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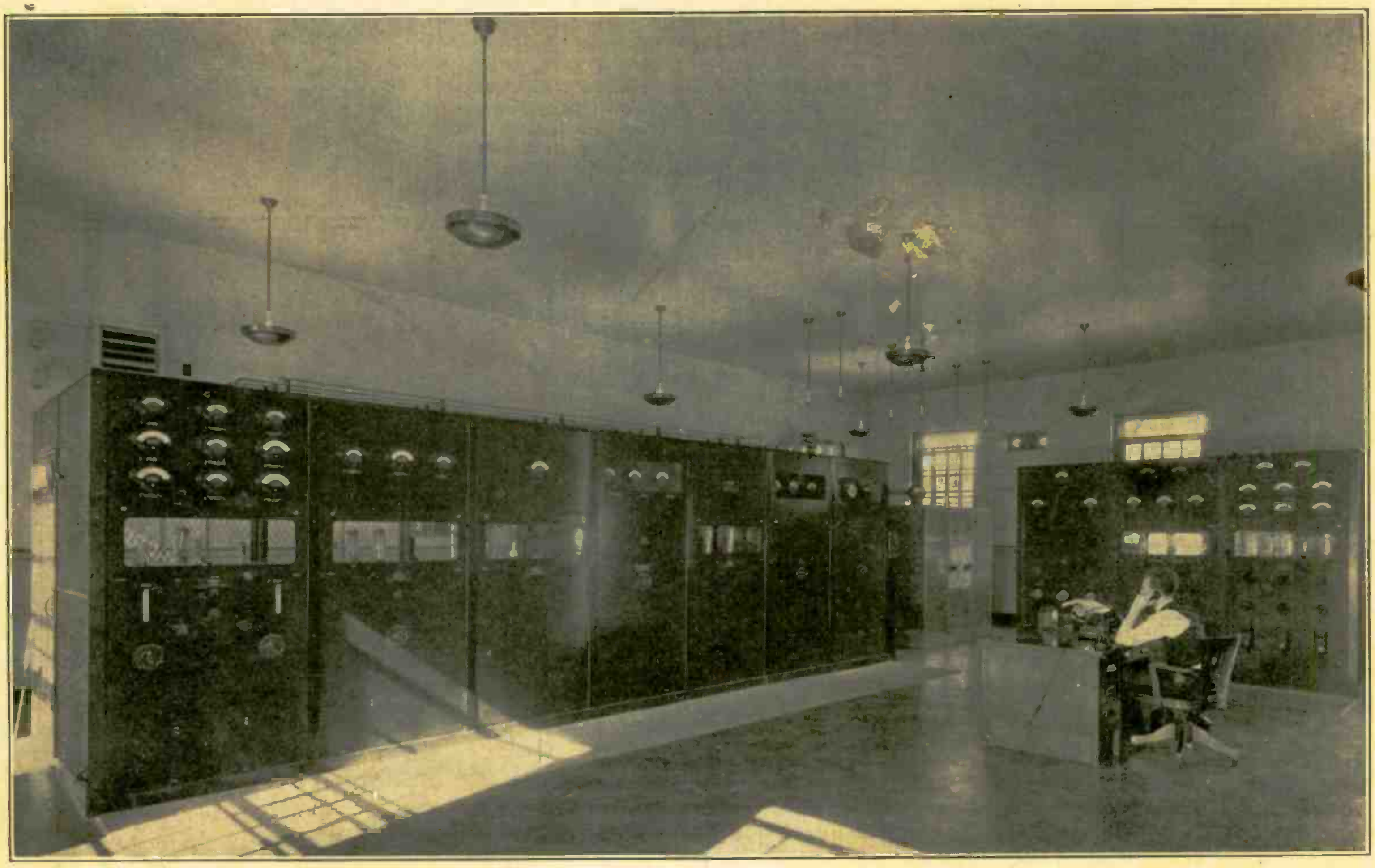

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COMMERCIAL RADIO

The Only Magazine in America Devoted Entirely to the Commercial Radio Man

MARCH, 1934

JAMES J. DELANEY, Editor

L. D. McGEADY, Bus. Mgr.

Labor Organization Control

In any organization, whether it be social, fraternal, or mutual benefit, the matter of control and management is a vital one. One point at which our own American ship wireless men have been at a strict disadvantage is this matter of organization management.

Participation of the active membership is badly needed. A sound note is struck in the new plan for board management. The very successful Association of Wireless and Cable Telegraphists operated by our British brethren again points the way. Can any imagine a better management than under the direction of a board consisting of from six to ten members actively engaged in the wireless operating field, serving a fixed term, with elections staggering so as not necessarily terminating at one period.

Nor, would any dispute the justice of dividing this board up into territorial representation, if the problem of periodical quorum can be solved. This board either by personal meeting or mailed ballot should very well be in a position to elect by themselves such officers as President or Chairman, and Secretary or Treasurer. If such a board were serving without personal remuneration, electing such officers as are paid from dues, with complete authority to pass upon the actions of such officers as have the actual handling of the finances, and other matters of membership concern, new life would be inspired in what would otherwise by chance drop into a listless affair.

Our whole hearted support is with board control. Regardless of what evils may beset the plan, they are sure to be fewer than clumsy, long drawn out indefinite officer elections by the membership, which at best are likely to cause factions where solidarity is most desired. This does not remove control from the membership, on the contrary it places more firmly and more securely in their hands what is justly theirs

Broadcast and Advertising

Already several devices have been developed so that the listener may remove the "blah" of advertising which becomes more staggering every day in broadcasted entertainment. Such well known artists as Eddie Cantor, and Will Rogers find it either necessary or desirable to put in their "puns" for their sponsors on the air.

Of course the program must be paid for, but the spirit of competition for giving the advertiser more and more for his money is causing the broadcast program to become more and more obnoxious to the listener in. Where are the days when the young folks could invite a dozen or more to the house and have an hour of dance music to finish off a pleasant evening? An hour or two of practically uninterrupted music with just a slight announcement of the source of the program. The day when the listener did not have to listen to the gaudy, catchpenny, diversified fifteen minute entertainment. At every opportunity we are reminded how superior our form of broadcasting is to the European plan of government controlled broadcasting. Strange is it not that the European visiting our shores does not find our own broadcasting either superior or more desirable than his own.

Time Moves On

Along with many other evolutionary movements comes the news from Washington of a new form of radio control.

A committee recommends a most logical move to the President, and the President immediately and openly advocates the logical recommendation.

A commission to control all communications, wire, or wireless is something that has long been needed. None of the desirable features are lost, and many that are not at present possible are accomplished. It is to be hoped that the plan will be pushed to completion in a most rapid manner. Certainly nothing is to be gained by slowly trying to remove a bad spot here and there, when all of the bad spots can be removed by one sweeping action. The new plan is compared to the Interstate Commerce Commission, a very worthy body that has been in existence for ever so many years. Let us hope that if and when such a commission is empowered to control communication it will function as worthily as the older commission.

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MERCURY ARC RECTIFIERS

By **MATT SLOAN**

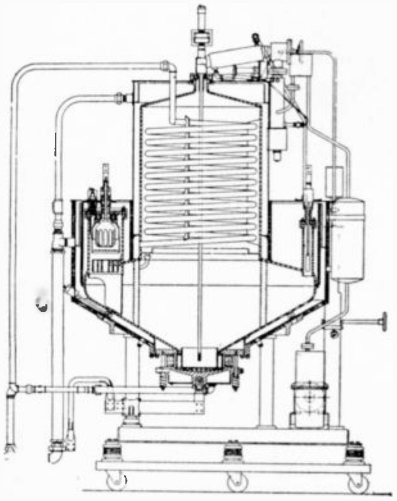
Along with other developments in the electrical field, first the original direct current generators, then for the ease of distribution, the alternating current generators, and the general use of transformers, the conversation back to direct current for required use in that field became a matter for solution.

The rotary type of converter either in self contained unit, or the motor-generator form became the usual form for local conversation, of alternating current to direct current.

The glass bulb rectifier was developed about 25 years ago, and has since become an invaluable adjunct of the radio field. Where great power is required the glass bulb rectifier has its limitations principally on account of mechanical features, which limit output.

The newer development in this field is the metal mercury arc rectifiers. These are already in large use in Europe by broadcasting stations in the radio field, and in industrial and utility plants of various natures throughout the World where direct current is essential.

It has been estimated that over 2,000 of this type of rectifier has been manufactured. Again it is figured that today there are approximately one million eight hundred thousand k.w. of mercury arc rectifiers installed. Of this approximately six hundred thousand k. w. are used on municipal direct current light and power systems and in industrial applications. More than one half of this total output is for the operation of the New York City municipally operated subway system, where the units are of standard 3,000 k. w. capacity, but have been tested for short period operation of 200 per cent load, and for one minute operation up to 300 per cent load. Some newer units will be 750 k.w. in multiples of four, making the total of 3,000 k. w., all about 650 volts.

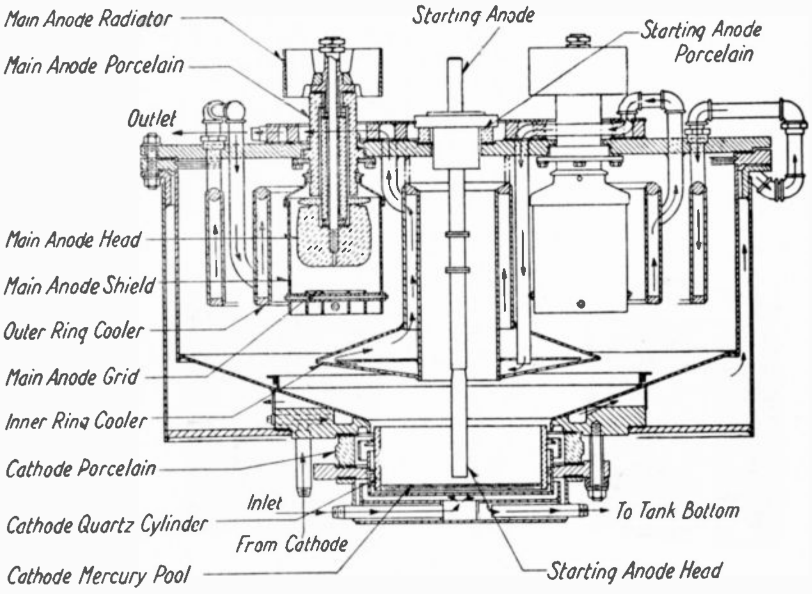


Mercury-cathode Thyratron, Rated at 5000 Amp. Average, 1500 Volts Maximum

(A.) Outline sketch of General Electric Co. rectifier.

While it is true that our largest broadcast station in the United States is using a multiple of glass bulb rectifier with a rated ability of 450 amperes, of which 100 amperes at 12,000 volts is required on the plate power of the transmitter, it is also true that similar stations of large rating in Europe are already using the metal built rectifier.

The essentials of the metal tank mercury arc rectifiers produced in this Country by the three leading manufacturers, General Electric Company, Westinghouse Electric & Mfg. Co., and Allis-Chalmers Mfg. Co., the latter being the Brown Boveri Design, are Mercury Arc Rectifiers.



(B.) Sketch showing make-up of Westinghouse Elect. & Mfg. Co. mercury arc rectifier.

(1) The starting anode which dips into the mercury pool at the bottom of the tank, or cathode point, and is raised causing an arc to start excitation, and is of lower than primary voltage.

(2)—The holding anodes, also of lower than primary voltage which continue firing thereby holding the arc in the event of one main anode failing to fire, and which assure continuous operation.

(3) The main anodes, one for each phase, usually either six or twelve.

(4) The cathode, or d. c. side of the unit insulated from the main tank, and forming a reservoir for about 90 lbs. of mercury, of which in actual operation on high power unit about 15 lbs. is in condensed form when load is heavy, from arc heat.

(5) The metal tank in which is contained the vacuum, the water cooling system, and other essentials.

(6) The grids, one for each primary anode, with constant d. c. excitation.

Accessory apparatus consists of transformers for the primary circuit, starting and holding anodes, a. d. c. sourse for maintained by a system of condensation of the mercury dissipated in heat and returning the mercury to its original form dropping it back to the cathode well. A water circulating arrangement for cooling the rectifier, either by motor operated force through a closed circulating system or other arrangement accomplishing the same results.

Of course in all mercury arc rectifiers of this type a system of relays are devised which either immediately take the rectifier out of service should trouble of grid excitation either of battery type, dry disc, or small motor generator type. A device for quick evacuation usually a motor with oil sealed pump attached to remove any gaseous matter which may show up internally in the rectifier, and a mercury pump by which vacuum is operation develope, or indicate by a system of self operation, when correction of an operating requisite is essential by an accessory device

A general cross section of three types of metal tank mercury arc rectifiers are shown in illustrating diagrams with this article.

Power factor of a rectifier of this design varies between 93 per cent and 96 per cent and is fairly constant. No means of power factor adjustment is provided for in these rectifiers. General efficiency of better than 98 per cent is claimed by all three manufacturers whose devices are considered in this article.

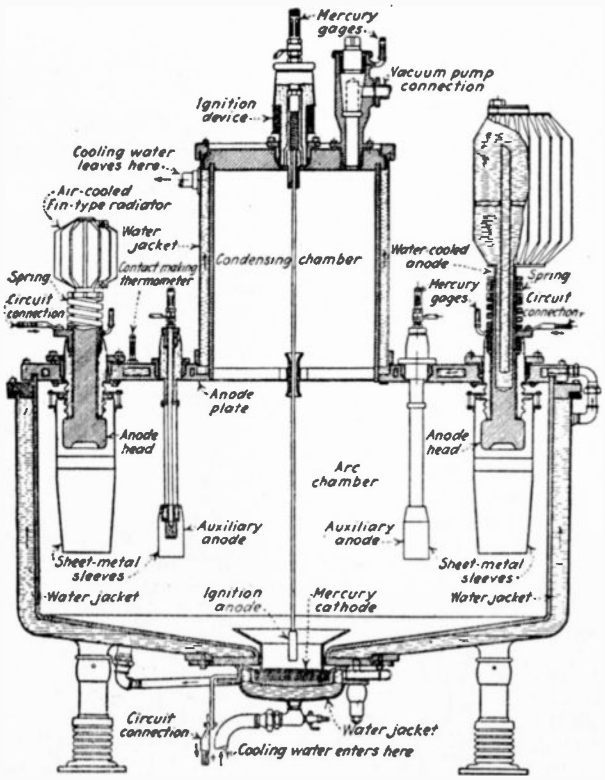
Water valves are provided in the cooling system at essential points for either manual operation, or automatic operation, where either greater or lesser supply is essential due to the heat of the water in the system. A tank supply of water takes care of any possible loss due to heating or leakage in the water system, and requires when there is no leakage in the water piping system very little attention in keeping the tank at safe operating level.

There is some little difference of opinion on the matter of maintenance cost in power use as between the rectifier and the older type of rotary converter, with not much in the way of conclusive evidence on either side. This indicates quite clearly that it is not a prime factor of decision, either in the use of a rotary converter, or a metal type rectifier.

With the safety relays of all types provided by manufacturers of metal tank rectifiers operation seems to be as constant for one type of converter as for the other, considering the rotary or rectifier.

The rectifier is by far the cleaner in operation over the rotary type, and where the main source of wear and tear on the device of the rotary type is mechanical, the water circulating system is the telling one in the metal type of rectifier due to corrosion. By the intoduction of chemicals into the closed water circulating system of the rectifier this trouble is being fast overtaken.

If the power demands of radio transmitting stations keep climbing, and the demands for direct current continue to mount, the metal tank mercury arc rectifier due to corrosion. By the introduc- known at the present time to be able to take care of the power demands, as the glass bulb rectifier will have to be installed in such great numbers as to make some other more permanent source desirable. Since there is little or no opportunity of renewal of parts for the mercury rectifier of the glass tube type, whereas in the metal tank type there is the opportunity of correcting individual faults and returning the rectifier to service, this will undoubtedly be a factor to be counted with in the matter of operation cost.



(C.) Outline sketch of typical Allis Chalmers Mercury Arc, Rectifier (Brown-Boveri Type).

NEW RADIO COMMISSION RULING

The Commission on February 20, 1934 adopted the following:

"With reference to Rule 214 the expression 'constant supervision of duly licensed operators' shall for the time being and until further notice, be construed to mean:

(a) For stations licensed to use frequencies below 30,000 kilocycles an operator of the grade required under Rules 403, 420 and 443 shall be on duty at the transmitter location, whenever the transmitter is being operated, or at the remote control point if authorized in accordance with Rule 213.

(b) For stations licensed to use frequencies above 30,000 kilocycles only, the operator shall be similarly employed as in (a) above, provided, however, in the case of two or more stations licensed in the name of the same individual or organization, except amateur, a licensed radio operator of any class except amateur and radiotelephone third class who has the stations within his effective control, may be on duty at any point within the communication range of such stations in lieu of the transmitter location or control point during the actual operation of the transmitting apparatus, and shall supervise the emissions of all such stations so as to insure proper operation in accordance with the station license (s)."

(Signed)—Herbert L. Pettey,
Secretary.

NOTE:—The rules referred to in the Commission's Order on the reverse hereof are contained in the revised edition of the Commission's Rules and Regulations which may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C., at a nominal cost.

For convenience, Rule 214 is quoted as follows:

"214. Only an operator holding a radiotelegraph class of operators' license may manipulate the transmitting key of a manually operated coastal telegraph or mobile telegraph station in the international service; and only a licensed amateur operator may manipulate the transmitting key at a manually operated amateur station. The licensees of other stations operated under the constant supervision of duly licensed operators may permit any person or persons, whether licensed or not, to transmit by voice or otherwise, in accordance with the types of emission specified by the respective licenses."

Rule 403 describes the various classes of amateur operator privileges.

Rule 420 states that amateur stations may be operated only by licensed amateur operators.

Rule 443 lists the various classes of commercial operator licenses and shows the validity of each license.

Therefore, in the case of stations licensed to operate on frequencies *below* 30,000 kilocycles, the proper class of operator must be employed depending upon the classification of the station to be operated.

It will thus be seen that there is no change in the Commission's policy with respect to the employment of licensed operators except when the same individual or organization, other than amateur, desires to operate two or more licensed stations on frequencies *above* 30,000 kilocycles.

AUDITORY PERSPECTIVE--LOUD SPEAKERS AND MICROPHONES.[*]

By E. C. WENTE and A. L. THURAS

Bell Telephone Labs., Inc.

As early as 1881 a large scale musical performance was reproduced by telephone instruments at the Paris Electrical Exhibition. Microphones were placed on the stage of the Grand Opera and connected by wires to head receivers at the exposition. It is interesting to note that separate channels were provided for each ear so as to give the music perceived by the listener the "character of relief and localization." With head receivers it is necessary to generate enough sound of audible intensity to fill only a volume of space enclosed between the head receiver and the ear. As no amplifiers were available, the production of enough sound to fill a large auditorium would have been entirely outside the range of possibilities. With the advent of telephone amplifiers, microphone efficiency could be sacrificed to the interest of good quality where, as in the reproduction of music, this was of primary interest. When amplifiers of greater output power capacity were developed, loud speakers were introduced to convert a large part of the electrical power into sound so that it could be heard by an audience in a large auditorium. Improvements have been made in both microphones and loud speakers, resulting in very acceptable quality of reproduction of speech and music; as is found, for instance, in the better class of motion picture theaters.

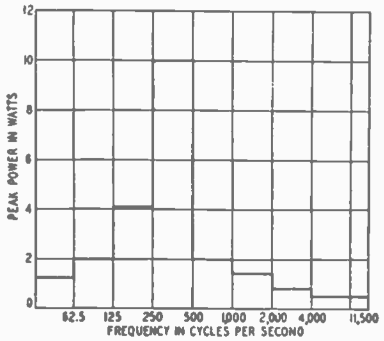


Fig. 1. Peak powers delivered by an orchestra within various frequency regions.

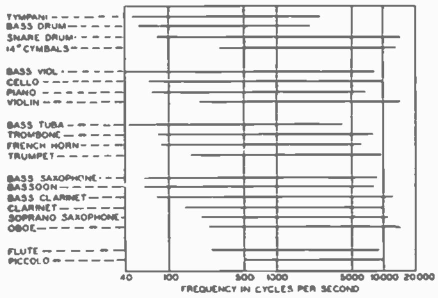


Fig. 2. Frequency transmission range required to produce no noticeable distortion for orchestral instruments.

