	66. %	61.9%
C	2.25	37	8	15	66.2%	

When the three phases thus tuned were thrown on together and the generator voltage raised to compensate for drop due to increased load, the general change produced was to increase the generator and closed circuit currents. As shown in the following observations, the radiation did not increase in the ratio of $\sqrt{3}$, and the generator to antenna efficiency dropped from 61.9 per cent. to 36.2 per cent. The sound produced in a wave meter telephone had no tone characteristic, but was arc-like in nature.

Fig. 7. Theoretic Oscillations in Three-phase Transmitter.

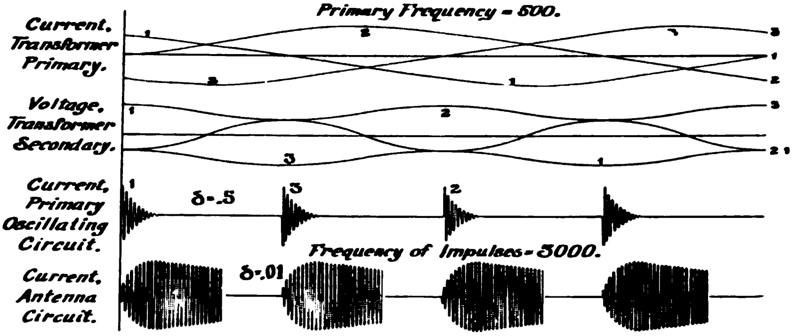

FIGURE 7

Phase	Gen. Output	Gen. Current	Closed Circuit Current	Antenna Circuit Current	Gen. to Antenna Efficiency
A	2.2	32	10.5	....	......
B	2	28	9.75	....	......
C	2	34	10.	....	......
ABC	6.2	..	....	19	36.2%

These observations taken from a test conducted with Washington on November 13, 1913, show that with two phases alone the inter-acting effects were less noticeable than with the three phases and the 1,000 spark tone was not completely lost.

Phase	Gen. Output	Gen. Current	Closed Circuit Current	Antenna Circuit Current	Gen. to Antenna Efficiency
A	2.05	30	9.25	....	......
B	2.05	29	9.25	....	......
A&B	4.1	..	....	17.5	46.4%

The procedure at first was to vary the low frequency circuit conditions by changing the primary reactance, the number of gaps, and the generator voltage and speed; first in the two, then in the three phases. It was found that any variation, except in generator voltage and speed, from the conditions of perfect single phase adjustment, merely made operation worse. The conclusion to be drawn was that the constants of the power circuits remain practically the same when operating with one, two or three phases. Thus the first and chief source of difficulty expected was found to be no difficulty at all!

The next step necessary was to vary the adjustments of the high frequency circuits. The wave lengths of the primary circuits were varied one set at a time; then two and three together. The coupling was similarly varied. As in the case of the low frequency circuits it was found that no change could be made that would increase the antenna current or over-all efficiency from the perfect adjustment for a single phase. Any change always resulted in a decrease of these values.

It was at about this stage, that owing to the tester's inability to discriminate between a 500 and 1,000 spark tone, a set of observations was unintentionally made with the sets adjusted to the lower spark frequency. This series of observations gave a noticeably higher efficiency with the three phases operating together than any previous series of observations. The experienced ear of Mr. Frank Hinners, who was called in to check up

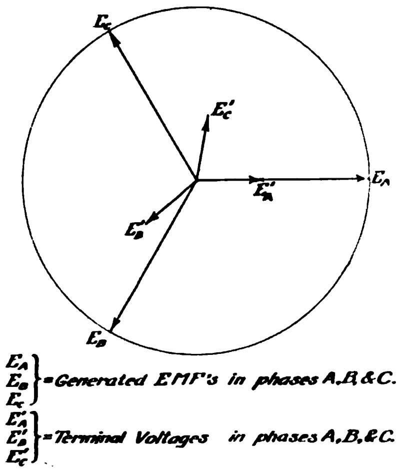

FIGURE 8

the work, quickly noted the difference in pitch due to the diminished spark frequency. It was this fortunate mistake that at once suggested that the time interval between primary circuit discharges might affect the efficiency in some way or other. With this in mind, it was recalled that two phases were generally found to be more efficient than three. Here also the time interval between successive discharges is greater. A theoretical consideration of the phase displacements when only two phases were used led to the construction of the circle diagram shown in Figure 8. Altho this was only a rough approximation derived on the assumption of steady cyclic conditions, it showed that the operating phases tended to approach maximum or 180 degrees separation. The higher efficiencies obtained in these two cases led us to suspect that the time interval between successive discharges was worthy of further investigation.

