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RADIO BROADCAST

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ENGINEERING · THE LABORATORY · SERVICING

Contents for April, 1929

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. . . *among other things*

SO MANY of you have said so many nice things about the March issue that there was some wonder in the editorial offices about the possibilities of compliments—and what is more to the point, real use and appreciation—on this number. But on examining the contents, which can be found not far to the left, we are just as proud to launch this issue as we were the preceding one. Mr. Morgan's story on the condenser loud speaker packs all the available information into three interesting pages, beginning on page 369. Mr. Dunham's article on page 375 gives dealers and servicemen an interesting outline of set testing routine which is practical down to the last period. The figures on set and tube sales for the last two years, compiled by the Editor should prove interesting and useful reading for everyone in the industry. And then, Mr. Kruse makes his bow as conductor of the new experimenter's section, Prof. Terman has a corking article on "power" detection, Mr. Jarvis puts a new angle on the selectivity question which is by no means a theoretical one, Roger Wise writes of characteristics of filament rectifiers, and there are our regular departments, all of them unusually interesting.

WE OWE a general apology for an error which crept into Mr. Kruse's article in the March issue which described the work of the Radio Frequency Laboratories. The caption under Fig. 1 should have read: "A model set using screen-grid tetrodes." The caption under Fig. 2 should have made clear that the device shown was used for checking the design of single stages which are placed in the central compartment.

THE May issue will contain the third of Prof. Terman's articles in his series on "Detection" and will deal with the principles of C-bias detection. In addition there is an interesting article on self-shielded coils, a discussion of audio-transformer measurements by J. Kelley Johnson, and many special articles of interest to radio dealers and servicemen. The latest addition to our new news section, "The Radio Marketplace," the Radio Dealer's Notebook, is continued with more practical data. Incidentally, the welcome given this feature by radio dealers has been most encouraging. Dealers who have not seen this feature are referred to page 407 of this issue and to page 332 of our March number. The service side of radio sales—the relation is written in that way intentionally—will not be neglected in our May number: an address given by the Editor at the Federated Radio Trades Association convention in Buffalo will be printed for the first time. That article, "The Inseparability of Sales and Service" emphasizes a division of the dealer's business that has had all too little attention.

—WILLIS KINGSLEY WING.

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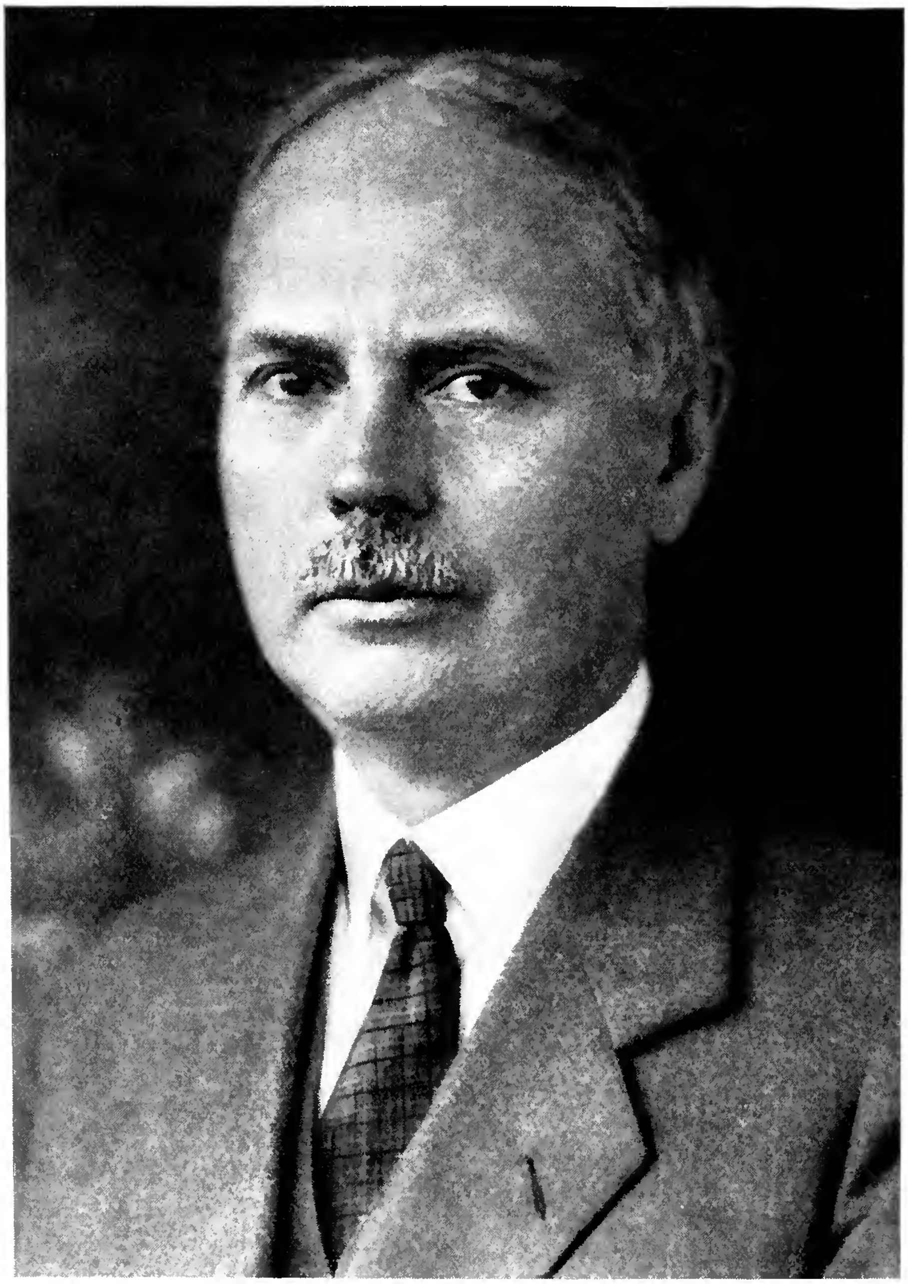