In the reproduction, in a large hall, of the music of a symphony orchestra the approach to perfection that is needed to satisfy the habitual concert audience undoubtedly is closer than that demanded for any other type of musical performance. The interest of the listener here lies solely in the music. The reproduction therefore should be such as to give to a lover of symphonic music esthetic satisfaction at least as great as that which would be given by the orchestra itself playing in the same hall. This is more than a problem of instrument design, but this paper will be restricted to a discussion of the requirements that must be met by the loud speakers and microphones, and to a description of the principles of design of the instruments used in the transmission of the music of the Philadelphia Orchestra from Philadelphia to Constitution Hall in Washington. Some of the requirements are found in the results of measurements that have been made on the volume and frequency ranges of the music produced by the orchestra.

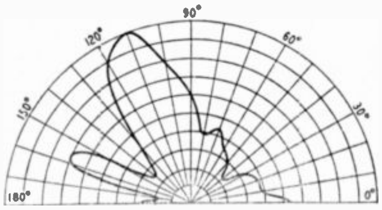


Fig. 3. Variation of intensity with direction of the sound radiated by a violin (660 cps).

General Considerations

The acoustic powers delivered by the several instruments of a symphony orchestra, as well as by the orchestra as a whole, have been investigated by Sivian, Dunn, and White. Figure 1 was drawn on the basis of the values published by them. The ordinates of the horizontal lines give the values of the peak powers within the octaves indicated by the positions of the lines. For a more exact interpretation of these values the reader is referred to the original paper, but the chart here given will serve to indicate the power that a loud speaker must be capable of delivering in the various frequency regions, if the reproduced music is to be as loud as that given by the orchestra itself. However, it was the plan in the Philadelphia-Washington experiment to reproduce the orchestra, when desired, at a level 8 or 10 db higher, so that with 3 channels each loud speaking system had to be able to deliver 2 or 3 times the powers indicated in Fig. 1. Sivian, Dunn, and White also found that for the whole frequency band the peak powers in some cases reached values as high as 65 watts. In order to go 8 db above this value, each channel would have to be capable of delivering in the neighborhood of 135 watts.

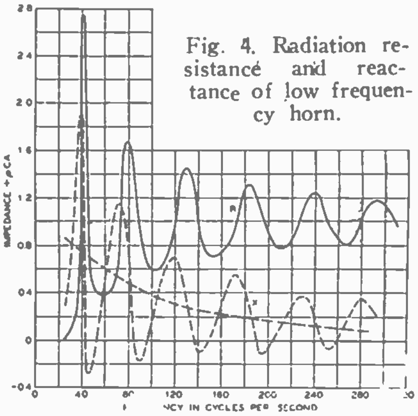


Fig. 4. Radiation resistance and reactance of low frequency horn.

The chart (Fig. 1) shows that the orchestra delivers sound of comparable intensity throughout practically the whole audible range. Although it is conceivable that the ear would not be capable of detecting a change in quality if some of the higher or lower frequencies were suppressed measurements published by W. B. Snow show that for any change in quality in any of the instruments to

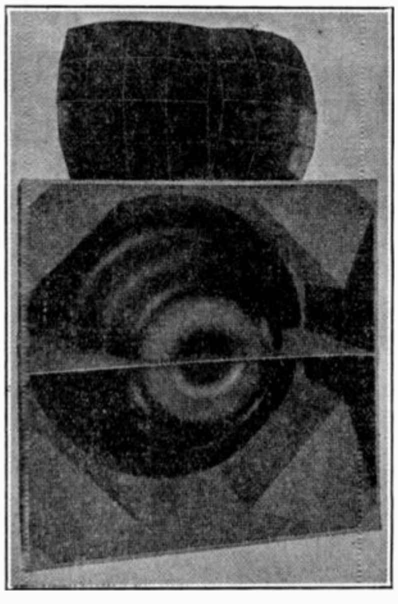


Fig. 5. Special loud speaker developed for auditory perspective experiment.

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[*] Reproduced from "Electrical Engineering," January, 1933

be undetectable the frequency band should extend from about 40 to about 13,000 cps. The necessary frequency ranges that must be transmitted to obviate noticeable change in quality for the different orchestral instruments are indicated in the chart of Fig. 2, which is taken from the paper by Snow.

Thus far only the sound generated by the orchestra itself has been considered. However, it is well known that the esthetic value of orchestral music in a concert hall is dependent to a very great extent upon the acoustic properties of the hall. At first thought one might be inclined to leave this out of account in considering the reproduction by a loud speaking system, as one should normally choose a hall known to have satisfactory acoustics for an actual orchestra. There would be no further problem in this if the orchestral instruments and the loud speaker radiated the sound uniformly in all directions, but some of the important instruments are quite directive; i.e., they radiate much the greater portion of their sound through a relatively small angle. As an example, a polar diagram giving the relative intensities of the sound radiated in various directions by the violin is given in Fig. 3, which is taken from a paper published by Backhaus. The directional characteristics of some of the instruments is one of the chief reasons why the music from an orchestra does not sound the same in all parts of a concert hall. The music which we hear comes to us in part directly and in part indirectly; i. e., after one or more reflections from the walls. Both contribute to the esthetic value of the music. The ratio of the direct to the indirect sound, which has been designated by Hughes as the *acoustic ratio,* is to a first approximation inversely proportional to the product of the reverberation time and the angle through which the sound is radiated. For a steady tone by far the greater part of the intensity at a given point in a hall remote from the source is attributable to the indirect sound. However, inasmuch as many of the tones of a musical selection are of short duration, the direct sound is of great importance; it is this sound alone which enables us to localize the source. So far as this ratio is concerned, a decrease in the radiating angle of a loud speaker is equivalent to a reduction in the reverberation time of the hall. The effect on the music, however, is not entirely equivalent, for the rate of decay of sound in the room is unaltered by a change in the directivity of the source, as this depends only on the reverberation time.

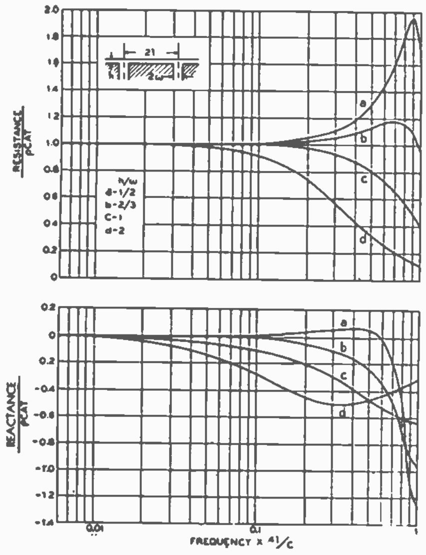


Fig. 6. Load impedance of speaker diaphragm

As already pointed out, some of the instruments of the orchestra are quite directive and others are nondirectional. In general, it may be said that the instruments of lower register are less directive than those of higher register. To have each instrument as reproduced by the loud speaker sound just as the instrument itself would sound in the same hall, the loud speaker would have to reproduce the music from each instrument with a directivity corresponding to that of the instrument itself. This manifestly is impossible. The best that can be hoped for is a compromise. Let the loud speaking system be designed so that it is nondirective for the lower frequencies, and at the higher frequencies it will radiate the sound through a larger angle than the most directive of the instruments and through a smaller angle than the least directive. Although this compromise means that the individual instruments will not sound exactly like the originals, it carries with it one advantage: At all the seats in the hall included in the radiating angle and at a given distance from the loud speaker the music may be heard to equal advantage, whereas with the orchestra itself the most desirable seats comprise only a certain portion of the hall. The optimum radiating angle is largely a matter of judgment; if it is too small the music will lack the spatial quality experienced at indoor concerts; if it is too large there will be a loss in definition.

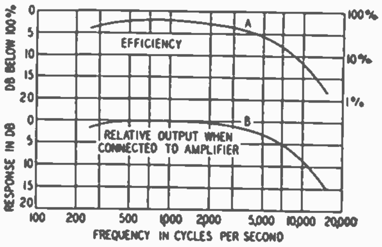


Fig. 7. Relative computed sound output of high frequency receiver.

There is another respect in which the directivity of the source can greatly affect the tone quality. Most loud speakers radiate tones of low frequency through a relatively large angle, but as the frequency is increased this angle becomes smaller and smaller. Under this condition the relation between the intensities of the high and low frequency tones as received directly will be different for almost all parts of the hall. Hence, even with equalization by electrical networks, the reproduction at best can be good only at a few places in the hall. Therefore, the sound radiated not only should be contained within a certain solid angle, but the radiation throughout this angle should be uniform at all frequencies.

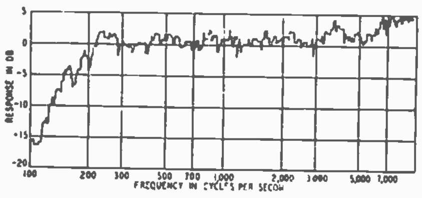
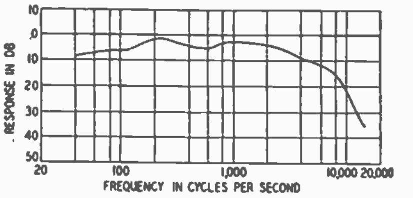


Fig. 8. Output-frequency characteristic of high frequency receiver as measured in a small room

The Loud Speaker

At present 2 kinds of loud speakers are in wide commercial use, the direct radiating and the horn types. Each has its merits, but the latter was used in the Philadelphia - Washington experiment because it appears to have definite advantages where such large amounts of power are to be radiated. The horn type can be given the desired directive properties more readily, and higher values of efficiency throughout a wide frequency range are more easily realized. In consideration of the large power requirements, high efficiency is of special importance because it will keep to the lowest possible value the power capacity requirements of the amplifiers and because, with the heating proportional to one minus the efficiency, the danger of burning out the receiving units is reduced.

Fig. 9. Output-frequency characteristic of combined low and high frequency receivers as measured in a large room.



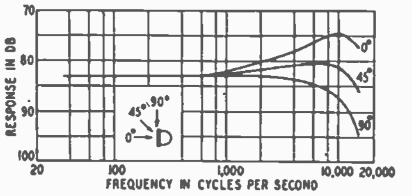


Fig. 10. Output-frequency characteristic of moving coil microphone

For efficiently radiating frequencies as low as 40 cps, a horn of large dimensions is required. In order that the apparatus may not become too unwieldy the folded type of horn is preferable, but a large folded horn transmits high frequency tones very inefficiently. As actually used, therefore, the loud speaker was constructed in 2 units; one for

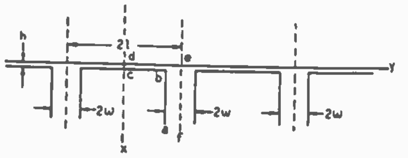


Fig. 11. Schematic diagram of diaphragm and parallel slotted wall of infinite length.

(Continued on Page 23)

PIONEER RADIO OPERATORS

By DR. LEE DE FOREST

(Continued from February Issue)

Operator Dart of the Boston station initiated the habit, later somewhat common, of setting fire to the top of his 208 ft. wooden tower. Not that it was Dart's intention or fault in any sense. Those old "formica" antenna insulators when damp and subject to say 50,000 volts of high frequency sometimes made excellent conductors. This was before the porcelain manufactorers made link or suitable strain insulators. But in this instance the mast caught fire twelve feet below the top, through the crossing of a guy wire and one of the strands of the big fan antenna, which burned through and draped itself about the pine timber. Boston Fire Company No. 7 having run 500 feet of hose was able to squirt water to 150 ft. altitude only! In course of time the mast broke off at a bolted joint. Dart courageously climbed up to that point with a fire-extinguisher on his back and finished the smouldering job. Within an hour the transmitter was again in full operation.

There was no Federal Radio Commission in those brave days; no regulation whatsoever, save the unwritten code of courtesy among wireless operators (of the same system)!

Our men considered the victories of Peace more worthy than those of War. In other words—"Never mind the Navy; get yours through first." And if a good old Yankee wireless jammed a Marconi lime-juicer—that was just too bad. And how! Those were the days when it became conclusively proven that a coherer and tape recorder, or e'en a Marconi magnetic-detector were simply not in it when it came to reading thru interference, or static, compared to an electrolytic detector, a pair of headphones, and a quick-witted Yankee op.

Against such a combination "Sparks" was simply out-classed. And yet it required a long, long struggle before the Marconi company learned its lesson and fell for the crystal and phone combination of their American rivals.

And long before the big-wigs of London had capitulated many a limey Sparks was concealing about his person a small chunk of "coal," as the Dunwoodie carborundum was later called. Through these months the very air was electrically charged, literally and figuratively. The communications achieved with our equipment repeatedly thrilled the natives and the Navy. A 1905 N. Y. Herald Headline Read: "Wireless Work Astonishes Navy. Record made on sending Christmas Greeting much Better Than Had Been Expected. Florida Gets Maine's Reply. Guantanamo Talks with Washington, a Feat Regarded Heretofore as Impossible." A few weeks later Colon repeated this feat extending the news record to 2150 miles, astounding the newspapers once more.

Those early Navy operators deserve utmost credit for the progress American wireless was now achieving. To mention just a few—Scanlan, still with Capt. Hooper in "Communications" at Washington. Watts, Sirback, of that record-breaking gang at Key West. Marriotti, Eaton, Geagan, Martin, Cameron at the Washington Navy Yard; and pre-eminent at the Brooklyn Navy Yard was always good old George Davis, who stuck to his wireless work up through United Fruit, Tropical Wireless, and finally became a vice president of the R. C. A. Bless his memory!

The Ship's Wireless Newspaper then put in its first appearance; the Cunard Daily Bulletin, printed 98 percent in London; The Atlantic Daily News on the Hamburg-American Line.

But all naval men were not agreed as to the value of this new wireless. To quote from the Boston Advertiser of January 18, 1906: "Naval men are growing more and more skeptical as to the value of the wireless system to the Department, unless the government can make of it a government monopoly. Under the existing circumstances it is coming to be regarded as a farce. It is little more, at best, than an amusing plaything, and one which costs a pretty penny, to no good or useful end." Under what present cocked hats are the heads which once voiced that interesting opinion?

And here is another quotation of that period, from the Chicago Tribune, interesting indeed today when almost every city has its police radio-station and radio-equipped cars!

"WIRELESS MESSAGE SENT TO A MAN IN AUTOMOBILE

DeForest Company's Experiment in Michigan Ave. Is Successful; Will Try Moving Machine Next

"An automobile equipped with a brass pole, from which dangled two wires, drew up in Michigan avenue yesterday afternoon, and at four o'clock received the following wireless telegraph message:

" 'William H. Oker, Automobile: How do you like your first wireless ride? The fire department, steamships. and railways ought to adopt the same method of communication.'

"The message had been sent from the deForest wireless telegraph office in the Railway Exchange Building.

"Later in the week experiments will be tried in receiving from an automobile running at full speed. 'All that is necessary for the success of this experiment,' said Mr. White, 'is that a wire be trailed upon the ground. Hereafter, we hope it will be possible for business men, even while automobiling, to be kept in constant touch with LaSalle Street'."

Realize that this first application of radio to an automobile occurred 29 years ago! The trailing ground lead was then deemed as indispensable, as was at first the trailing antenna in aviation communication. And today the trailing ground behind a rushing cop's car might prove a useful purpose at that!

But returning to navy wireless operators and operations, nothing in the early history of American wireless gave to that new development such an impetus as did the success of the first wireless installation on a U. S. cruiser, the old (then new) West Virginia.

President Theodore Roosevelt chose that fine speedy vessel for his trip north from the Gulf in October, 1905. And were our boys proud that the Bureau of Equipment had selected our wireless instruments for that job? The President boarded the cruiser at New Orleans, and northern stations began almost immediately to copy her message to the accompanying cruisers, the Maryland, Colorado and Pennsylvania.

Operator P. S. Geagan at Washington Navy Yard copied the first night out as follows. "West Virginia in good communication with Jupiter Inlet. Savannah and St. Augustine have heard no messages, but West Virginia requests Savannah to listen closely for them as they may have messages anytime. West Virginia also requests weather report from Savannah." As soon as the West Virginia got in touch with Key West the first message to be transmitted from Washington to the cruiser was a personal one from Mrs. Roosevelt to the President, congratulating him on his forty-seventh birthday.

All our stations along the coast now began to hear that sterling fine transmitter in the President's cruiser It was extra good "copy" for all local newspapers. Said the N. Y. Sun:

"Cruiser West Virginia, at sea, via Savannah. October 28th. The weather is perfect, a moderate breeze blowing from northeast, and the sea smooth. The President is quartered in the Admiral's cabin and is enjoying the trip immensely. The ship is keeping up a uniform speed of 18 knots, and everything is running smoothly. This is the first time in the history of our navy when a squadron cruised in company at a speed of 18 knots and over.

"At 1:45 P. M. we picked up the Pennsylvania and Colorado off Key West and are now cruising in squadron. As we passed the warships each manned the rail and saluted the President's flag. It is the customary honor, and the President returned the salute from the Admiral's bridge. Tonight the President will dine with the wardroom officers, and according to the navy custom while at sea on Saturday night, will join in the toast, 'Sweethearts and Wives.'

"Cleveland, Ohio, Also Got the Cruiser

"General Manager Galbraith of the deForest Wireless Company said yesterday that the wireless station at Cleveland, Ohio, had advised him that they were in 'perfect communication' on Friday night with Savannah, Key West, St. Augustine, and the armored cruiser West Virginia in the Gulf of Mexico, the broad Columbia, and very much up

Continued on Page 30)

Classification of Bridge Methods of Measuring Impedances*

By JOHN G. FERGUSON

An analysis is made of the requirements for satisfactory operation of the simple four-arm bridge when used for impedance measurements. The various forms of bridge are classified into two major types called the ratio-arm type and the product-arm type, based on the location of the fixed impedance arms in the bridge. These two types are subdivided further, based on the phase relation which exists between the fixed arm impedances. Eight practical forms of bridges are given, three of them being duplicate forms from the standpoint of the method of measuring impedance. These bridges together allow the measurement of any type of impedance in terms of practically any type of adjustable standard. The use of partial substitution methods and of resonance methods with these bridges is discussed and several methods of operation are described which show their flexibility in the measurement of impedance.

INTRODUCTION

Bridge methods have been used for the measurement of impedance from the very beginning of alternating current use. In fact, the history of the impedance bridge dates back to the earlier bridges developed for the measurement of direct current resistance. While some objection may be raised to this method of measurement on the count that it is not direct indicating, in the sense that an ammeter or voltmeter is, this has been more than offset by the high accuracy of which it is capable. Bridge methods of measuring impedance have accordingly continued to hold a high place in the field of electrical measurements and except perhaps at the higher radio frequencies are considered supreme for this purpose over the whole frequency range, where high accuracy is the principal requirement.

The peculiar advantages of the bridge method are most evident where emphasis is laid on the circuit characteristics rather than on power requirements. In power engineering it may be more logical to make measurements in terms of current, voltage, and power, since these are the quantities of immediate interest. In communication engineering, however, where design is based for the most part on circuit characteristics, and power considerations are only of secondary interest, it is natural that bridge methods, which furnish a direct comparison of these circuit characteristics should be generally preferred.

Due to the wide field of usefulness and great flexibility of the impedance bridge, a very large amount of development work has been done and a considerable amount of literature has been published covering various types and modifications. In fact, the subject has become so broad and the information so voluminous that the engineer who has not specialized in the subject has every excuse for a feeling of considerable confusion when he finds it necessary to make a choice among the numerous circuits available. Perhaps the greatest single obstacle to a still more extensive use of the impedance bridge in industry is this very multiplicity of types combined with a rather complete lack of any practical guide for the engineer who is interested principally in the measurement itself and looks on the bridge simply as a means to this end.

Very little information is available as to the relative merits of the various types of bridges, the great majority of published articles being confined to a description of a particular circuit used by the author for a particular purpose.

The present article furnishes a comparison of the relative merits of the large number of circuits which are available for making the same measurement and should serve as a guide to the engineer who is more interested in results than in acquiring a broad education in bridge measurements. An outline is given of the fundamental requirements which must be met by bridges used for impedance measurements, and a classification is made which serves as a help in the choice of a bridge for any particular type of measurement. The relative merits of the simpler types of bridge are discussed from the standpoint of the measurement of both components of an impedance, particularly with reference to measurements in the communication range of frequencies from about 100 to 1,000,000 cycles. Where only the major component of an impedance is desired, for instance where only the inductance of a coil or the capacitance of a condenser is desired, the requirements are not so severe and many forms of bridges may be used which are not suitable for the purpose here outlined. Bridges are also used to a large extent for other purposes than impedance measurements, such as for frequency measurements. These applications will not be considered here.