The first transmission test was conducted on the afternoon of November 13, last. The letters A, B, C, and ten second dashes were used, the letters to identify the phases in operation. Audibility observations were made simultaneously at the Bureau of Standards and at Arlington Radio Station, crystal detectors and telephones being used. The Fessenden Heterodyne receiver was made use of at Arlington in the reception of the three phases together. The observations recorded were as follows:

Phases	Antenna Current Transmitter	Strength of Signals, Bureau of Standards	Strength of Signals, Arlington	
A	13	32 X	......	
B	15	36 X	......	
C	15	42 X	300 ohm	
AB	17.5	55 X	200 ohm	
AC	17.5	65 X	160 ohm	
BC	17.25	60 X	160 ohm	With Heterodyne
ABC	19	...*	40 ohm	With Heterodyne

* Reading and spark tone poor.

The tone observed in a wave meter telephone at the sending station corresponded with that received at the Bureau of Standards and at Arlington. Resonance curves (Figure 9) taken during this test by Messrs. Geo. H. Clark and Guy Hill of the Navy Department showed a noticeable decrease in wave length and a substantial increase in the damping of the antenna circuit only when the three phases were used together. The maximum potentials developed in the antenna increased in the ratio of $\sqrt{2}$ and $\sqrt{3}$, but the current increased in less ratio. This was interpreted to mean that all three phases discharged together at intervals, and that reaction between antenna and closed circuits occurred. The energy of the three phases must have been completely and simultaneously transferred to the open circuit at some instants and then partly transferred back to the primaries. This could have occurred only if the wave trains in the antenna circuit, caused by the discharge of one phase, persisted until the discharge of the following phase.

With this theory in mind, we set about finally to verify or disprove our supposition. Assuming 1–3000th second between discharges, the following simple calculation showed that the amplitude of wave trains in the antenna at the time of discharge of the next phase was not negligible.

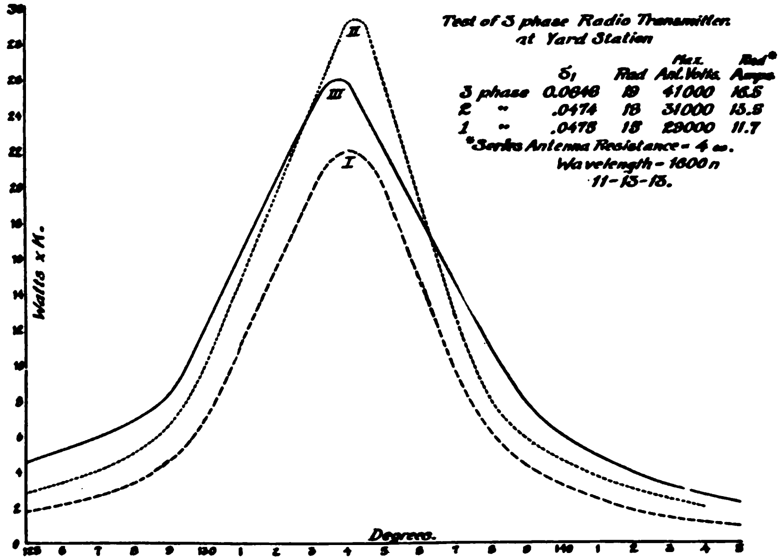

FIGURE 9

Taking the antenna constants as found in the first transmission tests; viz.:

Wave Length $= \lambda =$ 1,600 meters
Period $= T =$ 1–187,000 second
Decrement $= \delta =$ 0.0475

We have:

Waves per 1–6th cycle = 1–3000 ÷ 1–187,000 = 62

$$\text{Current amplitude at discharge of next phase} = I_{(max)}\, \varepsilon^{-62\delta} = \frac{I_{(max)}}{19.3}$$

i. e., the amplitude of oscillations in the antenna at the time of discharge of the next phase was at least 1–20th the maximum amplitude.

Now, the effective value of the maximum current is given by the equation:

$$I_{(eff)} = \frac{\omega\, C\, E_{(max)}}{\sqrt{2}} = 48 \text{ amperes}$$

where:

$\omega = 2\pi \cdot 187{,}000 = 1{,}170{,}000$
$C = 0.002 \cdot 10^{-6}$ mfd.
$E_{(max)} = 29{,}000$ volts

Thus the effective value of current in the antenna at the time of the discharge of the next phase was at least 2.4 amperes, indicating a substantial overlapping of consecutive wave trains.

A consideration of Figure 10 will give a clear idea of the reactions resulting from such overlapping. It will be seen first that it tends to build up the antenna potential amplitudes, so that at the time of the next discharge, this potential is proportionately increased. Furthermore, as the residual current in the antenna circuit impresses an E. M. F. across the condenser in the primary oscillating circuits, which compounding with the low frequency transformer E. M. F., causes the gap to break down earlier in the cycle, the time of the next discharge will be advanced. Finally, due to the conductive state of the gap, the residual energy in the antenna circuit will be partially transferred back to the primary circuit next discharging. This in turn accounts for the increased damping, the reduced wave length and lowered efficiency previously noted.

We reasoned further that if the overlapping of wave trains in the antenna was the cause of the phenomena observed, then a sufficient increase in the natural decrement of the antenna to diminish such overlapping, should increase the efficiency so as to equal that obtained by one phase alone. If the antenna damping could be further increased so as to make the wave trains entirely independent, a 3,000 spark tone should be distinctly audible.