Louis B. F. Raycroft

Vice President, National Electrical Manufacturers Association

THE SERVICEMAN'S RESPONSIBILITY TO THE INDUSTRY

It is the serviceman's responsibility to keep the radio receiver sold. The satisfaction which the products of our industry give the user may be jeopardized by unskillful installation and failure to instruct the new owner in the maintenance and manipulation of his new receiver. We recognize the importance of service and no progressive manufacturer is without an active and extensive service organization. Indeed, through the Radio Division of the National Electrical Manufacturers Association, the industry has collaborated in the preparation of a course for dealer technicians, with the objective of improving the standards of consumer contact with the radio dealer after the sale is made.

As radio retreats from the position of a seventh-day wonder and becomes a stabilized fixture in the home, the importance of the dealer technician in the radio structure rises proportionately. We have already observed many instances of dealer success founded upon a reputation for good servicing. RADIO BROADCAST'S *contributions to better servicing by its articles for the instruction of the dealer technician are helping to raise service standards and increasing consumer satisfaction and confidence in the products of our industry.*—L. B. F. RAYCROFT, *Vice-President in charge of the Radio Division, National Electrical Manufacturers Association.*

Data of Interest to Dealer-Servicemen

NEW USES FOR POWER AMPLIFIERS

By FRED H. CANFIELD

One use of radio apparatus that has grown in striking fashion in the last year is the wide application of powerful audio amplifiers to all sorts of non-radio uses. In the installation and operation of these amplifiers, the local radio-trained man, whether he be dealer, independent serviceman, or whatnot, is best equipped to do the work. This article by Mr. Canfield, a member of the Radio Broadcast *editorial staff, attempts to show the breadth of the field and how the real demand for public-address equipment can be turned to the profit of the individual.*

—The Editor.

RADIO dealer-servicemen—and everyone else in the business world, for that matter—are approached constantly by promoters and high-powered salesmen who offer—always very confidentially—some "wonderful" get-rich-quick scheme which must be acted upon immediately in order to derive the full benefits. These men have their hooks baited for the novice of the business world and to this class their arguments sound very convincing. On the other hand, the hard-boiled business man, recognizing instantly these men and their schemes, dismisses them from his office as soon as they are detected. Without listening to their story he knows the fallacy, for from experience he has found that earning money legitimately requires hard steady plugging. Also, he suspects (rightfully perhaps) that the salesmen themselves hope to get rich quick by selling him their ideas.

The writer of this article has nothing to sell (except a manuscript now and then), and it does not bring an extra cent to his pocket if radio dealer-servicemen follow the suggestions presented in the following paragraphs. Therefore, inasmuch as there is no ulterior motive, it is advised that serious consideration be given the following plan which points to a way in which radio dealers and service organizations may increase their revenue. No guarantee is given that one's income may be doubled almost immediately, but the ambitious man, who is not afraid to work hard for his money, may find that it is a solution to his problem.

Enough valuable space has now been taken by the introduction so the "meat" of the article will be attacked without delay. The first question which it is necessary for the dealer-serviceman to ask himself is, "From what sources do I derive the greater part of my income?" Secondly, he should debate over the question, "What other sources of revenue are available if I should decide to increase the scope of my business?"

In most cases the answer to the first question is that the business includes the repair of radio receivers, custom set-building, and the sale of tubes, small replacement parts, and accessories. To these three items the dealer may also add the sale of complete receivers. In answering the second question many dealer-servicemen have explained that they have found it difficult to make a business consisting exclusively of radio support a large firm; the result has been that they were forced to enter other closely allied fields such as electrical contracting, sale of electrical appliances, sale of musical instruments, phonographs, etc. The writer advises another alternative for increasing revenue.