THE GENERAL BRIDGE NETWORK

Any bridge may be considered as a network consisting of a number of impedances which may be so adjusted that when a potential difference is applied at two junction points, the potential across two other junction points will be zero. For this condition, there are relations between certain of the impedances which enable us to evaluate one of them in terms of the others. Thus the bridge is essentially a method of comparing impedances. The impedances of the bridge may consist of resistance, capacitance, self and mutal inductance, in any combinations, and they may actually form a much more complicated network than the simple circuit shown in Fig. 1. Consequently, the number of different bridges which can be devised for the measurement of impedances is extremely large. However, since only four junction points are significant, any bridge circuit may be reduced to a network of six impedances connected between these four points, as shown in Fig. 1. These impedances are direct impedances, that is there are no mutual impedances between them.

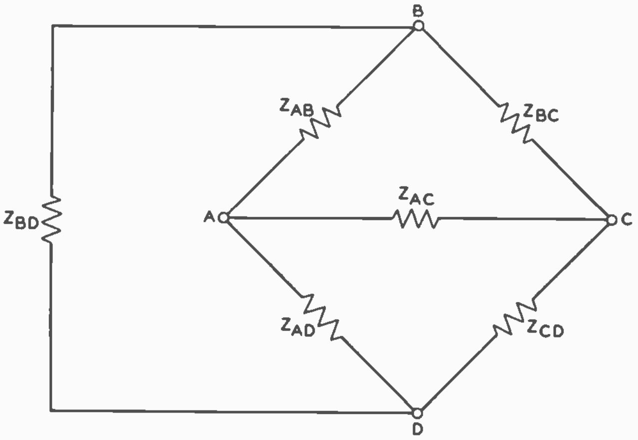


Fig. 1—Schematic of the impedance bridge reduced to its simplest form.

If a potential is applied at *BD* and the balance condition is that the potential be zero across *AC*, then the points *BD* are called the input or power source terminals and the points *AC* are called the output or detector terminals. The impedances Z_{BD} and Z_{AC} then act simply

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*Presented at Summer Convention of A.I.E.E., Chicago, Illinois, June, 1933.

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as shunts across the power source and detector respectively and do not affect the balance relation. The balance is not affected if the power source and detector are interchanged in a bridge reduced to this simple form and hereafter no distinction will be made in this respect.

After the bridge has been reduced to the form of Fig. 1, the equation for balance is

$$Z_{CD}Z_{AB} = Z_{BC}Z_{AD},$$

from which

$$Z_{CD} = \frac{Z_{BC}Z_{AD}}{Z_{AB}}.$$

Thus, if Z_{CD} is the unknown impedance, equation (1) evaluates it in terms of the other three impedances. Equation (1) is a vector equation and therefore the value of Z_{CD} both in magnitude and phase, or both components of it when considered as a complex quantity, may be obtained from this equation.

Although the above equations and subsequent discussion are based primarily on the use of impedances, it should be remembered that all of these relations may be obtained in the same general form if the bridge arms are considered as admittances.

THE BRIDGE REQUIREMENTS

If the impedances of equation (1) are replaced by the complex equivalents $R + jX$, then

$$R_{CD} + jX_{CD} = \frac{(R_{BC} + jX_{BC})(R_{AD} + jX_{AD})}{R_{AB} + jX_{AB}} \qquad (2)$$

From this equation R_{CD} and X_{CD} may be evaluated in terms of the other six quantities. Thus, if each component of the impedances of three arms is known, each component of the fourth impedance in terms of the other six components can be determined.

In obtaining the balance, any or all of the six component impedances occurring in the right hand side of equation (2) may be adjusted. Since there are two unknown quantities to be determined, at least two of these components must be adjusted. From the standpoint of simplicity and speed in operation and in order to keep the cost of the circuit to a minimum, it is desirable that not more than two of the known components be adjustable. It is also essential that the choice be such that a variation of one adjustable standard balance one component of the unknown, irrespective of the other component. In other words R_{CD} should be balanced by one known standard, this value of the standard being independent of the magnitude of X_{CD}, and, in turn, X_{CD} should be balanced by another standard, the value of which should be independent of the magnitude of R_{CD}. This condition of independent adjustment for the two components is essential for satisfactory operation of the bridge, since it allows the balance to be made more rapidly and systematically, and a given setting of one standard always corresponds to the same value of one component of the unknown, independent of the magnitude of the other component, thus allowing the calibration of each of the adjustable standards in terms of the unknown component which it measures.

To meet this requirement, the two components for use as adjustable standards should be so chosen that, when equation (2) is reduced to the general form

$$R_{CD} + jX_{CD} = A + jB, \qquad (3)$$

where A and B are real quantities, one of the adjustable impedances will appear in A and not in B, while the other will appear in B but not in A.

Consideration of equation (2) shows that if adjustable standards consisting either of both components of Z_{BC} or of both components of Z_{AD}, are chosen, and if the impedances of the two remaining arms are selected so that their ratio is either real or imaginary, but not complex, then equation (2) reduces to the form of equation (3). No other combination will meet the requirement taking equation (2) as it stands. Since for the general case there is no essential difference in the resulting type of bridge whether Z_{AD} or Z_{BC} is used as our adjustable standard, this means that there is really only one method of adjustment, namely the use of both components of one adjacent impedance.

However, if it is realized that parallel components may be used instead of series components for the standard, then equation (2) may be rewritten as follows:

$$R_{CD} + jX_{CD} = (R_{AD} + jX_{AD})\ (R_{BC} + jX_{BC})\ (G_{AB} - jB_{AB}) \qquad (4)$$

where

$$G_{AB} - jB_{AB} = Y_{AB} = \frac{1}{Z_{AB}}.$$

From this it follows that G_{AB} and B_{AB} may be used as the adjustable standards, by making the product $Z_{AD}Z_{BC}$ real or imaginary.

Thus there are two methods of adjustment possible, either the two series components of an adjacent arm or the two parallel components of the opposite arm.

Having chosen the adjustable standards, there remain in each case two arms, adjacent in one case and opposite in the other, which have fixed values. These impedances must meet certain definite requirements, as already stated.

For the case of adjustment by an adjacent arm, that is, by Z_{AD}, equation (2) may be written in the form

$$R_{CD} + jX_{CD} = \frac{Z_{BC}}{Z_{AB}}(R_{AD} + jX_{AD}). \qquad (5)$$

Then in order that this equation fulfill the requirements expressed by equation (3), the vector ratio of the fixed arms must be either real or imaginary but not complex, that is, the difference between their phase angles must be 0°, 180° or ± 90°.

For the case of adjustment by the opposite arm Z_{AB}, equation (4) may be written in the form

$$R_{CD} + jX_{CD} = Z_{BC}Z_{AD}\ (G_{AB} - jB_{AB}) \qquad (6)$$

Then in order that this equation fulfill the requirements of equation (3), the vector product of the fixed arms must be either real or imaginary, but not complex, that is, the sum of their phase angles must be 0°, 180° or ±90°.

In the case of bridges of the type indicated by equation (5), the fixed arms always enter the balance equation as a ratio, and are therefore called ratio arms, the bridges of this type being called ratio arm bridges.

In the case of bridges of the type indicated by equation (6), the fixed arms always enter the balance equation as a product, and are therefore called product arms, the bridges of this type being called product arm bridges.

These two types may be further subdivided according to whether the term involving the fixed arms is real or imaginary.

It should be pointed out at this time that the fixed arms are fixed in value only to the extent that they are not varied during the course of a measurement.

They may be functions of frequency, and may be arbitrarily adjustable to vary the range of the bridge, but they are not adjusted in the course of balancing the bridge.

CLASSIFICATION OF BRIDGE TYPES

The foregoing discussion shows that all simple four arm bridges meeting requirements specified may be divided into four types. The balance equations of these four types may now be simply derived from the general equations (2) and (4).

1. *Ratio Arm Type—Ratio Real*

If Z_{BC}/Z_{AB} is real, then

$$\theta = \theta_{BC} - \theta_{AB} = 0° \text{ or } 180°$$

That is

$$Z_{BC}/Z_{AB} = R_{BC}/R_{AB} = X_{BC}/X_{AB} \qquad (7)$$

Substituting equation (7) in equation (5) and separating,

$$R_{CD} = \frac{R_{AD}R_{BC}}{R_{AB}} = \frac{R_{AD}X_{BC}}{X_{AB}}, \qquad (8)$$

and

$$X_{CD} = \frac{X_{AD}R_{BC}}{R_{AB}} = \frac{X_{AD}X_{BC}}{X_{AB}}. \qquad (9)$$

For this type it follows from equations (8) and (9) that the components of Z_{CD} are balanced by components of Z_{AD} of the same phase, that is R_{AD} will balance R_{CD}, and X_{AD} will balance X_{CD}.

2. *Ratio Arm Type—Ratio Imaginary*

If Z_{BC}/Z_{AB} is imaginary, then

$$\theta = \theta_{BC} - \theta_{AB} = \pm 90°.$$

That is

$$Z_{BC}/Z_{AB} = jX_{BC}/R_{AB} = -jR_{BC}/X_{AB} \qquad (10)$$

Substituting equation (10) in equation (5) and separating,

$$R_{CD} = -\frac{X_{AB}X_{BC}}{R_{AB}} = \frac{X_{AC}R_{BC}}{X_{AB}}$$

and

$$X_{CD} = \frac{R_{AD}X_{BC}}{R_{AB}} = -\frac{R_{AD}R_{BC}}{X_{AB}}. \qquad (12)$$

For this type it follows from equations (11) and (12) that the components of Z_{CD} are balanced by components of Z_{AD} 90° out of phase, that is X_{AD} will balance R_{CD} and R_{AD} will balance X_{CD}.

3. *Product Arm Type—Product Real*

Ir ($Z_{BC}Z_{AD}$) is real, then

$\theta = \theta_{BC} + \theta_{AD} = 0°$ or $180°$

That is

$$Z_{BC}Z_{AD} = Z_{BC}/Y_{AD} = R_{BC}/G_{AD} = -X_{BC}/B_{AD}. \qquad (13)$$

Substituting equation (13) in equation (6)

$$R_{CD} = \frac{G_{AB}R_{BC}}{G_{AD}} = \frac{G_{AB}X_{BC}}{B_{AD}} \qquad (14)$$

and

$$X_{CD} = -\frac{B_{AB}R_{BC}}{G_{AD}} = \frac{B_{AB}X_{BC}}{B_{AD}}. \qquad (15)$$

For this type the components of Z_{CD} are balanced by componetns of Y_{AB} of the same phase, that is G_{AB} will balance R_{CD} and B_{AB} will balance X_{CD}.

4. *Product Arm Type—Product Imaginary.*

If ($Z_{BC}Z_{AD}$) is imaginary, then $\theta = \theta_{BC} + \theta_{AD} = \pm 90°$

That is

$$Z_{BC}Z_{AB} = Z_{BC}/Y_{AD} = jR_{BC}/B_{AD} = jX_{BC}/G_{AD}. \qquad (16)$$

Substituting equation (16) in equation (6)

$$R_{CD} = \frac{B_{AB}R_{BC}}{B_{AD}} = \frac{B_{AB}X_{BC}}{G_{AD}} \qquad (17)$$

and

$$X_{CD} = \frac{G_{AB}R_{BC}}{B_{AD}} = \frac{G_{AB}X_{BC}}{G_{AD}}. \qquad (18)$$

For this type the componnts of Z_{CD} are balanced by components of Y_{AB} 90° out of phase, that is B_{AB} will balance R_{CD} and G_{AB} will balance X_{CD}.

The relations given in these equations are summarized in Table I.

TABLE I
BRIDGE TYPES

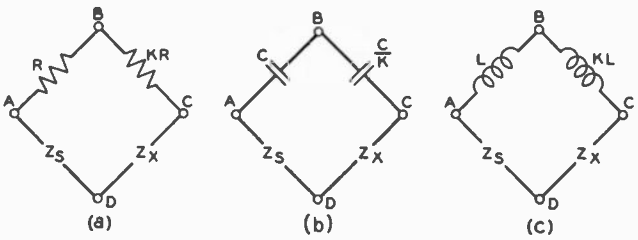
Unknwn	Adjustable Standard			
	Ratio Arm Type		Product Arm Type	
	Ratio Real	Ratio Imaginary	Product Real	Product Imaginary
R_{CD}	R_{AD}	X_{AD}	G_{AB}	B_{AB}
X_{CD}	X_{AD}	R_{AD}	B_{AB}	G_{AB}
G_{CD}[1]	G_{AD}	B_{AD}	R_{AB}	X_{AB}
B_{CD}[1]	B_{AD}	G_{AD}	X_{AB}	R_{AB}

[1] These values may be derived by using admittances in place of impedances and vice versa throughout.

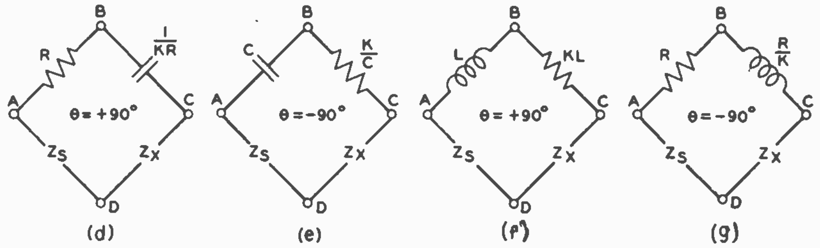
ACTUAL BRIDGE FORMS

The fixed arms may be made up of single resistances or reactances or of complex impedances provided they meet their phase requirements. Since the choice of complex impedances has no practical advantages over simple reactances or resistances the choice of fixed impedances should obviously be made on the basis of the simplest practical type. So they will be limited for the present to simple resistance, capacitances, and self inductance.

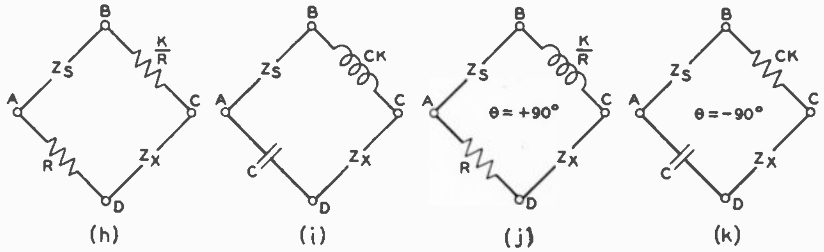
Fig. 2 gives all of the combinations of fixed arms which meet the phase angle requirements already stated, when limited to simple resistance, inductance, or capacitance. For all forms, the magnitude of one arm is given in terms of the other and of a constant K, such that the only term which appears in the balance equation is the term K. None of these bridges represents a distinctly new type but since the classification is by means of the fixed impedance arms, one of them may be used to measure several types of impedance. Accordingly, it may correspond to more than one of the well-known bridge types. For this reason, any references to, or comparison with existing special types of bridge are omitted.



1 RATIO ARM TYPE $\theta = \theta_{AB} - \theta_{BC} = 0°$



2 RATIO ARM TYPE $\theta = \theta_{AB} - \theta_{BC} = \pm 90°$



3 PRODUCT ARM TYPE $\theta = \theta_{AD} + \theta_{BC} = 0°$

4 PRODUCT ARM TYPE $\theta = \theta_{AD} + \theta_{BC} = \pm 90°$

Fig. 2—The various forms of 3-arm bridges divided into four types. Forms f, g and j are impractical.

Table II gives the balance equations for each type of bridge for the measurement of any component of the unknown impedance in terms of resistance, capacitance, and inductance. These equations are simply derived from the general equations (8) to (18) by substitution of circuit constants for impedances and by the introduction of the constant K. This constant must be evalu-

TABLE II
BALANCE EQUATIONS

Unknown	Ratio Arm Type			Product Arm Type		
	$\theta=0$	$\theta=+90°$	$\theta=-90°$	$\theta=0$	$\theta=+90°$	$\theta=-90°$
$R_{CD}=$	KR_{AD}	KL_{AD}	K/C_{AD}	KG_{AB}	K/L'_{AB}	KC'_{AB}
$L_{CD}=$	KL_{AD}	—	KR_{AD}	KC'_{AB}	KG_{AB}	
$C_{CD}=$	KC_{AD}	$1/KR_{AD}$	—	KL'_{AB}	—	$1/KG_{AB}$
$G_{CD}=$	KG_{AD}	$1/KL'_{AD}$	C'_{AD}/K	R_{AB}/K	L_{AB}/K	$1/KC_{AB}$
$L'_{CD}=$	KL'_{AD}	—	K/G_{AD}	C_{AB}/K	K/R_{AB}	—
$C'_{CD}=$	KC'_{AD}	G_{AD}/K	—	L_{AB}/K	—	R_{AB}/K
Figures..	2A 2B 2C	2D 2F[2]	2E 2G[2]	2H 2I	2J[2]	2K

[2] These forms are not practical.

R, L and C = series components of complex arms.

G, L′ and C′ = parallel components of complex arms.

K has the value indicated on the individual circuits of Fig. 2.

$\theta = \theta_{AB} - \theta_{BC}$ for Ratio Arm Type

$\theta = \theta_{AD} + \theta_{BC}$ for Product Arm Type

(Continued on Page 20)

A BUNGLED AFFAIR

By VOLNEY G. MATHISON

As per schedule the "Yosemite," small and dirty Pacific Coast steam-schooner, loaded lumber at St. Helens. Also as per regular schedule, the wily and silver-tongued steamer-ticket agents in Portland roped in some fifty or sixty unsuspecting land-lubbers and hypnotized them into parting with quite a number of perfectly good American dollars, in exchange for which the victims received long, pink tickets, entitling them to a "first-class passage to San Francisco on the new, magnificent, and luxurious (?) steamship 'Yosemite'"

On the day before the "Yosemite" was due to sail, the afore-mentioned land-lubbers were herded aboard a little river boat and were taken down the Columbia River to St. Helens, twenty-five miles below Portland. Here they were hustled aboard the dilapidated old steam-schooner, the gangplank and lines were quickly taken in, and the engine-telegraph signaled "full-ahead." By the time the crowd of provincial travelers had awoke to a tardy realization of the fact that they had been victimized, they found themselves out in the middle of the broad Columbia, and very much up against the necessity of staying aboard and making the best of a bad deal.

As usual, some of the more militant of the humbugged ones raised quite a fuss. A particularly strenuous protester was a small, dark-complexioned man, who had a conspicuously nervous manner, and who seemed to be afflicted with a very snarly disposition. He had a small, black satchel, which he appeared to be determined to not let out of his hand for a moment. After poking his nose into his two-by-four stateroom, and then, accidentally wandering into the sailor's mess-room, where he saw a gang of terrible Finns devouring huge platters of codfish and corned beef he decided, evidently, that he had seen enough. He demanded to be told where he could find the captain of the vessel, and was informed that the master's quarters were on the upper deck.

Hastening up a companion-way, the angry passenger found an important looking, uniformed young man, who was majestically pacing to and fro on the upper deck. His trousers were freshly pressed and the setting sun was brilliantly reflected in his shining brass buttons and gold bands.

"Hey, what kind of a skin-game do you call this, anyway?" caustically snarled the under-sized stranger, planting himself squarely in front of the promenading officer.

"Er—what's that?" spluttered the surprised knight of the uniform, halting involuntarily.

"Huh! You're a bunch of dirty, cheating, lying, rotten fakirs, and you know it!" stormed the passenger hotly, as he shook an excited fist under the nose of the astonished listener. "When I bought my ticket for this boat, I asked the agents why she didn't come up to Portland to take on her passengers, and the skunks told me that she was nearly a quarter of a mile long and had to stay down the river where there was room enough for her to turn around in! And they said that she had three captains and five smokestacks and six decks and a big brass band on every deck—!"

"But—!"

"Where's the three dining saloons and the moving picture show? Where's the swimming pool and the ballroom? Where's—!"

"Well, what are you tellin' me all about it fer?" sharply interjected his listener. "I didn't sell you your ticket, did I?"

"Keep quiet, **Jack Lambert!" he grated** in a steely tone, drawing a big automatic from his coat pocket.

"No, but you're the captain of this steamship, aren't you?" snapped the buncoed one, glaring at the officer's glittering gold buttons

"No, I'm the chief radio operator," announced Peter Bockstrup, with dignity, drawing himself up to his full height.