Series resistance was accordingly inserted in the antenna circuit. This resistance was gradually increased, the high frequency circuits being carefully retuned. The curve in Figure 11 shows the effect produced. It will be seen that the generator to antenna efficiency reached a maximum when the total antenna resistance was increased to 13 ohms. It was noticed at this point that the hissing sound of the spark previously quite rough, now became smooth. Calculations showed that here the wave trains overlapped at 1–300th to 1–500th maximum current amplitude. As was to be expected, the 3,000 spark tone now became apparent.

With the antenna constants arranged to eliminate the harmful reaction between phases, so apparent in the first transmission test, a second test with Washington was conducted on November 17. The resonance curves (Figure 12) showed that the antenna decrement remained constant while using one, two or three phases. The antenna currents also increased in proper ratio. The maximum potential developed with the three phases,

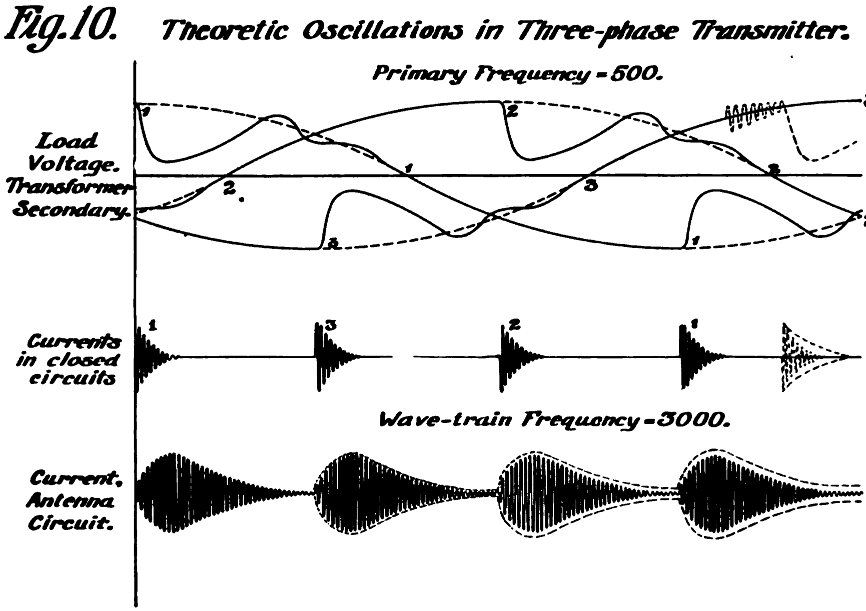

FIGURE 10

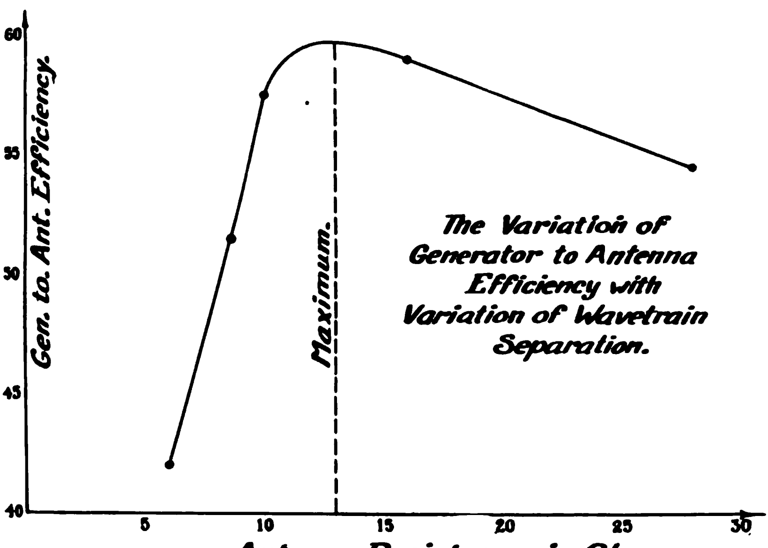

FIGURE 11

increased in the ratio of the $\sqrt{3}$ (over that of a single phase) showing that at some instant the three were still discharging together. The maximum potential developed in the antenna for two phases was 23,400 volts as compared to 21,000 volts for a