"Piffle!" snorted the disagreeable stranger, and he went away.

Feeling a good deal irritated because of this affront, Peter Bockstrup started toward the wireless room. Upon going to it, he found another passenger standing in the doorway and looking in at the radio equipment. He was a tall, well-built man with a rather hard, yet not unattractive face, which was slightly disfigured by a small birthmark on the left cheek.

"Pardon me," he said easily, stepping aside as the chief wireless operator approached. "I was just taking the liberty of glancing in at your apparatus."

"Oh, that's all right," answered Peter Bockstrup, unconsciously contrasting the man's agreeable and somewhat distinctive manner with the nervous and snarling disposition of the small stranger whom he had just encountered. "Come in an' sit down awhile if you want to."

"I will, thanks," responded the passenger with alacrity, stepping inside. "There doesn't seem to be any place for one to go and while away the time on this steamer—her passenger accommodations are hardly to be called attractive, to my notion."

"Yep, that's right," agreed the chief wireless operator, proffering a broken-down chair to his visitor. "In fact, this scow's so darned cramped up a fellow can't hardly get out of his bunk in the mornin' without fallin' overboard."

The stranger laughed appreciatively, and thus the ice was broken. Peter Bockstrup found the passenger, who said his name was Collinge, to be a pleasing talker. He gave an impression of having traveled extensively and seen much, his observations were interesting and he conversed freely on many subjects, yet, when talking directly about himself, he exhibited a peculiar reserve, which the wireless operator could not understand.

It was almost midnight when Collinge left the wireless cabin and went to his room.

Shortly afterward, the "Yosemite" slowed down abreast of Astoria and the river pilot was taken off by his launch. Two hours later the little steam-schooner crossed out over the bar and set her course for San Francisco.

When Peter Bockstrup arose at six o'clock in the morning to relieve his second operator, he found the ship bucking into a strong, southwesterly gale. A sixty-mile wind had whipped the ocean into long lines of high, white-capped seas, among which the old steam-schooner was rolling and pitching violently. Going into the radio room, Peter Bockstrup discovered his assistant seated in the middle of the floor, clasping a fire-bucket firmly between his knees, into which he was involuntarily ejecting foodstuffs at frequent intervals. Even the chief wireless operator, seasoned veteran that he was, with four months of sea service to his credit, had a rather uneasy feeling in the pit of his stomach.

The gale increased in fury. The "Yosemite" began to ship seas, which shook her from stem to stern, and which sent clouds of salt spray flying along her decks. Peter Bockstrup thought of the disagreeable stranger who had so rudely accosted him the evening before, and the chief wireless operator laughed to himself as he mentally pictured the unhappy passenger being tossed around in his uncomfortable bunk. Peter Bockstrup did not have any doubt but that the fellow was thoroughly seasick, and, therefore, he was greatly astonished when the wireless room door was suddenly jerked open and the verv object of his thoughts squeezed inside. He was dripping with water, having evidently been drenched while clambering up to the upper deck upon which the radio shack was located. In one hand he tightly gripped the small black satchel which he brought aboard with him, and his face was an ashen gray.

"There's a dangerous crook on board this ship, and I want to send a message to the police!" he burst out, shivering as though with an ague, and the cringing, terrified manner in which he spoke was in remarkable contrast to his caustic, snappy style of the evening before. "He doesn't know that I'm carrying this—" he indicated the satchel in his hand, "—and if he should find out about it, he'd surely do away with me and steal it!"

"Steal what?" quired Peter Bockstrup, puzzled.

"I'm a special messenger of the DeLacey Detective Service," answered the passenger, nervously glancing over his shoulder, "and I'm carrying a package of jewelry from the Ellingsworth vaults in Portland to Mrs. Ellingsworth in San Francisco. She expects to wear the jewelry at some reception affair next week—but she never will though, if Lone Lambert discovers that I have it here with me—!"

"Lone Lambert!" broke in the chief wireless operator, interrogatively.

"He's a big man with a small birthmark on the left side of his face," said the queer passenger, with another nervous shiver. "He looks and acts somewhat like a gentleman traveler, but he's only a desperate crook, however."

"Birthmark! You mean Mr. Collinge!" ejaculated Peter Bockstrup, incredulously. "You're out of your head, I reckon."

"No, I'm sure he's Lone Lambert," whined the other. "I saw him once quite a while ago when he was running an oil-stock swindle and some other fake promotion schemes. Things got too hot for him in that line, as it was discovered that he had a record for clever robberies and crookedness as far back as they could trace him. He's wanted by the police of a dozen cities."

"Well, you might be right, but I reckon you're all wrong because only rubes an' hicks get fooled into comin' aboard this five-smokestacker," affirmed Peter Bockstrup, with a faint smile. "And, anyway, if the jewelry stuff's worth so much, why didn't you send it by express?"

"That's none of your business," snapped the passenger, smarting under the implied sarcasm and forgetting his fright in his rising anger. "I came here to send a message—not to argue with you!"

"All right, all right," hastily answered Peter Bockstrup, and he handed the passenger a pad of sending blanks.

The passenger took the note-book from his coat pocket, and consulting it frequently, he wrote out the message, composed entirely of code words.

"It's to a private address," said the chief wireless operator, looking at it.

"That's a special police address," responded the messenger, shortly.

Peter Bockstrup checked the telegram.

"Forty words," he said. "That'll be six dollars and fifteen cents to Frisco."

The passenger paid the charges and went out.

The chief wireless operator called up the naval station at North Head and sent the message. He had just finished when Collinge rapped on the door and came in.

"Was that sneaky-looking little fellow in here a few minutes ago filing a telegram?" he asked, sharply, motioning toward the pad laying on the operator's desk.

"Er—yes," answered Peter Bockstrup, with some hesitation, "but I can't tell you nothin' about it—it would be against the law." He prudently covered the pad with his hand.

"Oh, that's all right you don't need to—the mere fact that he did send a message tells me all I wish to know," replied Collinge, with a strange, hard smile. "I'd wager a hundred dollars to a dozen Russian rubles that he's got stolen goods in his possession again."

"Stolen goods!" ejaculated Peter Bockstrup, astonished. "Isn't he a special messenger, then?"

Collinge laughed, shortly.

"Did he tell you that?"

"Yes, he did," blurted out the chief wireless operator, half involuntarily. "And he said he was takin' a bunch of jewelry to Frisco for a woman to wear at a party next week!"

"Humph! That's a good one," Collinge chuckled, grimly. "Lone Lambert a special messenger. Ha ha!"

Peter Bockstrup's eyes opened wide with amazement.

"You say his name's Lone Lambert?"

"Yes, why?"

"But—er—gosh!" spluttered the astounded chief wireless operator. "That's who he said you was!"

"Well, I'll be damned!" exploded Collinge, and he laughed, heartily. Then he drew back the lapel of his coat, revealing a Pinkerton detective badge.

"You're a detective!" gasped Peter Bockstrup.

Collinge smiled.

"Supposed to be one," he replied.

"Yet, I really didn't even know that Lone Lambert was on board until I happened to see him duck into his stateroom a few minutes ago."

There was a pause.

"As I was intending to say before, you shouldn't have sent that telegram," Collinge continued, "but, of course, it's too late, now. Give me the pad and I'll write out one for headquarters, so that they'll be ready for us when we dock at San Francisco."

Peter Bockstrup handed the message pad to Collinge. Like the nervous passenger before him, he took out a note-book and consulted it to obtain code words, which he wrote down on the blank. The chief wireless operator observed that Collinge's telegram was also to a private address. He started his motor-generator, got hold of the station at North Head again, and sent the message. Collinge stayed in the wireless room until Peter Bockstrup had signed off, and then he went out.

About fifteen minutes later just as an unusually violent wind-squall struck the "Yosemite," causing her to pitch and lunge more wildly than ever before, the chief wireless operator heard the beckoning whistle of the speaking-tube connecting the radio cabin with the ship's bridge.

"Hello there," he answered, taking the tube off its hook.

"Say, Sparks"—it was the captain's voice, barely audible above the howling of the storm—"your wireless gear bane gone overboard! It carried avay fore an' aft, both together at vunce an' vent all over the side. You bane come out an' have a look, qvick!"

"All right," answered the chief wireless operator, and he made for the door. With difficulty he forced it open against the wind, and went outside. The gale was blowing with such fury that he was obliged to cling to the deck railing in order to keep his feet. He looked up at the ship's masts and saw that his aerial had entirely disappeared. Even the lead-in wires had broken off, near the roof insulator, and were gone.

As he stood clutching the iron railing with both hands and staring up at the bare sticks, he became aware of the fact that Collinge was at his side.

"It's darned queer that your whole antenna went overboard at once," he shouted, his voice almost drowned by the roar of wind and water. "Let's go and look at the halyards."

Holding onto anything offering a hand hold, the chief wireless operator and Collinge made their way to the main-mast shrouds. There they found the manila aerial halyard still fast in the rigging, with a short piece hanging down. Col-

(Continued on Page 28)

FILTER CIRCUITS FOR VOLTAGE DOUBLING SERVICE

By DR. BEN KIEVIT, Jr.*

It is a well known fact that the type of filter circuit used in conjunction with a tube rectifier has a marked effect on the regulation characteristics, ripple content, and peak currents of the rectified power which can be supplied. General factors involved in the choice of rectifier will depend upon the sort of equipment to which the power is to be delivered. Consideration must be given to such questions as:

(1) DC voltage required.

(2) DC current drain (total.)

(3) Voltage regulation necessary.

(4) Heater voltage rating of the rectifier.

(5) Cost.

In the following paragraphs a discussion is given on filter circuits as applied in connection with a Sylvania 25Z5, with particular emphasis on various factors related to the first three points outlined above.

This tube is a 25-volt heater type high vacuum rectifier designed for full-wave circuit operation. Furthermore, since both of its cathodes are brought out to separate base pins the tube may be used as a voltage doubler. It is this latter type of service that is of present interest.

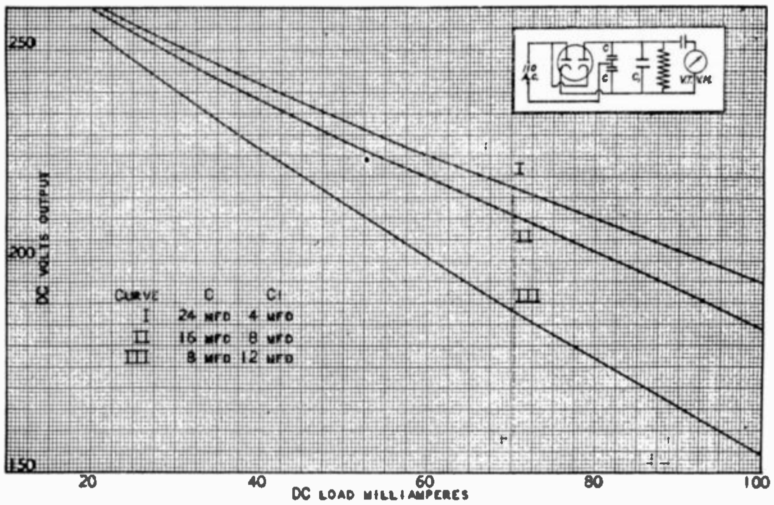


Figure 1.

The general circuit for voltage doubling includes two condensers arranged in series, which are connected between plate No. 2 and cathode No. 1. The common condenser terminal connects directly to one side of the 110 volt AC input. The other side of the line goes to plate No. 1 and cathode No. 2.

Two variations in the simple filter circuit have been studied and the results are shown in the accompanying drawings No. 1 and No. 2. In the former the diagram indicates a condenser C1 shunted across the load. Voltage regulation curves were taken for DC load current values from 20 to 100 milliamperes using an AC input voltage of 110 volts R.M.S. The capacitances of the condensers marked C and C1 had the values as indicated. Thus for each curve the effective capacity was maintained at 16 mfd. It is evident the conditions for curve I are superior to those for II and III. However, this does not tell all of the story.

It will be noted that the conditions for curve II on Drawing No. 1 are identical with those for I in No. 2. In the latter is shown the hum content, measured in AC volts by means of a vacuum tube voltmeter, as a function of the output current. At the high current values the hum becomes excessive.

Elimination of this undesirable condition is best accomplished by the introduction of a choke (see circuit diagram) having a low DC resistance. For measurements obtained with this circuit the condensers marked "C" were maintained at 16 mfd. each. Changing C1 to 8, 4, and 2 mfd. respectively, gave results shown by curves II, III, and IV. It is evident that the circuit conditions for Curve II are the most satisfactory.

A single voltage regulation curve is shown which applies to Curve II, III, and IV (choke included in circuit) since the DC output volts, for the various condenser arrangements, indicated differences on the order of only about one volt. It is true that the available voltage is somewhat less when a choke is inserted than without it, due to the DC drop through the coil. But the sacrifice in voltage may be offset by the advantage of decreased hum in the rectified power delivered.

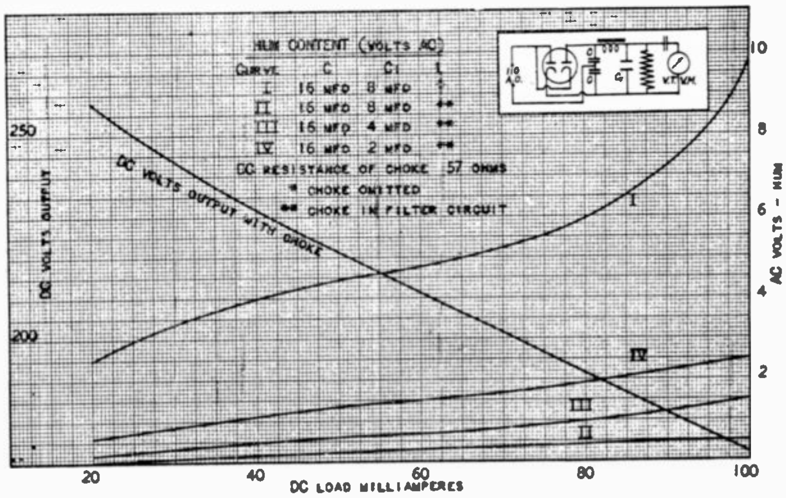


Figure 2.

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*Hygrade Sylvania Corp.

COMMITTEE OF EXPERTS APPLY RADIO TO THE TELETYPEWRITER

Organization of a committee of radio experts to study the practicability of utilizing radio for the operation of the nation-wide network of Department of Commerce aeronautical teletypewriter circuits, was announced by Rex Martin, Assistant Director of Aeronautics of the Department in charge of air navigation.

The committee is as follows: Mr. Martin, chairman; Paul Goldsboro, president Aeronautical Radio, Inc., Washington; W. H. G. Finch, secretary and chief engineer American Radio News, New York; Eugene Sibley, chief communications section and W. E. Jackson, chief radio section, Aeronautic Branch, Department of Commerce.

The 13,000 miles of leased land-wires that comprise the Department of Commerce aeronautical teletypewriter system throughout the United States are for the dissemination of hourly weather reports along the airways and for the transmission of weather maps every four hours. The hourly weather reports are broadcast to airmen in flight through Commerce Department airway radio stations.

If the committee headed by Mr. Martin finds it can apply radio to the operation of the teletypewriter machines on the airways, this will result in a substantial saving to the Government thru the elimination of the leased land-wires. The Department's airway radio stations and corps of trained radio operators would take over the radio phases of teletypewriter operation.

The committee plans a trial installation of radio-operated teletypewriters between Newark, N. J., and Washington, D. C., which will parallel the land-wire circuit already in operation. Both the hourly weather reports and the weather maps will be transmitted over the experimental circuit and an excellent opportunity of comparison between the two methods will be available. In connection with plans for this installation, Joseph Hromada, a Department of Commerce radio expert now on duty in Chicago, has been ordered to Washington.

Mr. Sibley will be in charge of the traffic phase of the experiment and Mr. Jackson will deal with the technical radio aspects. Mr. Finch will contribute experience already obtained by the American Radio News in transmitting press dispatches by radio teletypewriter between New York and Chicago, and Mr. Goldsboro, who co-ordinates the radio activities of the scheduled airlines, will advise with the committee in this regard.

Tests of radio-operated teletypewriters for transmission of aeronautical weather data along the Federal airways will begin in April between Washington and Baltimore.

It was decided to install two parallel radio circuits between Washington and Baltimore—one circuit to operate on 2,960 kilocycles and the other on 60 megacycles. Two transmitters, one for each circuit, will be located at the Washington airway radio station, and the two receivers will be installed at Logan Field, Baltimore.

If the committee find that the teletypewriter machines on the Federal Airways System can be operated by radio, this will result in a substantial saving to the Government through the elimination of the leased land wires, of which there are now some 13,000 miles. These teletypewriter circuits are used for the dissemination of hourly weather reports along the airways and for the transmission of weather maps every four hours.

HEARD ON 600 METERS

Nov. 26—

9:02 PM—600 meters—KEK DE JKMB SVC. HR SVC 8 PM WX SS TOHSEI MARU BND KEK FM KOK QRB 402 MILES FM KEK

9:05 PM —600 meters—KPK DE JKMB SVC. HR SVC 8 PM WX SS TOHSEI MARU BND KPK FM KSE QRB 402 MILES FM KPK

9:10 PM—600 meters—KPH DE JKMB SVC

705 meters—KPH DE JKMB SVC—8 PM WX SS TOHSEI MARU BND KPK FM KSE QRB 402 MILES FM KPK

9:22 PM—600 meters—KSE DE JKMB SVC AR

9:22 PM—600 meters—KFS DE JKMB SVC. SVC 8 PM WX SS TOHEI MARU BND KEK FM KOK QRB 402 MILES FM KEK QRU AR.

9:24 PM—600 meters—KOK DE JKMB SVC

9:24 PM—600 meters—KSE DE JKMB

9:25 PM—600 meters—KOK KOK KOK KOK VE VE VE KSE KSE KSE DE JKMB SVC and so on far into the night.

73 de PN of KJOO

POLICE RADIO CHANGES NECESSARY

The Federal Radio Commission adopted a new allocation plan for state and municipal police frequencies, effective May 1, 1934, in keeping with revised rules and regulations recommended by the Engineering Division, which provide for additional police channels made available at the Mexico City Conference.

The plan adopted requires adjustment of the present frequency assignments to police stations and allows for future assignments to municipalities or states requesting police radio facilities.

Since previous to this plan state police stations were allocated only three frequencies, nine frequencies are now available, the plan provides for an orderly growth of this service as additional states install radio equipment.

Nearly five years ago the Commission allocated three frequencies for that purpose. The Commission three years ago assigned 9 frequencies for police use, one year ago the number was increased to 11, and under the new plan 20 channels will be immediately available for state and municipal radio systems in the United States.

There are now 128 municipalities and 8 states equipped with their own radio police communication systems. More than 4000 police cars are equipped with receiving sets, and, judging by the success of recent experiments, it is conceivable that all of them will eventually be equipped with transmitting sets permitting two-way communication.

Every police radio communication system in the United States is licensed by the Federal Radio Commission. The Commission has assisted in the development of police radio systems by rendering technical advice and counsel. Also the Inspectors in charge of the field service, located in 20 important cities, have been available to the police for consultation.

In order that the Commission might be accurately informed as to the existing conditions, a questionnaire was sent to the licensees of municipal police stations requesting a definite reply to some pertinent questions. Only thirteen cities objected to a frequency change.

It will be necessary to change only three assignments of the thirteen cities objecting to a frequency change. The change, however, will amount to only four kilocycles in each case, and is made necessary because of the fact that their existing assignments do not coincide with the channel frequencies designated by the Mexico City agreement.

In connection with this plan, a study has been made of the power that should be allocated to police stations. Inasmuch as the conditions under which municipal police stations operate are not to be changed materially, no change in the rules and regulations were made. There is no rule at the present moment specifying the maximum power that may be installed at state police stations. It was, therefore, decided that as a matter of policy the maximum power be limited to 5 KW day, 1 KW night, and that the states be en couraged to install a number of transmitters of less power rather than

(Continued on Page 17)

Broadcast Station News

NBC Issues Program Policies

In connection with the new N B C Program Policies, Richard C. Patterson, Jr., Executive Vice President of N B C, has issued the following statement:

> "The relationship between advertisers and the public is a matter of primary concern to all those interested in advertising. With the cooperation of leading broadcast advertisers and the advertising agencies, the National Broadcasting Company has attempted to crystallize current trends of thought on this subject in a statement, bound in handy booklet form. In the future, NBC will be guided in all its presentations by the program standards and program procedures there set down.
>
> "In order that broadcast advertising may be developed to the advantage of both the advertisers and the public, its policies should be kept in constant touch with changing public attitudes. N B C invites suggestions or criticisms with regard to any aspect of the policies stated."

Of particular interest are the following excerpts taken from "N B C Program Policies" and quoted verbatim:

> "Its (broadcast program) primary appeal should be to the listener's interest. Unpleasant or gruesome statements should be avoided as more likely to offend than to instruct or entertain."
>
> "Tiresome repetition or too much detail should be avoided. For instance, the advertiser's street address and the like should not be reiterated to the point of annoyance."
>
> "Statements of prices and values must be confined to specific facts. Misleading price claims or comparisons must not be used.

As a safeguard against misuse of broadcast facilities for unfair competition the policy is stated as follows:

> "Commercial programs shall not refer to any competitor, directly or indirectly, by company name, by individual name, or by brand name—regardless of whether such reference is derogatory or laudatory."

With regard to testimonials, N B C states that the advertiser or his agency must submit to the National Broadcasting Company, at least three days in advance of the broadcast, "either an indemnification signed by the advertiser or his agency, or a written release authorizing its use for advertising purposes, signed by the person making the testimonial and sworn to before a notary public and must furnish the National Broadcasting Company a full copy thereof."

Wet or Dry?

The Federal Radio Commission authorized the following statement regarding the use of radio broadcasting stations for the purpose of advertising liquor:

"The Federal Radio Commission calls renewed attention of broadcasters and advertisers to that Section of the Radio Act of 1927 which provides that stations are licensed only when their operation will serve public interest, convenience and necessity, and asks the intelligent cooperation of both groups in so far as liquor advertising is concerned.

"Although the 18th Amendment to the Constitution of the United States has been repealed by the 21st and so far as the Federal Government is concerned there is no liquor prohibition, it is well known that millions of listeners throughout the United States do not use intoxicating liquors and many children of both users and non-users are part of the listening public. The Commission asks the broadcasters and advertisers to bear this in mind.

"The Commission will designate for hearing the renewal applications of all stations unmindful of the foregoing and they will be required to make a showing that their continued operation will serve public interest, convenience and necessity."

A Centralized Agency

President Roosevelt recommends the control of all communication systems of the nation, telegraph, telephone, and radio be put under one commission directly under the control of one Commission.

The practical side of this seems to recommend such an agency. Carried out along the lines of the Interstate Commerce Commission it is believed much better results would be obtained than at present.

Some of the points the committee believes would be remedied are:

"Prevent discrimination.

"Prevent speculative management.

"Prevent the 'watering' of stocks."

The main units noted by a Committee report to the President, to be controlled, would be The American Telephone and Telegraph Company, Western Union Telegraph Company, International Telephone and Telegraph Company, Radio Corporation of America, and subsidiaries of these units. Of course all smaller units would also come under the same control and regulations of such a board if established.

Comparison is made in the report with Great Britain's system where all are under one control.

The Pro's and Con's of both sides were well discussed by the Committee, in their report.

Protest on Company Unions

The American Federation of Labor have been making some pointed attacks on the wave of "Company Unions" sprouting up in all industries all over the country, and have enlisted in their condemnation of these organizations many members of the Congress, both Senate and House of Representatives.

The organizations are described as reactionary and in conflict with the original plans of the NRA.

Among the proposals are:

1.—Corporations are to be prohibited by law from forming, fostering, and financing unions preparing their constitutions and guiding and directing their activities.

2.—The National Labor Board would receive power to subpoena witnesses, swear them under oath and examine the books and financial records of concerns whose cases are under consideration.

3.—The Labor Board would receive mandatory power to hold elections where these are requested by employes or where the board feels that such elections are necessary to determine who shall represent the men for collective bargaining.

4.—Labor should have representation on all boards and code authorities.

5.—Adequate protection is to be afforded to all workers who organize into unions so that they shall be free from discharge, lockout, and intimidation.

Police Radio Changes Necessary

(Continued from Page 16)

one or two transmitters of maximum power.

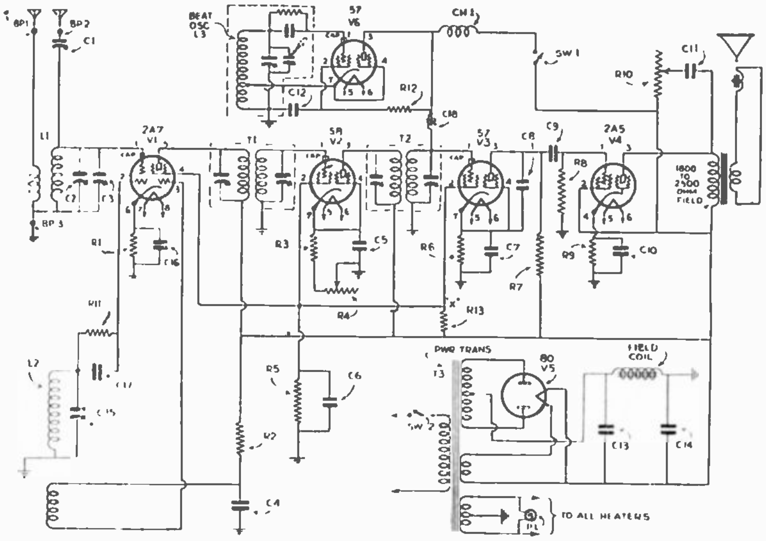
In addition to stations licensed for police service in the conventional medium-high frequency band, there are outstanding at this time experimental authorizations which permit 50 municipalities to operate 125 stations in the ultra-high frequency range.

THE SUPREME SIX SHORT WAVE SUPER

By H. G. CISIN

The Supreme Six Super is a deluxe short wave set designed for discriminating fans. While there is nothing particularly difficult about the construction of this receiver, it is not recommended for beginners. It is more suitable for those who have passed their novitiate or for custom set builders who have demands for a medium-priced short wave receiver capable of top-notch performance.

The Supreme Six is designed for high efficiency over the entire short wave band. A 2A7 combined first detector and oscillator is used at V1, while the single I. F. stage employs a variable mu 58 tube at V2. Type 57 tubes are used for the beat oscillator V6 and the second detector V3. The output tube is a 2A5 pentode. Thus it is apparent that the newest and most efficient pentodes are used in this circuit. The 2A7 pentagrid converter tube actually performs the dual functions (first detector and oscillator) better than two separate tubes. The principle of electron coupling supplants the older reactive coupling, offering advantages in eliminating undesirable intercoupling effects between signal, oscillator and mixer circuit and also in reduction of local frequency radiation. As a further advantage, the circuit is greatly simplified and greater oscillator stability is attained. The desirability of the 58 tube as an I. F. amplifier is recognized by all competent radio engineers. The 57 tube is particularly recommended as a biased second detector because of its ability to deliver a large audio frequency output voltage of good quality with a fairly small i. f. signal input.



SUPREME – 6 Short Wave SUPER

It also functions extremely well as a beat oscillator. The 2A5 output tube, which is resistance coupled to the second detector, has a rated power output of 3 watts. Its advantages over older types of power output tubes are large power output with relatively small input-signal voltage and low hum-level due to heater cathode construction. The 80-type rectifier and the filter circuit employed in the Supreme Six are conventional and still modern in design.

Provision is made in the Supreme Six for employing long or short antennas or for the use of a noise-eliminating antenna. Plug-in coils at L1 and L2 give a range of from 15 to 2000 meters in four steps. The beat oscillator is used only when working C. W. or to tune in a distant station more readily. Of course, the beat oscillator is turned off as soon as the distant station is tuned in properly. The potentiometer at R4 provides excellent control of volume. Tone control also, is provided at R10. Hammarlund tuning condensers are used at C2-C15 and C3.

The new Hammarlund "air tuned" i. f. transformers (465kc) are used at T1 and T2. They are of the tuned primary, tuned secondary type with both plate and grid coils of Litz wire. They are tuned to resonance by means of air dielectric variable condensers of special design. The new-type beat frequency oscillator L3 also employs air dielectric condensers and is tunable by means of a vernier condenser turned by a lever. By moving the lever one way or the other, a 1000 or 1500 cycle beat note is produced. When so adjusted the Supreme Six provides a remarkable degree of "single signal" selectivity for C. W. reception.

The lead-in system with this receiver eliminates the problem of local interference from electric appliances, etc.

In constructing the Supreme Six, mount all sockets first, fastening the shield bases for V1, V2 V3 and V6 at the same time. Next mount the power supply transformer and then the dual variable condenser C2, C15.

The following parts are mounted on the front chassis wall as shown in the diagram: R4, C3, SW1 and R10 (combined with SW2.) The triple binding posts BP1, 2 and 3 and a four prong speaker socket are mounted on the rear chassis wall. ,

The two Hammarlund I. F. transformers T1, T2 are mounted next and also the beat oscillator L3. The electrolytic condenser C13 is secured by means of the single-hole insulated mounting.

The chassis is now turned upside down and the cardboard container electrolytic condenser C14 is fastened to the inner side chassis wall by a thin metal strap. The Find-All a. f. choke CH1, is secured to the underside of the chassis by means of one of the fastening screws used to hold the L1 coil socket in place. All other parts including trimmer C1, fixed resistors and fixed condensers, are soldered in place while the wiring is being performed. Naturally, each resistor or condenser should be placed as near as possible to the part with which it functions. Thus, the trimmer condenser C1 is soldered to the terminal of the short antenna binding post; resistor R6 is soldered to the cathode terminal of socket V3, etc. After the dial has been fastened to the shaft of the variable condenser and to the inside of the front chassis wall, the set is ready for wiring.

Hook-up wire is recommended. This possesses the push-back feature found to be desirable to both by professional and amateur radio men. Filament circuits are wired in first. Then other circuits are wired in the following order—grids, plates, cathodes, negative returns and by-pass condensers, power supply and filter circuits.

It will be noted that the various tube elements are designated by different numbers on the schematic digram. This is done to help the novice in wiring up the tube sockets. In wiring socket V1, look at the bottom of the socket and start marking from the two large hole filament terminals in a clockwise direction. The filament terminals are 7, and 8, the next terminal (Plate) is 5, then 4, 3, 2 and 6. The screen grid clip is No. 1.

Looking at the bottom of sockets V2,

V3 and V6 in the same way, the filament terminals (large holes) are 5 and 6. Then, numbered in a clockwise direction, the other terminals are 3 2 4 and 7 respectively. The filament terminals of socket V4 are 5 and 6, while other terminals are 3, 2, 1 and 4 respectively.

In wiring the coil socket L1, look at the bottom of the socket with the two large hole terminals at the right Then the upper right terminal is the ground terminal, the lower right is also the ground (bottom of secondary.) The upper left is the connection which goes directly to the binding post (top of primary) while the lower left terminal connects the other trimmer C1. Socket L2 is wired as follows: Place the socket with the two large holes at the right looking at the bottom of the socket. Then the lower right terminal is connected to the ground and the upper right to R2 and C4. The lower left terminal connects to the stator of C15 and the upper left to grid 3 of tube V1.

To adjust the Supreme Six preparatory to placing it in operation tune the I. F. transformers as close to 530 kc. as possible. Turn on the beat oscillator, turn set upside down and rotate the screw on the bottom of the beat oscillator until a rushing noise or roar is heard. Then tune in a code station and make final adjustment by means of the rod or lever at the top. This varies the pitch. If the voltage of the power supply transformer is greater or less than 150 volts each side at 75 mils, then R13 must be changed so that the voltage drop between the point "X" and ground will be 100 volts. Note that condenser C18 merely consists of a few turns of No. 20 push-back wire wound closely about a similar wire but not electrically connected to it.

A de luxe short wave receiver for the radio connoisseur. A 2A7 tube performs the double function of first detector and oscillator. The other tubes employed are a 58 i. f., a 57 beat oscillator, a 57 second detector, a 2A5 power output tube and an 80 rectifier. This receiver uses the new air-tuned Hammarlund I. F. transformer and plug-in coils. The beat frequency oscillator provides excellent "single signal" selectivity for C. W. reception.

COMPLETE LIST OF PARTS REQUIRED FOR THE SUPREME SIX SHORT WAVE SUPER

C1—Hammarlund Equalizing Condenser 25 to 80 mmfd., type EC-80.

C2, C15—Hammarlund Dual Variable Condenser, .00014 mfd. per section, type, MCD-140-M.

C3—Hammarlund Midget Condenser, 20 mmfd., type MC-20-S.

C4, C5, C7, C12, C16—Aerovox Cartridge Condenser, .1 mfd., type 484-N.

C6—Cartridge Condenser, 25 mfd., type 484-N.

C8—Mica Condenser, .00025 mfd., type 1460.

C9—Cartridge Condenser .01 mfd., type 484-N.

C10—Electrolytic Cartridge Condenser, 10 mfd., 50 volts, type PR50.

C11—Cartridge Condenser, .05 mfd., type 484-N.

C13—Electrolytic Condenser, inverted insulated mounting, 4 mfd., type 15.

C14—Electrolytic Condenser, Cardboard Container, 8 mfd., type P5.

C17—Mica Condenser, .0002 mfd., type 1467.

R1, R3—Flexible Resistor, 300 ohm., type 2 G 300.

R2. R13—Resistor, 20,000 ohm., 1 watt, type F1.

R4—Potentiometer, 10,000 ohms., type RI-240.

R5—Resistor, 30,000 ohm. 1 watt, type FI.

R6—Resistor, 40,000 ohm., 1 watt, type FI.

R7—Resistor, 250,000 ohms., 1 watt, type FI.

R8—Resistor, 1 meg., 1 watt, type FI.

R9—Resistor 400 ohm., 10 watt, type H897.

R10—Potentiometer with Switch (SW1) 100,000 ohm., type RI-242-P.

R11—Resistor, 60,000 ohm., 1 watt, type FI.

R12—Resistor, 150,000 ohm., 1 Watt, type FI.

L1, L2—Plug-in Coils—four to each set—covering short wave band from 15 to 200 meters, type 704 SWS.

L3—Hammarlund "Air-Tuned" Beat Oscillator, 465 kc., type ATO.

CH1—Find-All Choke.

SW2—Rotary Switch, type M-12827.

T1, T2—Hammarlund "Air-Tuned" I. F. Transformers, 465 k. c., type ATT-465.

T3—Flush-type Power Transformer, type C1492.

BP1, BP2, BP3—Triple Posts, type M13029.

The following additional parts are required:

4—4-Prong Moulded Sockets (L1, L2, V5 and Speaker Socket.)

4—6-Prong Moulded Sockets (V2, V3, V4, V6.)

1—7-Prong Moulded Socket (V1.)

1—Drilled Metal Chases 14 inches x 8 2 inches high.

1—*Trutest Fan-type Dial with Pilot Light, type H9813.

3—*Trutest "ST" Tube Shields, type M13265.

1—*Lafayette 11 "Junior Model Dynamic Speaker," 2500 ohm. field with output transformer for 2A5 tube, type W19290.

4—Screen Grid Clips.

1—Roll Corwico Braidite Hook-up Wire, Solid Core.

1—*Lafayette 2A7 Pentagrid Converter Tube (V1.)

1—*Lafayette 58 Tube (V2.)

2—*Lafayette 57 Tubes (V3, V6.)

1—*Lafayette 2A5 Tube (V4.)

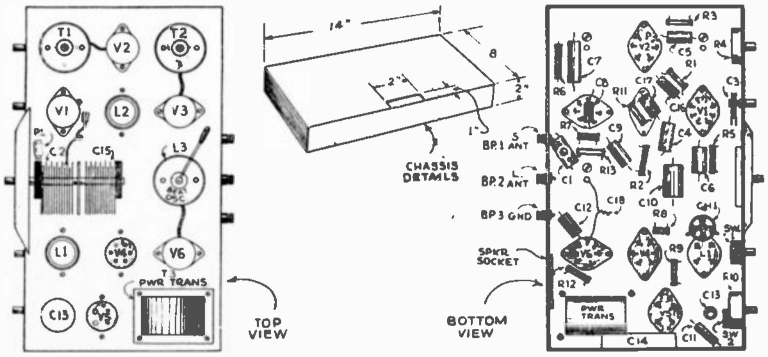
1—*Lafayette 80 Tube (V5.)

5—Knobs.

1—Wire Noise-eliminating Aerial Lead-in System.

*Lafayette and Trutest Products are marketed by Wholesale Radio Service Co., N. Y. C.

Note: Numbers in parentheses refer to corresponding numbers on diagrams.



SUPREME - 6 Short Wave SUPER

Classification of Bridge Methods of Measuring Impedances

(Continued from Page 12)

ated from the relation between the ratio arms or product arms shown in the individual bridge forms of Fig. 2. At the bottom of Table II are given the corresponding bridge figures for reference. This table shows no bridges having a phase relation of 180° between the fixed arms. A little consideration will show that since the phase relation between the unknown and the standard for such bridges must also be 180°, they cannot be used to measure any but pure reactances or negative resistances. Accordingly, they are not considered herein. In the case of the 90° relation, both signs must be considered and result in bridges which are complimentary with respect to one another, that is while one measures only inductive impedances, the other measures only capacitive impedances. Thus Table II shows the imaginary type subdivided into two subtypes, depending on the sign of the angle.

As an example of the use of this table: Suppose it is desired to measure the series resistance and inductance of an unknown impedance. This may be done by using adjustable standards of series resistance and inductance, series resistance and capacitance, parallel resistance and capacitance, or parallel resistance and inductance, by choosing the particular type of bridge for the purpose. For instance, referring to Table II, if it is desired to measure the series resistance in terms of conductance, and the series inductance in terms of parallel capacitance, the product arm bridge with real ratio, that is either Fig. *2h* or *2i*, would be used.

Since there are six types of balance equations given in Table II, it follows that five of the circuits of Fig. 2 are duplicates of others from the standpoint of the balance equations which they give. For instance, there is no difference whatever in the theoretical operation of the bridges of Figs. *2a*, *2b*, and *2c*. The choice must be determined entirely from other considerations. In the same way, as indicated by the figures tabulated in Table II. Figs. *2d* and *2f* give identical results as do Figs. *2e* and *2g*, and Figs. *2h* and *2i*. From the practical standpoint, there may be, and actually there is, considerable difference in the merits of these different forms. At this time, we may simply state that where a choice is possible, resistance is the preferred form of fixed arm and capacitance is preferred to inductance. This allows us to choose our preferred forms as Fig. *2a*, Fig. *2d*, Fig. *2e*, and Fig. *2h*.

A study of Table II shows that bridges of fixed ratio arm type always measure the series components of the unknown in terms of series components of the standard and, conversely, they measure the parallel components in terms of parallel components of the standard. Bridges of product arm type measure the series component of the unknown in terms of parallel components of the standard and conversely.

None of the balance equations of Table II includes frequency, that is, all of them allow the evaluation of each component of the unknown directly in terms of a corresponding component of the standard with the exception that in some cases the relation is a reciprocal one. Practically any form of standard may be chosen in order to measure a given type of unknown impedance.

PRACTICAL CONSIDERATIONS

So far the question whether the requirements for the fixed arm impedances given in Fig. 2 can be met in practice has not been considered. It may be well to point out that the performance of the bridge is determined very much by the degree to which the phase angle requirements are met. If there is appreciable error here, the two balances will not be entirely independent and necessary corrections will be complicated and difficult to make. Consequently, the first essential for a satisfactory bridge is that its fixed arms meet their phase angle requirements. For a general purpose bridge these requirements must hold independent of frequency at least over an appreciable frequency range.

The forms given in Fig. 2 meet their phase angle requirements at all frequencies provided the arms are actually pure resistances or reactances If they have residuals associated with them, it is still possible to meet the phase angle requirements in most cases, at least over a reasonable frequency range, as discussed below.

Resistances can be made to have practically zero phase angle, and condensers, particularly air condensers, may be made to have phase angles of practically 90°. In the case of condensers having dielectric loss, this loss may be kept quite small. However, it takes such a form that the phase difference of the condenser is approximately independent of frequency. For this reason, it can not be represented accurately either as a fixed resistance in series with the condenser or as a fixed conductance in shunt, when considered over a frequency range. Due to the small amount of this loss, it is usually satisfactory to represent it in either one form or the other, whichever is the more convenient.

In the case of inductance, there is always a quite appreciable series resistance which, for the usual size of coil, can not be neglected and must accordingly be corrected for.