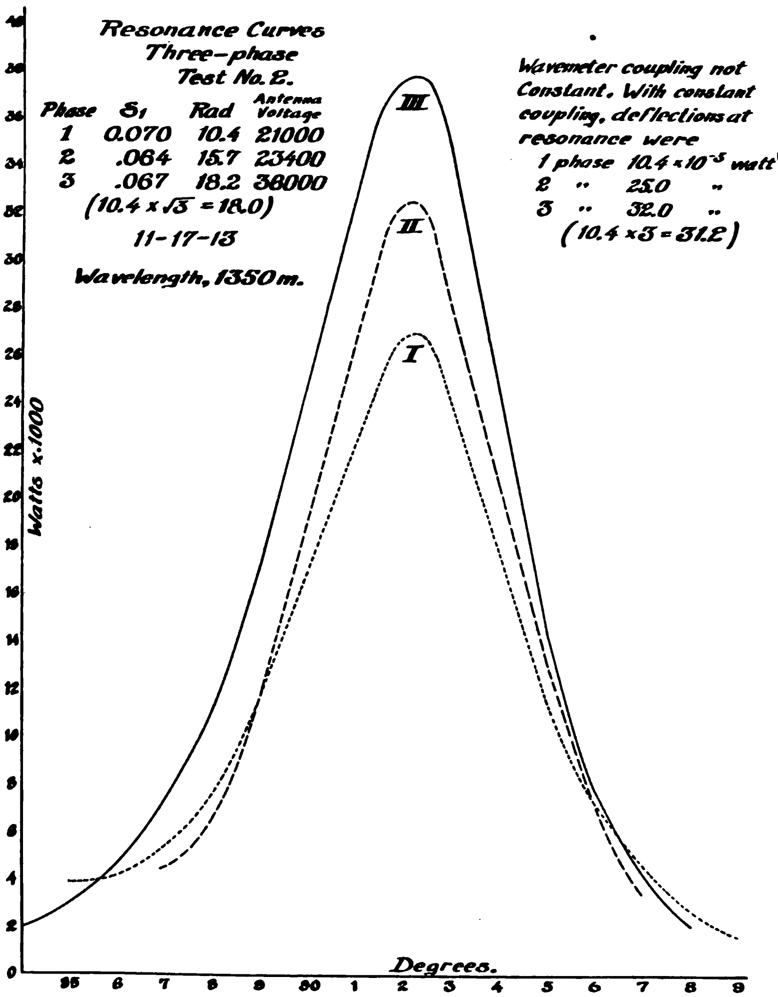

FIGURE 12

single one. It was evident that the inter-acting effects for two were less serious than for three.

One point still remained to be cleared up:—"What is the character of the discharges when the wave trains overlapped at 1–300th of the current amplitude or more?" As the observations recorded at the Bureau of Standards in the last test indicated substantial increase in received energy, but a noticeable decrease in audibility, the wave train formation was evidently not of a very audible character.

A satisfactory explanation for this almost total loss of tone and a correct conception of the spark discharge frequency and resulting wave train formation, was not gained until quite recently. By courtesy of the officials of the New York Navy Yard, we were given the opportunity to use three ½ kilowatt panel sets in three phase connection employing a "dummy" antenna composed of compressed air condensers. Here we were able to observe the spark discharge frequency with the aid of a rapidly rotating neon tube connected to a high potential point in the antenna circuit. We experienced no difficulty in obtaining the pure 3,000 spark frequency as confirmed by telephone and stroboscope. By decreasing the damping of the dummy circuit to a minimum the wave trains were made slightly to overlap and total loss of this 3,000 spark tone followed. The number of discharges was evidently 3,000 per second but they appeared irregularly spaced, and this lack of periodicity accounts for the loss of tone. With two phases, the tone was similar to that of a 1,000 sparks per second, because the ear probably grouped into one the discharges of the two near phases.

These tests have demonstrated that the three phase operation at 500 cycles destroys the clear high pitched tone which is considered so essential for reliable telegraphic communication, in sufficient measure to compel the use of tikker or other similar methods of reception, wherein the received energy is broken up into periodic groups having a frequency well within the range of telephonic sensibility. The increased use of undamped wave transmission by important high power stations, will soon compel the majority of ship and shore stations to include in their equipment this effective and at the same time inexpensive type of receiver. Then the use of a polyphase high spark frequency telegraph transmitter may seem justifiable. However, it must be kept clearly in mind that the maximum wave length efficiently obtainable will be determined by the antenna damping; i. e., the greater the damping the greater the wave length which may be efficiently employed. Thus in long distance telegraphy, where high power is essential and where the antenna constants would be predetermined, the multiphase system may have many desirable characteristics. Three times as much power can be obtained using three phase current as compared with single

FIGURE 13—Front of O.5. K.W. Panel Set

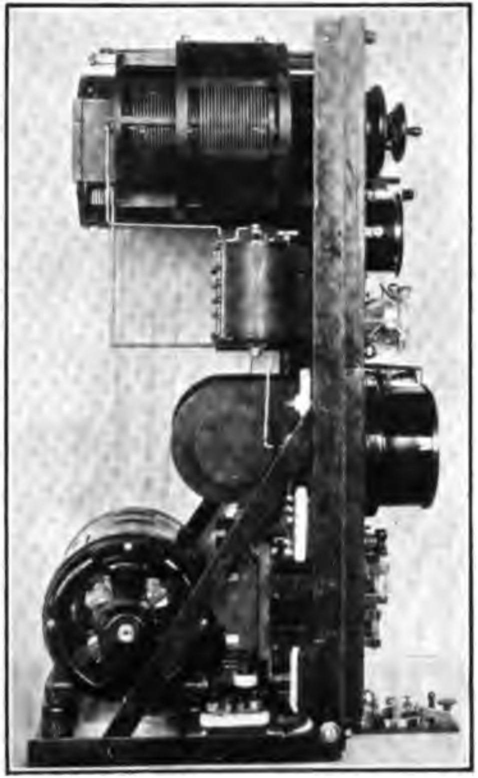

FIGURE 14—Side of O.5 KW. Panel Set

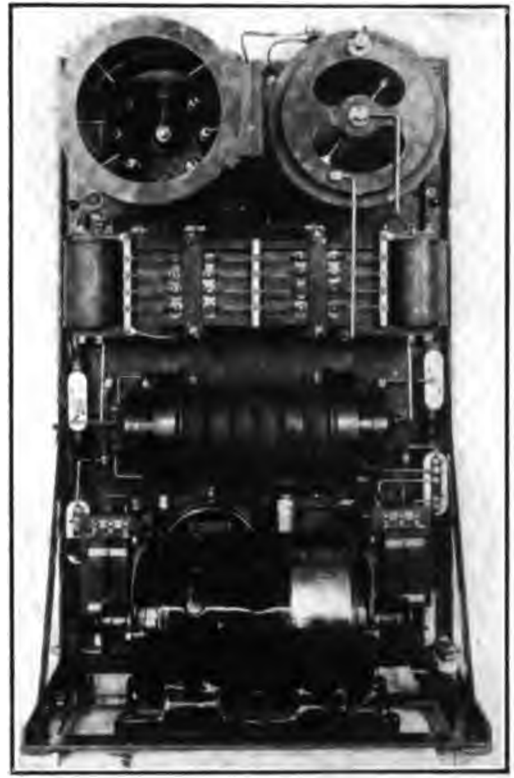

FIGURE 15—Back of O.5 K.W. Panel Set

phase, the radiation is more continuous and the efficiency noticeably greater.

On the other hand, the use of a low spark frequency polyphase transmitter may find immediate application. There are many localities in this and other lands, where polyphase alternating current at lighting or power frequencies exists. Here a multiphase quenched spark transmitter of moderate power could emit a clear tone two or three times higher in pitch than would be possible with a single phase set. Except at extraordinarily long wave lengths, the overlapping of wave trains would be impossible. The saving affected by the elimination of the motor generator is an item worthy also of consideration.

The system described appears practical for telephony. By arranging the antenna constants so that the wave trains overlap by the proper amount the oscillations produced, even by a 500 cycle three phased transmitter, can be made completely to lose their tone characteristics. The high frequency radiation thus obtained is very constant, and causes only a slight steady hissing sound in the telephones. It is believed that the voice variations superimposed on this current would be effectively received especially if the generator frequency were further increased. A three phase 2,000 or 3,000 cycle generator can be readily constructed and should be entirely suitable for this use.

One point that has immediate practical importance has been clearly brought out by these tests. That is the effect of the overlapping of the wave trains. In the past it has been customary to think of wave trains as very widely separated. This was especially true in the days of high antenna damping, short wave length and low spark frequency. In modern 1,000 spark quenched gap sets, with wave length range up to 3,000 meters and with loading coils of reasonably low resistance this factor cannot be neglected. Several radio engineers conversant with 500 cycle quenched spark operation have recently noted that for a given generator output more gaps are required and that the efficiency of the sets rapidly diminishes as we approach the longer wave lengths.

It is believed that one of the most important causes of this variation is the overlapping of wave trains, and that this determines the upper limit of the wave length range which can effectively be used on any given antenna.

SUMMARY: The attempt to produce a nearly continuous radiation of energy and high tone frequencies by the use of polyphase transmitters is historically considered. The work of Eisenstein and Seibt is described. Experiments with two and three phase transmitters were made; and it was

found that the wave trains produced by successive discharges in adjacent phases overlapped in the antenna, thereby causing unmusical tones in the receiver and a diminution of transmitter efficiency. This decrease in efficiency is due to the increased reaction of the antenna on the closed oscillating circuits and the consequent disturbance of the regularly spaced spark discharges of the transmitters of each phase. By increasing the antenna damping, thereby lessening the overlapping of successive wave trains, the musical quality of the tone was improved and the transmitter efficiency markedly increased. Tests on dummy antennae and actual long distance tests were made. The production of practically sustained radiation, susceptible of reception by the use of the ticker or analogous devices, and produced by polyphase transmitters, is favorably considered. The limitation of quenched spark transmitter efficiency by the overlapping of rapidly successive wave trains is discussed.

DISCUSSION.