With the above considerations in mind, the forms of Fig. 2 may now be considered from the practical standpoint. It is readily seen that the requirements of the real ratio type bridge can be met using resistances, capacitances, or inductances. In the case of the imaginary ratio type, the requirements can be met, at least very approximately, in the case of Figs. *2d* and *2e*. However, in the case of Figs. *2f* and *2g*, any resistance series with the inductance must be corrected by a capacitance in series with the resistance, if the correction is to be independent of frequency. Since the value of this series capacitance will, in general, be large, this form of correction is unsatisfactory. For instance, for a bridge in which the value of R is 1000 ohms, and the inductance has a high time constant, the series capacitance required is in the order of 3µf. By using a standard of inductance having larger series resistance, we may reduce this capacitance but we then have a form of bridge which is, in effect, a compromise between Figs. *2f* and *2g*, and Figs. *2d* and *2e*, which has no practical advantages over the latter. Accordingly, the forms of Figs. *2f* and *2g* must be impractical, particularly as Figs. *2d* and *2e* give identical performance.

In the case of the product arm type the requirements can be met by Fig. *2h* and can be met by Fig. *2i* by adding a conductance in shunt with the capacitance to compensate for the series resistance of the inductance. However, even though this allows us to meet the requirements, this form is less satisfactory than that of Fig. *2h* due to the difficulty of designing an inductance standard having inductance and series resistance invariable an appreciable frequency range. Again the requirements can be readily met by Fig. *2k*, but in the case of Fig. *2j* series resistance of the inductance can be corrected only by shunting the resistance arm by pure inductance, which is impractical. This is unfortunate since it rules out one form of bridge for which there is no duplicate and, consequently, makes the measurement of inductive impedances by bridges of this type impractical.

Summarizing the above, practical considerations rule out Figs. *2f*, *2g* and *2j*, reducing to five the number of different bridge types. There are eight forms remaining, namely three of the real ratio type, each capable of giving the same performance, two of the imaginary ratio type which are complementary, together giving a measurement of inductive and capacitive impedances; two of the real product type which will measure all types of impedance; and one imaginary product type which is capable of measuring only capacitive impedances.

The only duplicate forms are in the case of the real ratio and real product types. In the case of the latter, Fig. *2h* is to be preferred in practically all cases to Fig. *2i*, as already explained, and thus we can say that, practically speaking, we have duplicate forms only in the case of the real ratio type.

The three forms of this type are all used and each has certain advantages for certain types of measurements. This type of bridge, commonly known as the direct comparison type, is probably used more than any other and is one of the most accurate types, particularly in the special case of equal ratio arms. This is due to the fact that a check for equality of the ratio arms may be readily made by a method of simple reversal without any external measurements, and by this means practically all the errors of the bridge may be eliminated. Resistance ratio arms are preferable for a general purpose bridge because they are more readily available and more adjusted to meet their requirements. They also give an impedance independent of frequency, which is usually desirable. Capacitance ratio arms have certain advantages for particular cases. They may be readily chosen to give high impedance values, this being an advantage in certain cases, for instance in the measurement of small capacitances at low frequencies. This form is also desirable where high voltages must be used, since the ratio arms may be designed to withstand high voltages without the dissipation of appreciable energy. It also has the advantage that where measurements are desired with a direct current superimposed on the alternating current, the direct current is automatically excluded from the ratio arms and thus all of the direct current applied to the bridge passes thru

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ELEMENTARY VACUUM TUBE ELECTRONICS

FILAMENT CONSTRUCTION

By BENJAMIN WOLFE

This article will tend to discuss in an elementary manner the elementary principles of the vacuum tubes filament as an electron emitter. In order to more fully understand these elementary principles, it may be necessary to review the elementary principles of the Electron Theory.

The Molecule is the smallest quantity of any substance that will retain all the chemical requirements of that particular substance. For instance; some certain substance which when composed will equal two atoms of some chemical substance combined with one atom of another chemical substance. The smallest quantity of this substance which will still retain all of its chemical requirements will equal a molecule. The Atom is the smallest division of an element, and elements are various forms of matter that cannot be further chemically subdivided. The normal atom is a neutral body. In a normal atom there are enough electrons to exactly counteract the positive charge on the Nucleus. Speaking theoretically if one electron was removed from an atom, then the atom would not have the necessary amount of electrons to counteract its positive charge. The atom due to its deficiency of electrons will assume a positive charge. On the other hand if we add an electron to an atom we are once more breaking their equality and of course their ability to properly neutralize themselves. Therefore the excess electron would cause the atom to assume a negative charge. The Electron being a negative particle of electricity. It should be understood that all substances are made up of molecules, which in turn are made up of atoms. The atom in turn has a number of positive Nucleus around it and around the Nucleus revolves the Electron in its own orbit. It requires a smaller temperature to cause a movement of electrons, than it would to cause a movement of molecules, because the electrons are so much smaller than the molecules. When molecules tend to evaporate the surface tension tends to change and the substance may take the form of a liquid gas, or it may vaporize. This is often what happens when the temperature applied to the filament is excessive, hence rendering the filament useless. From this it can be seen that the life of a filament is shortened to a great extent by excessive temperature.

Electronic emission is obtained in respect to a filament, or any other substance for that matter, by simply heating the substance to a point where electrons tend to boil off of it. In the case of a filament we simply heat the filament, generally by means of an external potential, to a point where electrons commence emission. There are several conditions necessary for high electronic emission which are as follows: namely, the tube must have as high a vacuum as possible. The proper heating potential must be applied. The substance used in the construction of a filament, should be one which has high electron emitting qualities. If the tube was not highly evacuated the air would tend to oxidize the filament and it would bring about a decided decrease in the electronic emission. By the process of evacuation of the tube we eliminate the traces of gas atoms present within the tube when the glass or metal parts of the tube are heated. In some instances a certain chemical compound is exploded within the tube during its evacuation. This compound tends to absorb stray gas atoms which may be present within the tube.

The effect of the emitted electrons on the filament of the tube is to leave the filament in a deficiency of electrons, thereby causing the filament to become positive. Since the filament has become positive in respect to the electrons emitted by it, it has the effect of causing a certain number of electrons emitted to be attracted back to the filament in order to equalize the charge. This causes a certain amount of electrons to form around the outside surface of the filament at all times. This in turn is known as the "Space Charge." The space charge if allowed to become excessive, will slow up the speed of the electrons and bring about a decided decrease in electronic emission. This negative space charge can be counteracted by placing a certain value of positive potential on the plate of the tube, and a much greater electron flow obtained. The higher this positive plate potential the greater the electron flow, since it can be made high enough to counteract all the effects of the space charge. However, before long the saturation point will be obtained and a further increase in plate voltage will cause no further increase in the electronic flow or plate current. Saturation point being the point where the plate voltage has reached such a value that with a given filament temperature it has drawn all the available electrons possible, and a further increase in plate voltage will cause NO further increase in electronic emission or plate current.

It is a generally accepted theory that the plate current of every tube is emitted from the filament in the form of electrons. The actual filament current flows from negative to positive thru the filament. All current flows in that direction from negative to positive, in accordance with our latest Electron Theory. When another current such as plate current is impressed across the filament, it will naturally take the path of least resistance. The current will also tend to flow from negative to positive thru the filament. However, practically all the plate current leaves the filament in the form of electrons before it gets high enough up the filament to reach the positive end of the filament. The positive charge on the plate drawing these electrons to it cause these billions of electrons to strike the plate at a high velocity. If too high a positive plate voltage is used the electrons will strike the plate with such high velocity that they will rebound and cause the plate to become extremely hot. If this condition is not corrected the plate may be rendered useless in a short time. This accentuates one point. The electron has mass. Anything capable of producing friction is a body and every body has Mass.

There are three general types of filaments used by Vacuum Tube Manufacturers. Namely the Tungsten Filament, the Oxide Coated Filament and the Thoriated Tungsten (XL) Filament.

The Oxide Coated Filament: An Oxide coating is placed over the Tungsten base and the electron emitting properties could be said to actually come from the Oxide coating. External connections are brought out at the base of the tube to permit external applied potentials for the purpose of electronic emission. This type of filament cannot be highly evacuated due to the fact that the Oxide coating tends to break away from the Tungsten filament base when it is put in a very high frequency furnace to be evacuted. If this type of filament is operated once at a temperature higher than normal it must always be operated at a higher temperature, because the Oxide coating tends to break away from the Tungsten base and this of course obviously shortens the life of the filament. Another fact is brought to view about this type of filament. High electronic efficiency cannot be obtained with this type of filament because a high degree of evacuation is not possible without destroying the Oxide coating.

The Thoriated Tungsten (XL) Filament: The Tungsten base is coated with a Thorium compound, approximately 1 atom thick and the high electron emitting properties come from the Thorium coating. External connections are brought to the base of the tube to permit external potentials to be applied. This type of filament only requires a low power for high electronic emission. It is an excellent emitter of electrons. It requires only a very small cross sectional area. It permits high evacuation thereby maintaining high electronic emission. However, in the case of high powered tubes where high voltages are used, the Thoriated filament will not stand the very high evacuation process necessary to eliminate the effect of gaseous conditions that may take place when operating at high power. It should

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Classification of Bridge Methods of Measuring Impedances

(Continued from Page 20)

the unknown and there is no dissipation due to the direct current in the ratio arms. The impedance of the ratio arms decreases as the frequency increases, which is usually a disadvantage but may have advantages in some cases, such as the measurement of capacitance. There may be a disadvantage in some cases due to the load on the generator being capacitive, thus tending to increase the magnitude of the harmonics, and again, in the case of the measurement of inductances, there may be undesirable resonance effects.

The inductance ratio arm type has advantages where heavy currents must be passed through the bridge, since the ratio arms of this type may be designed to carry large currents with low dissipation. A modification of this type, where there is mutual inductance between the ratio arms, gives the advantage of ratio arms of high impedance with a corresponding low impedance input. A further modification consists in making the ratio arms the secondary of the input transformer, thus combining in one coil the functions of ratio arms and input transformer. This form, of course, departs from the simple four-arm bridge, but is mentioned here due to its simplicity and mutual practical advantages.

SUBSTITUTION METHODS

In any of the bridges discussed and, in fact, in practically all bridges it is possible to evaluate the unknown by first obtaining a balance with the unknown in the circuit and then substituting for it adjustable standards which may be adjusted to rebalance the bridge. This is, in general, a very accurate method, eliminating to a large degree the necessity for the bridge to meet its phase angle requirement. However, in the case of complete substitution of standards to balance both components of the unknown, the method has no advantage except accuracy over the bridges of type 1, Fig. 2, since standards of the same type as the unknown must be used and, in general, this method lacks the flexibility of bridges of type 1, obtained by their unequal ratio arms. On the other hand, the use of substitution to measure the resistance or conductance component of the unknown has many advantages, the principal one being that it allows the choice of a type of bridge which will give directly the reactance component of the unknown in terms of an adjustable resistance and then by use of the substitution method to balance the resistance or conductance of the unknown by means of a second adjustable resistance, thus obtaining the ideal method of balance, using two adjustable resistances.

For the purpose of illustration, the case of the measurement of an inductive impedance may be taken. In general the most desirable method would be to balance the reactance by means of series resistance. This can be done by means of the bridges of Figs. *2e* or *2g*. Choosing Fig. *2e* as the preferred form, the bridge would normally take the form of Fig. *3a*.

For normal operation, C_{AD} and R_{AD} would be the adjustable standards. The series inductance of the unknown would be given directly as KR_{AD}, while the series resistance would be given as K/C_{AD}. This measurement of the series resistance requires an adjustable capacitance and a computation due to the reciprocal relation. Now suppose a fixed value for C_{AD} were used and an adjustable resistance standard R_s placed in series with Z_x, giving the form of Fig. *3b*, in which R_{AD} and R_s are the adjustable standards. If terminals Z_x are short circuited, the conditions for balance are $R_s = K/C_{AD}$ and $R_{AD} = 0$. Then the unknown Z_x is inserted and the bridge rebalanced. The inductance of the unknown is given, as for Fig. *3a*, as KR_{AD}, but since C_{AD} is unchanged the total resistance in CD is unchanged. Therefore, the series resistance of the unknown will be equal to the change in R_s between the two balances.

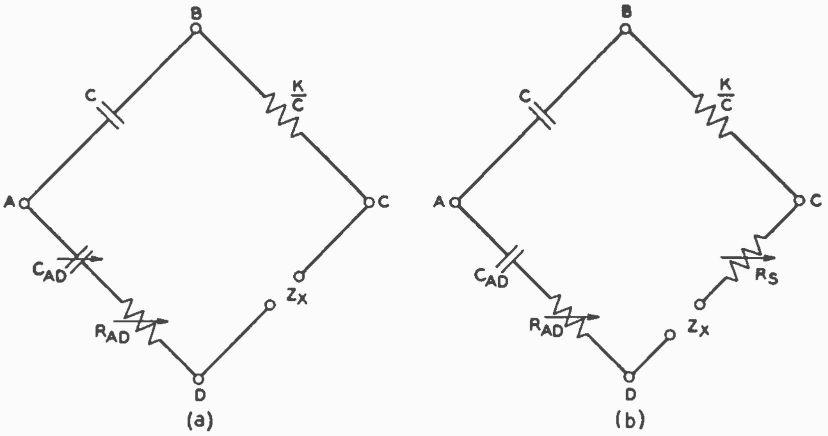

Fig. 3—(a) Bridge of type 2 for measuring self-inductance. (b) The same bridge modified by the use of partial substitution.

This bridge circuit may be recognized as the familiar bridge due to Owen,[3] and it is, theoretically at least, when used as described, an exceedingly desirable bridge for inductance measurements.

It should be pointed out here that since either C_{AD} or R_s may equally well be used to balance R_x, it is not necessary to use either one or the other exclusively in any one bridge. The adjustments may be combined so that the capacitance adjustment will take care of large changes and R_s of small changes; that is, C_{AD} may be used for coarse adjustment and R_s for fine adjustment. This compromise is in general more satisfactory than either method used alone.

The imaginary product arm type, particularly the form of Fig. *2k*, is also well adapted to modification to enable it to measure capacitance and conductance in terms of two adjustable resistances.

There is a further modification of the substitution method, which is in common use. As already explained, there is little practical advantage in the substitution

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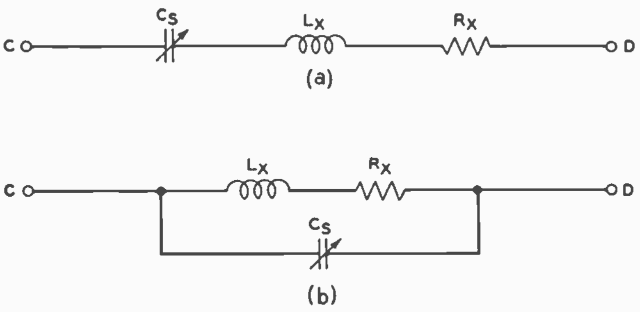


Fig. 4—(a) The CD arm of the bridge as used for series resonance measurements. (b) The CD arm of the bridge as used for parallel resonance measurements.

Auditory Perspective—Loud Speakers and Microphones

(Continued from Page 8)

the lower, the other for the higher frequencies, an electrical network being used to divide the current into 2 frequency bands, the point of division being about 300 cps.

The Low Frequency Horn

When moderate amounts of power are transmitted through a horn the sound waves will suffer very little distortion, but when the power per unit area becomes large, second-order effects, usually neglected in considering waves of small amplitude, must be taken into account. The transmission of waves of large amplitude through an exponential horn has been investigated theoretically by M. Y. Rocard. His investigation shows that if W watts are transmitted through the throat of an exponential horn a second harmonic of intensity of RW will be generated, where R is given by the relation

$$R = \frac{(r+1)^2 f^2 \times 10^7 W}{2pc^3 f_0^2 A},$$

in which f is the frequency of the fundamental, f^0 the cut-off frequency of the horn, c the velocity of sound, p the density of air, and A the area of the throat of the horn, all expressed in cgs units. It may be noted that the intensity of the harmonic increases with the ratio of the frequency to the cut-off frequency of the horn; this is another argument against attempting to cover too wide a range of frequencies with a single horn. In Fig. 1 it is shown that in the region of 200 cps the orchestra gives peak powers of about 10 watts. If, therefore, 30 watts be set as the limit of power that the horn is to deliver at 200 cps, 32 cps as the cut-off frequency of the horn, and 30 db below the fundamental be assumed as the limit of tolerance of a second harmonic, from eq 1 a throat diameter of about 8 in. is determined.

If the radiation resistance at the throat of the horn is not to vary appreciably with frequency, the mouth opening must be a substantial fraction of a wave length. This condition calls for an unusually large horn if frequencies down to 40 cps and below are to be transmitted. However, the effect of variations in radiation resistance on sound output can be kept down to a relatively small value if the receiving unit is properly designed. This will be explained in the next section. The low frequency horn used in these reproductions has a mouth opening of about 25 sq. ft. As computed from well-known formulas for the exponential horn the impedance of this horn with a throat diameter of 8 in. is shown in Fig. 4. These curves were computed under the assumption that the mouth of the horn is surrounded by a plane baffle of infinite extent, a condition closely approximated if the horn rests on a stage floor.

Low Frequency Receiving Unit

When a moving coil receiving unit, coupled to a horn, is connected to an amplifier having an output resistance equal to n—1 times the damped resistance R of the driving coil, it can easily be shown that the sound power output is

$$P = \frac{\left(\frac{EBLT}{nR}\right)^2 r \times 10^{-9}}{\left[T^2 r + \frac{B^2L^2 \times 10^{-9}}{nR}\right]^2 + (x^d + T^2 x)^2} \text{ watts}$$

where E is the open circuit voltage of the amplifier, L the length of wire in the receiver coil, T the ratio of the area of the diaphragm to the throat area of the horn, r + jx the throat impedance of the horn, and x^d the mechanical reactance of the diaphragm and coil, the mechanical resistance of which is assumed to be negligibly small. From Fig. 4 it may be seen that the mean value of x increases as the frequency decreases to a value below 40 cps, and that x is smaller than r except at the very lowest frequencies. If, therefore, the stiffness of the diaphragm be adjusted so that x^d is equal to T^2 times the mean value of x at 40 cps, the second term in the denominator may be neglected without much error because it will have but little effect upon the sound output except at the higher frequencies, where the mass reactance of the coil and diaphragm may have to be taken into account.

If minimum variations in sound output are desired for variations in r,

$$\frac{B^2L^2 10^{-9}}{nRT^2} = r^0$$

where r^0 is equal to the geometric mean value of r, which is approximately equal to Apc.

If α is the ratio of the resistance at any frequency to the mean value, and if the second term in the denominator is neglected, eq 2 becomes

$$P = \frac{E^2}{nR} \frac{\alpha}{(1+\alpha)^2}$$

In Fig. 4 it is shown that above 35 cps α has extreme values of 2.75 and 0.36, at which points there will be minimum values in P, but these minimum values will not lie more than 1 db below the maximum values. Hence, if the receiver satisfies the condition of eq 3, the extreme variations in the sound output will not exceed 1 db, although the horn resistance varies by a factor of 7.5. Also it may be stated here that when the condition of eq 3 is satisfied the horn is terminated at the throat end by a resistance equal to the surge resistance of the horn. Thus eq 3 establishes a condition of minimum values in the transient oscillations of the horn.

The mean motional impedance of the loud speaker is

$$\frac{B^2L^2 \times 10^{-9}}{T^2 r^0}$$

which, from eq 3, is equal to nR. The condition of eq 3 therefore specifies that the efficiency of the loud speaker shall be

$$\frac{n}{N+1}.$$

The maximum power that an amplifier can deliver without introducing harmonics exceeding a specified value is a function of the impedance into which it operates. Therefore, to obtain the maximum acoustic power for a specified harmonic content, the load impedance should have the value for which the product of the loud speaker efficiency and the power capacity of the amplifier has a maximum value. This optimum value of load impedance for the amplifier and loud speaker used in the Philadelphia-Washington experiments was found to be about 2.25 times the output impedance of the amplifier; the corresponding value of n then is 2.6 and the required efficiency 72 per cent. For best operating condition a definite value of receiver efficiency thus is specified.