John Stone Stone: It seems that practically the entire difficulty experienced by Mr. Simon in his experimental work arose from the irregularity of the spark discharges. Their regular sequence was disturbed by the over-lapping of the wave trains in the secondary circuit and by the reaction from the secondary on the primary circuit. To overcome these troubles, it was necessary to insert resistance in the aerial circuit, thereby increasing the damping of the wave trains to such an extent that the reaction of the secondary on the primary ceased until after the primary circuit current had been quenched. I desire to add, however, that the proper form of resistance to insert in an aerial for the purpose mentioned would be a carefully designed spark gap, of low resistance to high currents, but of high resistance to low currents.

The reason for the use of this form of resistance is that it would effectively eliminate the tail end of each wave train without seriously affecting the initial portions thereof. Since there is but little practically usable or sound producing energy at the end of the wave train, it is just as well if it is eliminated.

Guy Hill: In line with the suggestions of Mr. Simon regarding the overlapping of the wave trains in the antenna and the reaction of the aerial circuit on the closed circuit and of Mr. Stone's suggestion relative to the introduction of a spark gap as a resistance in the aerial circuit, I may mention that if by the introduction of such a gap, the reaction is appreciably diminished it might be well to adopt such measures, even in the case of single phase 500 cycle sets operating at very long wave lengths. This matter may well be worth going into.

John L. Hogan, Jr.: It has been suggested that if 60 cycle current were available, it would be possible by the use of a three phase transformer to obtain 360 sparks per second with the advantages of a high note at the receiving station. The National Electric Signaling Company has a very similar case to this in practice, at the New London station.

There we had 60 cycle, three phase current supplied. We thought of using there a three phase set, thereby getting a high frequency spark, but the simplicity and cheapness of installing a non-synchronous rotary gap giving musical spark of some 600 groups per second made the more complicated three phase set not worth considering.

Aside from the possibility of securing sustained waves, or radiation with very high train-frequency, for radio telephony or pure-note heterodyne operation, the only commercial use I can see for a three phase system is in very powerful stations for sending over long distances. It is possible that the triplication of parts necessary will be more than balanced in operating and first costs by the saving in the purchase of a 120 cycle, three phase or 60 cycle, three phase standard alternator instead of a 360 or 180 cycle special machine. This is speculative, however, and I am inclined to doubt the economic value of any multiphase system I have studied, especially when the trend toward sustained-wave and heterodyne operation is taken into account.

A METHOD FOR DETERMING LOGARITHMIC DECREMENTS.*

BY

LOUIS COHEN.

The only method available at present for the determination of the logarithmic decrement of damped oscillatory currents is the Bjerknes method, which depends on the following principle:—

A resonant circuit, comprising an inductance, variable condenser and a thermo indicating instrument, is loosely coupled to the exciting circuit the logarithmic decrement of which we seek to determine. The reasonant circuit is first adjusted so as to be exactly in resonance with the exciting circuit, and then slightly displaced from the resonance position by varying the capacity of the condenser, and the corresponding two current readings noted. Making use of certain formulae established by Bjerknes, we can evaluate the sum of the logarithmic decrements of the exciting and resonant circuits from the values of the current readings thus obtained. The formulae derived by Bjerknes for this problem are as follows:—

When the two circuits are in resonance, the square of the current in the resonant circuit is given by the expression:

$$I_r^2 = \frac{E^2}{16\,L_2^2\,\alpha_1\,\alpha_2\,(\alpha_1 + \alpha_2)}. \qquad (1)$$

For the non-resonant condition, the square of the current in the resonant circuit is given by

$$I^2 = \frac{E^2}{16\,L_2^2} \cdot \frac{\alpha_1 + \alpha_2}{\alpha_1\,\alpha_2} \cdot \frac{1}{4\pi^2\,(n_1 - n_2)^2 + (\alpha_1 + \alpha_2)^2}, \qquad (2)$$

where α_1 and α_2 are the damping factors of the exciting and resonant circuits respectively, and n_1 and n_2 are the free oscillation frequencies of the circuit when in resonant and non-resonant conditions respectively. From the two formulae given above, we can easily derive an expression for the sum of the damping factors of the two circuits, which is as follows:—

$$\alpha_1 + \alpha_2 = 2\pi\,(n_1 - n_2)\,\frac{I}{\sqrt{I_r^2 - I^2}} \qquad (3)$$

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* Delivered before The Institute of Radio Engineers, New York, March 4, 1914.

The sum of the logarithmic decrements per complete period of the two circuits is

$$\delta_1 + \delta_2 = 2\pi\left(1 - \frac{n_1}{n_2}\right)\frac{I}{\sqrt{I_r^2 - I^2}}, \tag{4}$$

The above expression is simplified if we adjust the capacity for the non-resonant condition so that the square of the current is reduced to one-half the resonance value, and also express n_1 and n_2 in terms of the capacities corresponding to these frequencies, and in this case formula (4) reduces to

$$\delta_1 + \delta_2 = \pi\frac{C_1 - C_2}{C_2}, \tag{5}$$

where C_1 and C_2 are the capacities corresponding to the resonant and non-resonant condition respectively.

The above formula is the one commonly used in the measurement of logarithmic decrements, and in the design of decremeters.

The limitations of the Bjerknes formula are well known. Certain approximations are introduced in the derivation of formula (2) which must be taken account of in every case, or the results may be in error as has been shown experimentally by Eccles and Makower.* It is very desirable, therefore, to develop another method for measuring logarithmic decrements which may be used as a check on the older method, and if found suitable may be introduced into general practice.

The method suggested here for the measurement of logarithmic decrements, is as follows:

As in the case of the Bjerknes method, we couple loosely to the exciting circuit a resonant circuit comprising an inductance and a variable condenser, and adjust it so as to be exactly in resonance with the exciting circuit. The value of the square of the current in the resonant circuit is given by

$$I_r^2 = \frac{E^2}{16\,L_2^2\,\alpha_1\,\alpha_2\,(\alpha_1 + \alpha_2)}, \tag{6}$$

when as in the previous formulae α_1 and α_2 are the damping factors in the exciting and resonant circuits. Now suppose an additional non-inductive resistance is introduced into the resonant circuit changing the resistance R_2 to SR_2, where S is

* "The Efficiency of Short Spark Methods of Generating Electrical Oscillations." W. H. Eccles and A. J. Makower. *The Electrician*, Vol. 65, page 1014, Sept. 30, 1910.

greater than unity. Evidently the damping factor α_2 is also changed in the same ratio and the current is reduced. If we designate the value of the current for this case by I, we shall have

$$I^2 = \frac{E^2}{16\, L_2^2\, \alpha_1\, S\, \alpha_2\, (\alpha_1 + S\, \alpha_2)}. \tag{7}$$

From (6) and (7) we get by division,

$$\frac{I^2}{I_r^2} = \frac{\alpha_1 + \alpha_2}{S\,(\alpha_1 + S\, \alpha_2)}. \tag{8}$$

If we vary the amount of additional resistance introduced into the resonant circuit until the square of the current is reduced to one-half the original value, we shall have by (8)

$$\frac{\alpha_1 + \alpha_2}{S\, \alpha_1 + S^2\, \alpha_2} = \frac{1}{2}. \tag{9}$$

Hence

$$2\, \alpha_1 + 2\, \alpha_2 = S\, \alpha_1 + S^2\, \alpha_2,$$

and

$$\alpha_1\, (2 - S) = \alpha_2\, (S^2 - 2),$$

or

$$\alpha_1 = \frac{S^2 - 2}{2 - S}\, \alpha_2. \tag{10}$$

We have here the value of α_1, the damping factor of the exciting circuit, expressed directly in terms of α_2. If the resistance and inductance of the resonant circuit are accurately known, the value of α_2 is also known, and we can then obtain the value of α_1 from equation (10). Knowing the value of α_1, the logarithmic decrement is

$$\delta_1 = \frac{\alpha_1}{n}. \tag{11}$$

In practical work it may prove difficult to obtain a sufficiently fine variation in resistance so as to reduce in every case the square of the current to one-half its resonance value, but this is not necessary. Suppose we introduce a fixed resistance in the circuit which will cause a reduction of the square of the current to some fraction of the resonance value which we may designate by m, we have by equation (8)

$$\frac{I^2}{I_r^2} = m = \frac{\alpha_1 + \alpha_2}{S\,(\alpha_1 + S\, \alpha_2)}. \tag{12}$$

From the above we can easily obtain the value of a_1 in terms of a_2 which is as follows:

$$a_1 = \frac{m S^2 - 1}{1 - m S} a_2. \qquad (13)$$

Putting $m = \frac{1}{2}$, equation (13) reduces to (10).

The method outlined above would be very simple in operation and ought to give accurate results if the constants of the resonant circuit are carefully determined. This method would be especially suitable for measuring small logarithmic decrement, because a_2 can be made small, and we therefore express one small quantity in terms of another small quantity.

To embody the principle suggested here in the design of decremeters, it is necessary only to have a resonant circuit the resistance and inductance of which are accurately known for the range of frequencies for which the instrument is to be used. A set of curves could be prepared to go with each instrument giving the values of R_2 and a_2 as functions of the frequency. Knowing the value of R_2, the value of S can be readily obtained from the known increase in resistance required to reduce the square of the current to one-half the original value, and we thus know all the factors which enter into formula (10). The frequency of the oscillations can, of course, be obtained with the same instrument.

SUMMARY: The Bjerknes method of determining the logarithmic decrement of the secondary of two coupled circuits is critically discussed. The Author suggests a new method for determining this decrement. An additional known resistance is inserted in the secondary (or resonant) circuit instead of in the primary circuit as is the case in the Bjerknes method. An expression for the logarithmic decrement of the secondary circuit in terms of the logarithmic decrement of the primary, and known or measurable quantities, is given. The practical application of the method is described.

DISCUSSION.

John Stone Stone: This is a most interesting contribution to an important subject.