The receiver may be made to satisfy the foregoing conditions regardless of the value of T, the ratio of diaphragm area to throat area. The area of the diaphragm has, however, a definite relation to the maximum power that the receiver can deliver at the low frequencies. The peak power delivered by the receiver is equal to $T^2 \alpha r_0 \xi^2 \omega^2 \times 10^{-7}$ peak watts where ξ is the maximum amplitude of motion of the diaphragm. Figure 1 shows that in the region lying between 40 and 60 cps, peak powers reach a value of from 1 to 2 watts. However, the low frequency tones of an orchestra are undesirably weak and may advantageously be reproduced at a relatively higher level. Therefore it was decided to construct the loud speaker to be able to deliver 25 watts in this region.

As the coil moves out of its normal position in the air gap, the force factor varies. Harmonics thus will be generated, the intensities of which increase with increasing amplitude. A limit to the maximum value of the amplitude ξ thus is set by the harmonic distortion that one is willing to tolerate. In this receiver the maximum value of ξ was taken equal to 0.060 in. Figure 4 shows that $\alpha\omega^2$ has a minimum value at about 50 cycles, where α is equal to about 0.4. These values give a ratio of 4.5 for T.

Inasmuch as

$$R = \frac{\sigma L^2}{v},$$

where σ is the resistivity of the wire used for the coil and v the volume of the coil, from eq 3 is obtained

$$B^2 v = n\sigma T^2 r^0 10^9.$$

The first member gives the total magnetic energy that must be set up in the region occupied by the driving coil. This value is fixed by the fact that all factors in the second member are specified. The same performance is obtained with a small coil and high flux density as with a large coil and low flux density, provided B^2v is held fixed, but the coil in any case should not be made so small that it will be incapable of radiating the heat generated within it without danger of overheating, nor so large that the mass reactance of the coil will reduce the efficiency at the higher frequencies.

This receiver unit, when constructed

according to the above principles and when connected to an amplifier and a horn in the specified manner, should be capable of delivering power 3 or 4 times that delivered by an orchestra in the frequency region lying between 35 and 400 cps, with an efficiency of about 70 per cent, and with a variation in sound output for a given input power to the amplifier of not more than 1 db throughout this range.

The High Frequency Horn

It is well known that a tapered horn of the ordinary type has a directivity which varies with frequency. Sound of low frequency is projected through a relatively large angle. As the frequency is increased this angle decreases progressively until, at frequencies for which the wave length is small compared with the diameter of the mouth opening, the sound beam is confined to a very narrow angle about the axis of the horn.

If we had a spherical source of sound (i. e., a source consisting of a sphere, the surface of which has a radial vibratory motion equal in phase and amplitude at every point of the surface), sound would be radiated uniformly outward in all directions; or, if we had only a portion of a spherical surface over which the motion is radial and uniform, uniform sound radiation still would prevail throughout the solid angle subtended at the center of the curvature by this portion of the sphere, provided its dimensions were large compared with the wave length. Throughout this region the sound would appear to originate at the center of curvature. Hence, for the ideal distribution of a spherical source within a region to be defined by a certain solid angle, it is necessary and sufficient that the radial motion be the same in amplitude and phase over the part of a spherical surface intercepted by the angle and having its center of curvature at the vertex and located at a sufficient distance from the vertex to make its dimensions large compared with the wave length. If, further, these conditions are satisfied for this surface at all frequencies, all points lying within the solid angle will receive sound of the same wave form. A horn was designed to meet these requirements for the high frequency band.

The horn, shown in the upper part of Fig. 5, comprises several separate channels, each of which has substantially an exponential taper. Toward the narrow ends these channels are brought together with their axes parallel, and are terminated into a single tapered tube which at its other end connects to the receiver unit. Sound from the latter is transmitted along the single tube as a plane wave and is divided equally among the several channels. If the channels have the same taper, the speed of propagation of sound in them is the same. The large ends are so proportioned and placed that the particle motion of the air will be in phase and equal over the mouth of the horn. This design gives a true spherical wave front at the mouth of the horn at all frequencies for which the transverse dimensions of the mouth opening are a large fraction of a wave length.

As the frequency is increased, the ratio of wave length to transverse width of the channels becomes less, and the sound will be confined more and more to the immediate neighborhood of the axis of each channel. The sound then will not be distributed uniformly over the mouth opening of the horn, but each channel will act as an independent horn. To have a true spherical wave front up to the highest frequencies, the horn would have to be divided into a sufficient number of channels to make the transverse dimension of each channel small compared with the wave length up to the highest frequencies. If it is desired to transmit up to 15,000 cps, it is not very practical to subdivide the horn to that extent. Both the cost of construction and the losses in the horn would be high if designed to transmit also frequencies as low as 200 cps, as is the case under consideration. However, it is not important that at very high frequencies a spherical wave front be established over the whole mouth of the horn. For this frequency region it is perfectly satisfactory to have each channel act as an independent horn, provided that the construction of the horn is such that the direction of the sound waves coming from the channels is normal to the spherical wave front.

The angle through which sound is projected by this horn is about 60 deg, both in the vertical and in the horizontal direction. For reproducing the orchestra 2 of these horns, each with a receiving unit, were used. They were arranged so that a horizontal angle of 120 deg and a vertical angle of 60 deg were covered. These angular extensions were sufficient to cover most of the seats in the hall with the loud speaker on the stage. The vertical angle determines to a large extent the ratio of the direct to the indirect sound transmitted to the audience. The vertical angle of 60 deg was chosen purely on the basis of judgment as to what this ratio should be for the most pleasing results.

The High Frequency Receiving Unit

In the design of the low frequency receiver one of the main objectives was to reduce to a minimum the variations in sound transmission resulting from variations in the throat impedance of the horn. However, the high frequency horn readily can be made of a size such that the throat resistance has relatively small variations within the transmitting region. On the other hand, whereas the diameter of the diaphragm of the low frequency unit is only a small fraction of the wave length, that of the high frequency unit must be several wave lengths at the higher frequencies in order to be capable of generating the desired amount of sound. Unless special provisions are made there will be a loss in efficiency because of differences in phase of the sound passing to the horn from various parts of the diaphragm. The high frequency receiver therefore was constructed so that the sound generated by the diaphragm passes through several annular channels. There are enough of these channels to make the distance from any part of the diaphragm to the nearest channel a small fraction of a wave length. These channels are so proportioned that the sound waves coming through them have an amplitude and phase relation such that a substantially plane wave is formed at the throat of the horn.

In the appendix it is shown that, for the higher frequencies where the impedance of the horn may be taken as equal to ρc times the throat area and for the type of structure adopted, the radiation resistance is equal to

$$\rho c a T^2 \left[\frac{1}{k^2h^2T^2+k^2l^2\cot^2 kl}\right]$$

and the reactance

$$-j\frac{\rho c a}{kh}T\left[1-\frac{1}{kl\cot kl+\left(\frac{hT}{l}\right)^2 kl\tan kl}\right]$$

where a is the area of the throat of the horn, T the ratio of the area of the diaphragm to the throat area,

$$k=\frac{\omega}{c},$$

and the other designations are those indicated in Fig. 11. At the lower frequencies the resistance is T^2r and the reactance T^2x where r and x are, respectively, the resistance and reactance of the throat of the horn.

Equation 6 shows that at a given frequency, other conditions remaining the same, the radiation resistance will have a maximum value when l is approximately equal to

$$\frac{\pi}{2k}=\frac{c}{4f}.$$

In Fig. 6 the resistances as computed from eq 6 are plotted as a function of frequency for several values of $\frac{h}{w}$. It is seen from these curves that the resistance at the higher frequencies is determined very largely by the relation of $\frac{h}{w}$ but is independent of it at the lower frequencies, where it is equal to $\rho c a T^2$. At the lower frequencies where the mechanical impedance of the diaphragm is negligible, the efficiency, as was the case for the low frequency receiver, depends upon the value of B^2v where v is the volume of the coil, but at the higher frequencies the efficiency decreases with increasing mass of the coil. It is advantageous, therefore, to keep v small and to make B as large as is practically possible. Values were selected to give the receiver an efficiency of 55 per cent at the lower frequencies. For these conditions the relative sound power output was computed by eq 2 on the assumption that the receiver was connected to an amplifier having an output impedance equal to 0.45 times that of the receiver

(Continued on Page 26)

FROM THE LABOR ANGLE

By LOUIS JURGENSON

There is a great deal of confusion about the interpretation of the wage scales in the Radio Broadcast Industry Code. We understand the Code Authority has made rulings on these wage disputes in ways favorable to the employers. This was to be expected, however, because the Code Authority has a majority consisting of employers or employer's representatives. But there is a small minority which will look after the interests and rights of the technicians. Through them the I. B. E. W. is endeavoring to get a fair and correct interpretation of the wage scales, which is briefly outlined as follows:

Forty dollars per week minimum at all stations classified by the Federal Radio Commission (not by the Code Authority) as Clear Channel-Unlimited, Clear Channel-Limited, Clear Channel Specified Hours, Clear Channel-Daytime, Clear Channel-Sharing Time and High Power Regional.

Thirty dollars per week minimum at all stations classified as Clear Channel-Part Time, Regional-Unlimited, Regional-Limited, Regional-Specified Hours, Regional-Daytime and Regional-Sharing Time; unless three or less technicians were employed by any of these stations on July 1, 1933, in which case the minimum shall be twenty dollars per week.

Twenty dollars per week minimum at all Regional-Part Time and all Local stations.

No apprentice should be employed unless the station has 20 or more regular employees. One apprentice is allowed for 20 to 39 regular employeees, two apprentices are allowed for 40 to 59 regular employees, etc. It is a violation to reduce the salaries or increase the hours contrary to those prevailing on November 1, 1933. To discharge a technician and re-employ him at less money or longer hours or to employ a new man for the same job at less money and longer hours is a violation of the intent and purpose of the Code. In fact, any act by an employer which tends to increase hours and reduce pay is a violation of the intent and purpose of the Code. And the intent and purpose of the Code is something that no employer should trifle with.

Mr. M. H. Hedges of the Research Department of the I. B. E. W. has been appointed to the Code Authority and will represent the technicians and see that their rights are upheld. Any complaints of Code violations should be addressed to him at 1200 15th St., N. W. Washington, D. C.

If fair rulings cannot be obtained from the Code Authority these rulings will be appealed to the Administrator of the Code or to the National Labor Board if necessary.

Do not hesitate to report violations if they exist at your place of employment. Do not fear employer retaliation. Every possible precaution will be taken to prevent any employer from knowing who the complainant is. It is this fear of retaliation that the unscrupulous employer depends on to permit him to violate the Code. We have it on good authority that only one member of the Code Authority, the Chairman, knows the name of the complainant, and if the Administrator finds "that the Code Authority is not truly representative or does not in other respects comply with the provisions of the Act" he "may require an appropriate modification of selection of the Code Authority." In order to prevent long delays on the part of the Code Authority and to remove the temptation to employers to chisel, we are insisting that where increases in salary are ordered as a result of Code violations, these increases be made retroactive.

The I. B. E. W. can act to correct violations only to the extent to which every individual technician will co-operate with us. It is every man's duty to report violations to us. Demand that you get your rights! You'll get action.

At a meeting held in San Antonio, Texas, with Vice President Ingram of the I. B. E. W. presiding and twenty-two San Antonio radio technicians present for the express purpose of discussing organization, twenty membership applications were signed for entrance to Radio Division of the San Antonio I. B. E. W. Local. A letter from this newly organized group says in part: "All of us have realized to what extent the I. B. E. W. represented the radio operating fraternity at the Code hearing in Washington. Hence, we all feel duly obligated to support those who have supported us, and further, we sincerely trust and hope that the radio operating fraternity of the United States at large will endeavor to give further and continued support to the Radio Division of the I. B. E. W. in their efforts to establish complete organization. We are sincere when we say this is the only medium wherby we may ultimately achieve success."

Radio Technicians of Greater Boston have held two meetings recently with I. B. E. W. officials with a view to establishing a Radio Division in that city. In Cincinnati organization of a Radio branch was completed within the past month. On the Pacific coast particular interest in organization has been shown by the radio technicians of Portland, Oregon and San Diego and Oakland, California.

Notwithstanding glowing reports of enthusiasm over the newly-organized company unions there is an undercurrent of resentment at the way the technicians were muzzled and coerced through fear of losing their jobs into accepting employer dominated form of collective bargaining. They would have us believe that technicians are one big happy family, just too happy for words, over the generosity, but those who think for themselves are aware of this sudden about face policy of conntenancing unions, yea, even encouraging unions. They know that it is only a device to permit compliance with the Code and a means of staving off inevitable organization by a truly representative union. They know that the threat of the I. B. E. W. fostered the company union with its resultant benefits, meagre as they are. And they know that the threat of the I. B. E. W. perpetuates it. General Johnson has said "There is no answer to the argument that many companies created unions after passage of the NIRA to influence their men in the choice of an instrumentality for collective bargaining. It is a counter-NRA device in some small part, at least." An intensive drive against the company unions is being pressed by the national administration on several fronts.

* * *

It is well to point out here that the NRA and the Code are not permanent. In fact the National Industrial Recovery Act expires in June, 1935, unless extended thereafter by the President. Codes can be reopened and revised. They can be revised downward as well as up if the technicians are not solidly behind their representatives and this is precisely what will happen if the technicians do not co-operate to the utmost with their organization. The employers will come to the reopening of the Radio Code in March, when, the Code Authority makes its report on technicians' hours and wages prepared to grab everything that isn't nailed down or guarded with shotguns. The I.B.E.W. will be there to represent the technician and renew the fight for a forty hour week.

The broadcasters are confident that they can produce statistics showing the impossibility of reducing the work week to less than forty-eight hours. The I.B.E.W. must convince the Administrator that in order to absorb the unemployed technicians it is imperative that the week be shortened to forty hours. If you are a competent broadcast technician write to Louis Jurgensen, Radio Representative, I. B. E. W., 130 East 25th St., New York City, give your qualifications and experience and the length of time you have been unemployed. If you know a technician who is unemployed, have him write. This is one of the first things you should do to help yourself to get a job. It's important, and only by helping your organization can you help yourself.

* * *

"We need the check of strongly organized labor on strongly organized capital."

* * *

Station WOWO-WGL, Ft. Wayne. Ind. signed a working agreement with the IBEW the later part of January.

Negotiations in this work was handled by E. C. McClain, and the local IBEW Business Manager, Mr. Avery.

Auditory Perspective—Loud Speakers and Microphones

(Continued from Page 24)

at the lower frequencies. Figure 7 shows the values so obtained. Corresponding values obtained experimentally when the receiver was connected to the horn previously described are shown in Figs. 8 and 9, where the sizes of the rooms in which the values were obtained were, respectively, 5,000 and 100,000 cu. ft. Both of these curves differ considerably from the computed curve, particularly as regards loss at high frequencies. The curve of Fig. 8 shows less, and that of Fig. 9 more loss at high frequencies. The computed curve, however, refers to the total sound output, whereas the measured curves give average values of sound intensity in a certain part of the room, values dependent upon the acoustic characteristics of the room.

The number of high frequency receivers that must be used for each transmitting channel is governed largely by the amount of power that the system is to deliver before harmonics of an objectionable intensity are introduced. The generation of harmonics in a horn when transmitting waves of large amplitude already has been discussed. Let it suffice here to say that, for a given percentage harmonic distortion, the power that can be transmitted through the horn is proportional to the area of the throat and inversely proportional to the square of the ratio of the frequency to the cut-off frequency.

Inasmuch as the moving coil microphones used for the transmission of music in acoustic perspective have been described previously they will not be discussed here at length. Their frequency response characteristic as measured in an open sound field for several different angles of incidence of the sound wave on the diaphragm are shown in Fig. 10 where it is seen that the response at the higher frequencies becomes less as the angle of incidence is increased. In general, this is not a desirable property, but with the instruments as used in this experiment the sound observed as coming from each loud speaker is mainly that which is picked up directly in front of each microphone; sound waves incident at a large angle do not contribute much.

At certain times the sound delivered by the orchestra is of very low intensity. Therefore it is important that the microphones have a sensitivity as great as possible, so that the resistance and amplifier noises may readily be kept down to a relatively low value. At 1,000 cps these microphones, without an amplifier, will deliver to a transmission line 0.05 microwatt when actuated by a sound wave having an intensity of 1 microwatt per sq cm. This sensitivity is believed to be greater than that of microphones of other types having comparable frequency response characteristics, with the possible exception of the carbon microphone.

Appendix—Load Impedance of a Diaphragm Near a Parallel Wall With Slot Openings

First assume a diaphragm and a parallel wall of infinite extent separated by a distance h and that the wall is slotted by a series of equally spaced openings as shown in Fig. 11. From symmetry it is known that when the diaphragm vibrates there will be no flow perpendicular to the plane of the paper or across the planes indicated by the dotted lines. Therefore only one portion of unit width, such as abcdef need be considered. Let the x and y reference axes be located as shown. If the general field equation

$$\frac{\partial^2 x}{\partial x^2}+\frac{\partial^2 x}{\partial y^2}+k^2 x=\xi$$

is applied when the diaphragm has a normal velocity equal $\xi e^{i\omega t}$ the following boundary conditions are obtained:

When $x = 0, \quad \frac{\partial x}{\partial x} = -\dot{\xi}$

$x = h, \quad \frac{\partial x}{\partial x} = 0$

$y = 0, \quad \frac{\partial x}{\partial y} = 0$

and when y = 1, the pressure is equal to the point of acoustic impedance and volume velocity or

$$\frac{p}{h}\int_0^h\left(\frac{\partial x}{dt}\right)_{y=1} dx=\frac{cp}{w}\int_0^h\left(\frac{\partial x}{dy}\right)_{y=1} dx$$

where x is the velocity potential, $k = \frac{\omega}{c}$, and c is the velocity of sound.

The appropriate solution of eq 8 then is

$$x=\frac{\xi}{k}\left[\frac{\cos ky}{kh\left(\cos kl+i\frac{h}{w}\sin kl\right)}-\frac{\cos k(x-h)}{\sin kh}\right]$$

The average reacting force per unit area of the diaphragm is

$$\frac{ikpc}{l}\int_0^l (x)_{x=0}\,dy$$

Thus, for the impedance per unit area, which is equal to the force divided by the velocity, is obtained

$$\frac{pcl}{w}\left\{\left[\frac{\sin^2 kl}{k^2l^2}\,\frac{1}{\cos^2 kl+\left(\frac{h}{w}\right)^2\sin^2 kl}\right]-j\frac{w}{h}\left[\frac{\frac{kh\cos kh}{\sin kh}\,kl-\frac{\sin kl\cos kl}{\cos^2 kl+\left(\frac{h}{w}\right)^2\sin^2 kl}}{k^2l^2}\right]\right\}$$

$$\equiv r'+jx'$$

In all practical types of loud speakers $\frac{kh\cos kl}{\sin kh}$ would be very nearly equal to 1; then

$$r'=\frac{pcl}{w}\left[\frac{1}{k^2l^2\left(\left(\frac{h}{w}\right)^2+\cot^2 kl\right)}\right]$$

$$x'=-j\frac{pcl}{h}\left[\frac{kl-\frac{1}{\cot kl+\left(\frac{h}{w}\right)^2\tan kl}}{k^2l^2}\right]$$

If the total area of the diaphragm is A and that of the corresponding channels a, then $\frac{A}{a}=\frac{1}{w}$, approximately, and the total impedance becomes

$$=\frac{pcA^2}{a}\cdot\frac{1}{\left(\frac{kh}{a}\right)^2A^2+k^2l^2\cot^2 kl}$$

$$x=-j\frac{pcA}{kh}\left[1-\frac{1}{kl\cot kl+\left(\frac{hA}{la}\right)^2 kl\tan kl}\right]$$

Classification of Bridge Methods of Measuring Impedances

(Continued from Page 22)

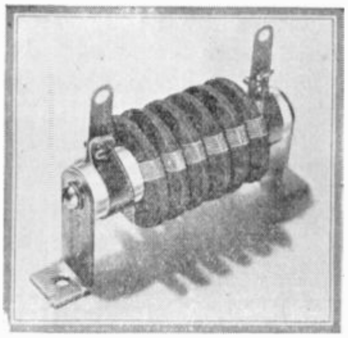
method for measuring either inductance or capacitance. However, there are occasions where the substitution of capacitance for inductance has advantages. Since the reactance of one is opposite in sign to that of the other, the method might more correctly be termed a compensation method, but in common with other substitution methods it can be made irrespective of the type of bridge. Various modifications of the general method may be used, but they are all classed under the general head of resonance methods.