From the nature of the tests described, it is evident that S can range only between $\sqrt{2}$ and 2 (or 1.414 and 2). The ratio S must, therefore, be determined with extreme precision, particularly when the ratio $\frac{a_1}{a_2}$ is small. The determination of these resistances with great accuracy on the other hand is not always very easy in the case of the high frequencies which occur in radio work. As an example of how great this precision may have to be in a given case, it is to be noted that an error of ½ of 1 per cent. in the ratio S will make an error of more than 100 per cent. in the ratio $\frac{a_1}{a_2}$ if $\frac{a_1}{a_2} = 0.068$, or approximately $\frac{1}{15}$. On the other hand, when the ratio $\frac{a_1}{a_2}$ is 20, an error of ½ of 1 per cent. in the ratio S gives rise to an error of 16 per cent. in the ratio $\frac{a_1}{a_2}$. When however the damping co-efficients or constants of the driving and driven circuits are not very different from each other ($\frac{a_1}{a_2}$ nearly unity) the method is subject to no such radical objection and should prove useful in the connection pointed out by the Author.

The difficulty I have indicated is perhaps not insuperable, however, for if the ratio of $\frac{a_1}{a_2}$ be not favorable to precision of measurement, it may be possible to add known resistances to both circuits until the ratio is favorable and then to take these added resistances into account in the final result.

It would seem, however, that in this case it might be necessary to resort to more than a single measurement and under these circumstances the test would lose its chief advantage, viz.: its beautiful simplicity which so highly commends it in the cases to which it is directly applicable as described by the Author.

Frederick A. Kolster: This paper deals with a subject in which I have been very much interested for some time, particularly in connection with the Bjerknes method of obtaining logarithmic decrements.

That there are limitations to the use of the method of Bjerknes is, of course, well known, but I am of the opinion that in practice these limitations are not so serious as the results of some experiments have indicated.

Mr. Cohen gives a reference to a paper by Eccles and Makower, which gives the results of some experiments in which the resistance of a circuit is determined from the decrement. It is not at all clear that the large errors obtained in these results are due to the limitations of the Bjerknes method and it is very reasonable to believe that they are due to other causes. I have made many tests similar to those of Eccles and Makower to check the accuracy of decrements obtained by the Bjerknes method and have always obtained excellent results.

In connection with the method given by Dr. Cohen, I am not convinced that there are sufficient advantages in it to warrant its general use in preference to the Bjerknes method. So far as the measurement of small decrements is concerned, the limitations of the Bjerknes method are in such cases, greatly reduced, and by far the most important source of errors lies in the measurement of δ_2.

To make use of the simplified formula (10), an accurately calibrated adjustable high frequency resistance is required in order that the half deflection condition can readily be obtained. This introduces an undesirable feature as it is difficult to determine with accuracy the true high frequency value of such a resistance.

To determine S in formula (10), ΔR, the value of the inserted resistance, and R_2, the resistance of the instrument must be accurately known; and unless they are determined with great precision, any advantages which the method may possess, quickly disappear, as can be seen by the way the value of S enters into the formula (10). For example, an error in S of 0.5 per cent., for $S = 1.60$, will produce an error in the value of δ_1 of nearly 7 per cent.

It is interesting to note that formula (8) is identical with the well known formula,

$$\delta_2 = \Delta\delta \cdot \frac{I^2\left(1 + \dfrac{\Delta\delta}{\delta_1 + \delta_2}\right)}{I_r^2 - I^2\left(1 + \dfrac{\Delta\delta}{\delta_1 + \delta_2}\right)}$$

which is sometimes used in determining δ_2 rather than δ_1.

Louis Cohen: Messrs. Stone and Kolster are entirely correct in their contention that to get reliable results by the method described in my paper it will be necessary to determine the value of S with great precision. The difficulty, however, is not so serious as it may appear. The resistance of the resonant circuit can be made very small by using small inductance and large capacity and by having the coil wound with low resistance stranded wire. Now suppose we introduce an additional resistance of about 5 ohms or more, which shall form part of the circuit; the resistance of the coil will then be only a small part of the total resistance in the circuit, and any error in the value of the high frequency resistance of the coil will therefore be inappreciable when taken in connection with the total resistance of the circuit. The added resistance may be in the form of fine straight wires of a high resistance material, whose high frequency resistance can be determined very accurately. If the resistance of the coil is ½ ohm, and the additional resistance is 5 ohms, then an error of even 5 per cent. in the value of the resistance of the coil, will introduce an error of only 0.4 per cent. in the total resistance of the circuit.

Similarly, the resistance which is to be further added in circuit to reduce the current can also be in the form of straight wires of high resistance material. In fact it will only require to have a number of small high resistance wires properly mounted, and by means of a switch to introduce as many as may be necessary until a certain reduction in the current is obtained, and then make use of Formula (13) to calculate the value of α_1.

In the case of straight wires the high frequency resistance can be calculated to any degree of accuracy desired, but even if there should be a small error, it will enter in about the same ratio in both readings, and the value of S will not be affected.