RESONANCE METHODS

If it is desired to measure the inductance of any inductive impedance, a capacitance standard may be inserted in series with it, and adjusted until the total reactance of the combination is zero. The only function the bridge performs is to measure the effective resistance of the combination and to determine the condition of zero reactance. Any of the bridges of Fig 2 will do this satisfactorily but those of real ratio type, that is the simple comparison type, are the most satisfactory since they give the resistance directly in terms of an adjustable resistance standard. This type of bridge is usually termed a series resonance bridge. The value of the inductance is computed from the resonance formula $\omega^2LC = 1$. It has the disadvantage that it involves the frequency, but it has the compensating advantage that the method, being essentially a direct measurement of the resistance of the resonance circuit, is very accurate for the measurement of effective resistance.

The condenser may equally well be shunted across the unknown, in which case the bridge circuit is called a parellel resonance bridge. However if the ratio of reactance to resistance of the unknown is not high, the expression for the series inductance in this case is not as simple as that for series resonance, and is not independent of the effective resistance, that is the two adjustments are not independent.

Fig. 4 shows the forms taken by the CD arm for resonance measurements. Fig. 4*a* is the series resonant circuit using an adjustable capacitance standard. Fig 4*b* is the parallel circuit using an adjustable capacitance standard.



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A Bungled Affair

(Continued from Page 14)

linge seized the end of the rope and examined it.

"Look!" he shouted, showing it to his companion. Peter Bockstrup looked and saw at a glance that the rope had been severed with a sharp knife. Waiting until there was a slight lull in the storm, the two investigators hurried over the lumber deck-load to the fore-mast riggin. The fore aerial halyard was found to have apparently, been cut half through, and to have then broken.

"What do you know about that for slick work!" exclaimed Collinge, sharply. "He cut this forward halyard almost in two, so it was barely holding, and then he went aft and cut the other one away altogether and thus sent the whole thing flying over the side!"

"You mean that Lone Lambert done it?" queried Peter Bockstrup, dismayed.

"Of course he did it," answered Collinge. "It was easy, as there's nobody on deck in this weather. The man at the wheel has his hands full trying to keep the old tub somewhere near her course, and the mate on watch seems to be staying inside. Lambert could easily have done this without anybody's noticing."

"Yep, I reckon that's right," answered Peter Bockstrup, gloomily, and the pair clambered back aft over the deck-load.

"Is there any way to mend it?" queried Collinge, in a worried tone, when they were back in the wireless room.

"No, not just now anyway," answered the chief wireless operator, dejectedly. "Nobody can get up to where the aerial halyard blocks are an' reeve new ropes in this storm. Anyhow, I haven't got no aerial wire or insulators or anythin.' I'd like to know what that ornery plug went an' cut the aerial away for, in the first place."

"That's easy to explain," responded Collinge promptly. "He simply fears that the police have followed his trail to where he boarded this boat and he knows that if this should happen to be the case, the captain would soon get a message ordering his arrest."

"Well, it won't do him much good, anyway, as long as you happen to be on board," rejoined Peter Bockstrup. "You can arrest him yourself."

Collinge did not immediately answer. He stood silent and seemed to be turning this suggestion over in his mind.

"Yes, I suppose I'll have to arrest him myself," he said, at last, with evident reluctance. "I'm out on an important case—a thousand times more important than any mere jewelry theft, and I don't wish to be mixed up in this thing. He could easily be picked up in San Francisco, but then he knows I'm on board and he'll likely hide the stuff or throw it overboard to save himself. However, I had rather merely declare him under arrest and then turn him over to your captain. He can deliver the prisoner to the police when we arrive, and that will leave me out of it."

The chief wireless operator took Collinge to the captain's cabin and the skipper was made acquainted with the situation. Captain Jensen became greatly excited as he listened to Collinge's talk.

"Yumpin' yiminy!" he exclaimed, rising from his chair. "Ve shall go right avay an' lock him up in the fo'c'sle."

The three hastened down to the suspected passenger's stateroom and found him lying in his bunk with all his clothes on, groaning with real or pretended seasickness.

"You—!" he screamed, catching sight of Collinge. Half-arising, he quickly plunged his right hand into his coat pocket. Before he could withdraw it, however, Collinge had seized his wrist in an iron grip.

"Keep quiet, Jack Lambert," he grated, in a steely tone, drawing a big automatic from his own coat pocket and sticking it in the small man's face. Releasing the other's wrist, Collinge produced a pair of bracelets.

The captive shrank back against the wall of his bunk.

"Damn you—!" he began, again, and then choked off his speech with a gurgle, as Collinge leveled his automatic at the small man's head and stiffened a finger upon the trigger.

"Shut up and behave or you're a dead one!" ominously threatened Collinge, snapping the bracelets on the prisoner's wrists. "I'm taking no chances with you—not any!"

Collinge began to search the prisoner. From one pocket he withdrew an automatic, quite similar to his own; from another skillfully concealed hiding place he took a tiny, but deadly derringer.

"Yumpin' yiminy, he bane vun bad feller eh!" muttered Captain Jensen.

"Now let's see the swag," said Collinge, pulling the prisoner's black satchel out from under a pillow. The bag was locked and Collinge searched the captive again, in an effort to find a key. He did not find it, but he did come upon a pocket knife, which interested him.

"This is what he cut the aerial halyards away with," stated Collinge, briefly, as he opened the knife and examined it. Peter Bockstrup and Captain Jensen looked at it also and they saw that the knife was wet and that a few fibres of manila were adhering to the blade.

The captive's small eyes glittered with rage, but he said nothing.

Collinge neatly slit the bottom of the satchel with the knife. Inside was a single parcel. Cutting the string on it, Collinge removed several paper wrappings and brought to view an elegant jewelry case. He pressed the catch and the case flew open, revealing a magnificent necklace of large, perfectly matched and almost blue-white diamonds.

"Whew! The Ellingsworth necklace!" murmured Collinge, lifting a part of the thing on his finger and watching it flash and sparkle. "It's worth a hundred and fifty thousand dollars, if it's worth a penny! We've surely caught Lone Lambert with the goods on him, this time!"

The captive's face was ashen and drops of perspiration stood out on his forehead. He was roughly laid hold of and dragged forward through the rain and spray to the forecastle. Here he was pitched into the paint locker, which was the only available place for him. After securing the door with two big brass padlocks, Captain Jensen called a big Finn sailor and ordered him to get a piece of timber and stand guard over the prisoner.

"If he bane get fresh and tries to run avay, chust bust him in the head with the stick," the sailor was instructed. "I skall have the mate take two other fellers to stand watches by you, so he von't have no chances to get avay by golly!" With this, Captain Jensen led the way aft.

"I skall take care of the necklace?" he queried, when they had reached his cabin. "It vere better inside my safe."

"Yes you better put it in your safe," rejoined Collinge, promptly. "I'm carrying some valuable stones myself, and you can keep them all together." As he spoke he drew a large, bulging wallet from his inner coat pocket. From it he took a small wad of tissue paper, which he opened, bringing to view a scintillating, remarkable looking brooch and a number of large unmounted stones. Placing the necklace case with the jewels, Collinge carefully wrapped it with the tissue paper, placed the package in the wallet and handed it to Captain Jensen.

"That's a fine pocketbook to have now, by golly!" remarked the skipper, as he placed the wallet in the safe and carefully locked the door.

For four days and nights the storm raged, unabated. The little steam-schooner pitched and rolled without a moment's cessation, but, nevertheless, managed to keep making about five knotts. During all this time Collinge kept an eye on the prisoner in the paint locker, brought him his food and allowed no one to go near him.

On the morning of the fifth day the "Yosemite" was abeam of Point Reyes. There, the weather suddenly began to improve. As soon as the wind had moderated somewhat Peter Bockstrup had the sailors string a short piece of aerial wire, which he had found among his spare gear. Having no insulators, he suspended the wire with pieces of fresh dry rope. As soon as the temporary aerial had been arranged, the chief wireless operator tightened coupling of his transmitter and called up NPG.

"W-Q-Y," the San Francisco naval radio station came back, immediately. "Everybody been trying to raise you last four days with rush message ordering arrest and giving full description of the crook called Lone Lambert reported aboard your ship—did you copy it?"

"N-P-G, de W-Q-Y," pounded Peter Bockstrup. "No, didn't get message, but we got crook safe—he cut aerial away first day out—couldn't fix it account no spares and bad storm—here's radio—Yosemite ck 14 dh rush Police S. F.—Have Lone Lambert prisoner will dock Meiggs wharf ten A. M.—Captain Jensen—."

Just as Peter Bockstrup was finishing off, he saw his aerial ammeter suddenly drop down to zero. Looking outside, the chief wireless operator saw that the rope insulator farthest from the lead-in evidently had been burned off by leaking current at the point where the wire joined the rope, with the result that the forward end of the improvised aerial had fallen to the deck and grounded.

As the ship was almost in port, and as he could see no particular necessity for getting the message describing Lone Lambert and ordering his arrest, when the criminal was already held captive, Peter Bockstrup decided not to try to do anything more with the aerial. Instead he set about changing into his "shore clothes."

An hour and a half later, the "Yosemite" slowly worked her way alongside at Pier 41. Surrounded by a large crowd of curious spectators, were two plain-clothes men and half a dozen policemen, waiting, with the patrol wagon, on the pier. Farther up the landing, near the street, a big, speedy-looking grey car backed up unobtrusively behind a pile of lumber and waited.

The ship had already been made fast when the detectives and policemen scrambled aboard.

"Where is he?" they demanded in a chorus, as they came up on the upper deck, where Captain Jensen and the chief wireless operator awaited them.

"Come right this way, gentlemens," said the skipper, proudly, leading the way. "He bane locked up forrard in the paint-locker."

Reaching the forecastle, the policemen all drew their revolvers and stood watchfully waiting as the skipper unlocked the door of the paint locker and threw it open.

"Hell!" burst out one of the plain-clothes men, upon seeing who was inside. "That's only Jack Evans, one of De Lacey's special messengers!"

"But the detective said he bane vun Lonely Lambert feller!" spluttered the skipper, sensing, even in spite of his thick headedness, that something was very much wrong.

"What detective?" demanded the plain-clothes man.

"It was Lone Lambert himself," interposed the messenger, grimly, as he stepped out of the paint locker. "He played one of his old favorite games again—flashed a fake Pinkerton badge and a pair of bracelets. When he took my gats he slipped a jack-knife in my pocket, and then pulled it out again, a minute later, so as to make it look as if I was the one who had cut down their wireless aerial. You know. Lone Lambert's bait is good enough to fool even smart fish, and as for these two simple-brained suckers—they just swallowed the hook, line, sinker and all! That's all there is to it."

"But, why—" began the plain-clothes man.

"Oh, I couldn't do a damned thing," interrupted the messenger, shortly, knowing what the detective was going to say. "He kept a big automatic in my face all the time and if I'd said one word he'd shot me dead—you know Lone Lambert!"

"Vait, it's all right, it's all right!" suddenly burst out Captain Jensen, in a tone of vast relief. "The package with the shinys is right in my safe."

The skipper rushed aft to his cabin, followed by the rest of the crowd. Making for his safe, the commander of the "Yosemite" hastily turned the combination, swung the door open and took out the bulging wallet.

"By golly, you see now, I wasn't so foolish that I let das feller keep the necklace," he exclaimed, triumphantly, as he removed the package from the wallet. Hurriedly, he tore away the tissue paper—then stopped and stared with an oath of incredulous dismay.

The little package contained only a few small crap dice and an empty necklace case!

Out on the pier, the big grey auto sped swiftly away and disappeared into the traffic of the street.

Pioneer Radio Operators

(Continued from Page 9)

Lee deForest, vice president of the company, said that in cooperation with the Navy the company was making elaborate preparations to keep the West Virginia in touch with the shore throughout her trip. 'We have stations at New Orleans, Southwest Pass, Key West, Savannah, Cape Hatteras, Washington and Atlantic City, and the West Virginia is equipped with the apparatus. No possible precautions have been neglected to keep President Roosevelt in complete touch with the outside world. In this matter the Navy is, of course, cooperating with us, and the naval stations at Pensacola and St. Augustine will also aid in keeping communication with the West Virginia perfect throughout her trip.'

"The Governor of Ohio will make an effort tonight to communicate directly with the West Virginia, and if he cannot do so he will utilize the wireless station at Havana as a central and thus have a talk with the President."

And not only did the coast stations copy the West Virginia on that history making trip. Fort Leavenworth, where Major (now General) Geo. O. Squier and Capt. Wm. Mitchell were experimenting with novel receiving circuits, with kite aerial, copied copiously. Cleveland of course, was right on the job sending and receiving from the cruiser. Governor Herrick sent this to Roosevelt: "On behalf of the people of Ohio I send you greetings and sincerest congratulations on your escape from injury in steamship accident and hope for your safe return. This is by American deForest Wireless Telegraph." One of the early messages which I prize most highly reads: "Received at Nottingham. Ohio. October 29, 1905. Battleship West Virginia off Florida East Coast. To Governor Myron T. Herrick: Hearty Thanks. I warmly reciprocate your good wishes. Theodore Roosevelt." Written in flowing hand of "Bu."—Bucher.

The N. Y Times reads: "President's Wireless Test—In Constant Communication With Land Throughout His Voyage. Washington November First—President Roosevelt took great interest, during his voyage around from New Orleans to Norfolk in the workings of the wireless system of telegraphy. He sent numerous messages to Mrs. Roosevelt, to members of the Cabinet, and to various friends, and was fortunate enough to receive messages also from the White House

And the N. Y. Herald added this bit of local color:

"Says New York Herald Wireless."

"The wireless operator on the roof of the tall building at No. 42 Broadway was sitting in his box-like office early yesterday morning with nothing to do. Presently he said he heard a faint ticking and listened intently.

" 'Hum!' he said after a few moments. 'It's the operator on the cruiser West Virginia talking to Savannah. We couldn't hear that if it weren't the quietest and dryest kind of night.'

"The cruiser West Virginia, which is bringing the President North, was in the Gulf of Mexico at the time. Shortly afterward a message came from the wireless operator at Cleveland saying that he also had heard the West Virginia 'talking.'

"An extra operator has been sent to reinforce the regular navy man, and extra men have been sent to the de Forest stations along the coast

"Dr. de Forest says that the President's vessel will never be so far out at sea that it will not be in easy communication with at least one of these stations. The only thing likely to destroy the connection is a heavy electrical storm, and then the disconnection would be only temporary."

At the finish of that historic first Presidential proof of wireless efficiency, Roosevelt's private Secretary Loeb, speaking of the unusal test that was made of the system said: "There was in fact, no time, from the start to our arrival in Hampton Roads, that the President was not in communication with the mainland. We had no difficulty whatever in picking up a station almost anywhere. The President sent several official messages to the various confident in the work that was done, and to rely on the correctness and promptness of wireless communication very much as we would in land telegraphy. The President was greatly interested, and studied the sending and receiving of messages carefully."

There is no doubt that the remarkable demonstrations of the efficiency and reliability of American wireless on this Rooseveltian cruise on the West Virginia definitely committed our navy to a fixed program of development of the new art which has ever since kept her foremost in the field of military communications.

Very much of the credit for the success of that demonstration is attributable to our fine civilian operator put on board the West Virginia for the voyage north from New Orleans, A. W. Dorchester. He trained the Navy operators day and night, and was tireless and sleepless in his determination to make the wireless on board worthy of the distinguished passenger who took so keen an interest in its every phase

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Elementary Vacuum Tube Electronics

(Continued from Page 21)

however to be noted that this condition only takes place when high powered tubes are used. A tube using this type of filament can be rejuvenated.

The Tungsten Filament: A certain amount of Tungsten Filament is mounted within the tube in such a manner as to be able to connect an outside potential to it to heat it, so that it may emit electrons. This type of filament can be used with fairly high filament voltages and therefore may stand fairly high power without burning out or having an actual injury done to it by momentary power surges. It also has the ability to absorb any stray gases that may be present in the tube after the tube elements have become heated. However, it is a very poor emitter of electrons. It requires the use of high power in order to obtain even fair electronic emission. Due to the high temperature required to operate it the Tungsten filament has a very short life.

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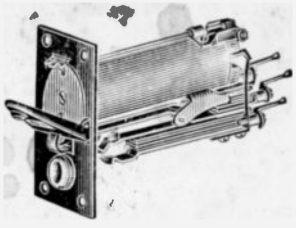


Relay and Jac's combination, 350 ohms, 6 volt $1.00

INDUCTION COILS, Battery Telephone Type . . . . $.75

NEW—Edison Storage Battery Type BB-1, 10 volt, 37 amp., contains 7 cells. Complete in steel portable case . . . $15.00

Magnavox anti-noise microphone, good for home broadcasting $1.50

CONDENSERS, Mica, op. volts 12,500 cap. .004

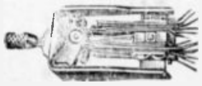
Dubilier, new	$7.50
Dubilier, used	5.00
Wireless spec., new	5.00
Wireless spec., used	2.50

Condenser, Dubilier, mica, volts 40,000, cap. .0012-.001-.0008 or .008 $10.00

Condenser, Dubilier, mica, op. volts 8,500 cap. .004 $5.00

Condensers, Dubilier, mica, op. volts 8,500 capacity .0004 mfd. $5.00

Condensers, Murdock .002 mfd. 5000 volt . . . $1.00



Anti-Capacity Switches W. E. 12 and 14 Terminals, all with Platinum Contacts, value $3.50 each. Our price 95c each

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120 d.c., 110 or 220 a.c., 500 cycle 250 watt	$30.00
120 d.c., 110 or 220 a.c., 500 cycle 500 watt	$40.00 to $75.00
120 d.c., 110 or 220 a.c., 500 cycle 1 kw.	$75.00 to $100.00
120 d.c., 110 or 220 a.c., 500 cycle 2 kw.	$50.00 to $150.00
120 d.c., 110 or 220 a.c., 500 cycle 5 kw.	$95 to $250.00
120 d.c., to 20 d.c., 2 kw	$60.00
120 d.c., to 400 d.c. 2 kw.	$45.00
120 d.c., to 600 d.c., 2kw	$65.00

Just bought 70 of these from U. S. Navy and you can have them at 1-4 of Navy's cost.

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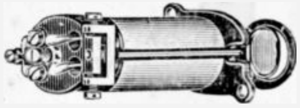
Used either as Generator or Dynamotor
Fil. Volts 6.9. Plate Volts 400-500.
Fil. Amp. 3.75 Fill M. A. 250.
Complete with filter 9-16 inch shaft, 3 in. long, weig t 80 lbs.



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110 volt a.c. 900 cycle self-excited 200 watts	$10.00
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110 volt a.c. 600 cycle, self-excited 250 watts	$25.00
1500 volt d.c. 660 mills, 1 kw., Esco 1750 r.p.m.	$45.00
240 volt 500 cycle, self-excited 2500 r.p.m. 250 watt, (also hand drive)	$25.00
120 volt d.c. 5 kw	60.00
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600 volt d.c. 2 kw.	45.00
220 volt a.c. 500 cycle 1 kw.	45.00
220 volt a.c. 500 cycle 2 kw.	60.00
12 volt d.c. 60 amp.	15.00
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Baldwin Headphones, Genuine Mica Diaphragm 2000 ohm. Regular $15.00 value $3.50

VOLTMETERS, D. C. portable new Weston model 45, 3 scale 0-3-15-150 guaranteed 1-4 of 1 per cent accurate . . $40.00

Ammeters, D.C., portable, new Weston model 45; 3 scale 0-1-5-15-150 with 3 scale external shunt and leads 1-4 of 1 per cent accurate $30.00

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All Types
1.2 Volts Per Cell

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M-8 Amps. 11.	Per cell	1.00
L-40 Amps. 25.	Percell	1.50
J-3 Amps. 37.	Per cell	3.00

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24-1500 Gen. Elec. 2 1-2 kw. output	$95.00
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12-750 volt 200 mills	30.00
32-350 volt 80 mills	9.00
32-300 volt 60 mills	7.50
Dynamotor Armatures, General Electric triple commutators, d.c. 24-1500 volt	$12.50

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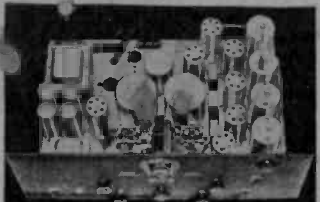

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1000	60,000	1.58
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Ohms		Ohms	
1000	$ .95	10,000	$1.18
2000	1.05	15,000	1.18
3000	1.12	20,000	1.45
4000	1.15	30,000	1.45
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Type	Price	Type	Price
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