The Solution

THE installation of public- and group-address systems is a branch of the radio business which has hardly been scratched commercially, although there is a big demand for specialists in this field. The work provides numerous opportunities for large profit to the serviceman who is willing to go out into the field and dig up prospects. It also has the added advantage of keeping the activities of the firm strictly within the radio field, which is highly desirable for several reasons.

In considering this question a factor which should not be neglected is the good-will publicity which may be derived in public-address work. It must be remembered that every public- or group-address installation is heard by thousands of persons. Therefore, if good reproduction is provided by the apparatus, it cannot help but reflect credit on the firm which engineered its construction. For this reason it is logical to assume that the firm making the most successful large installations will lead also in the servicing field, providing newspaper advertising emphasizes the fact that such work receives the same careful consideration.

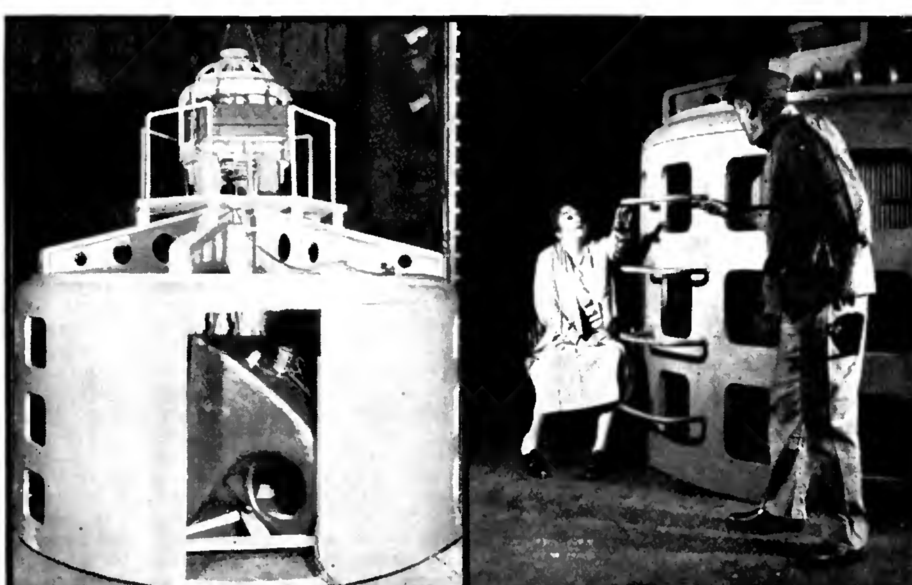
Another factor in favor of public-address work is employment of the same staff of men in all branches of the business. With a little study a good serviceman may learn quickly how to build and install the large amplifiers which are required in this work, and this feature tends to increase the efficiency of the business. On the other hand, if the firm enters the electrical or musical field in order to increase its income, extra trained men are required.

Public- and group-address work should not be considered only as an extension to a regular radio business, as, in most cities, this line of work done could be made to provide sufficient income for a good size firm. Although it is obviously impossible to build up as large a clientele as in the servicing field, the income derived from each customer per year is much greater, due to much higher cost of the apparatus and the need for more frequent inspections. These factors will be considered in greater detail later.

It should also be pointed out that specialists in public- and group-address work may develop other sources of revenue aside from installing and servicing. For example, many firms renting public-address systems for special occasions have found this a very profitable undertaking. Other radio dealers, after making an amplifier installation, provide an operator for the apparatus during the hours it is in use, and, where an operator is not needed, the amplifier is inspected at regular intervals rather than waiting for a service call. It is also possible, in many cases, for the serviceman to design and build the amplifier rather than install a manufactured outfit, thus providing additional work for the shop.

Selling P. A. Amplifiers

PROBABLY this question has already reached the reader's mind. "How can I sell public- or group-address amplifiers?" It requires hard work in the field until the business is established; hanging a shingle outside your door stating that you are a "specialist in public- and group-address amplification" will not help in most cases. However, even in a small town there are hundreds of potential purchasers who are just waiting for you to "sell" them the idea. In the following paragraphs a few of the various types of installations which have been made by dealer-



—Amplion Corp. of America

A public-address amplifier is used to produce the hum of a dynamo in any desired volume in presenting the play Dynamo at the Martin Beck theatre, New York City. The rear view (left) shows the electrodynamic horn loud speaker inside the dynamo. The picture on the right shows a scene during the third act of the play

servicemen in all parts of the country will be considered.

Dance halls, cabarets, restaurants, and road houses are places where public-address systems have been used with great success. In such places the amplifier is used mostly in connection with an electric turn-table for the reproduction of phonograph records, but it frequently is employed for announcing and for radio music. In the restaurant business a public-address amplifier is a real asset as well as an economy. By connecting the amplifier with a phonograph pick-up unit it is possible for the proprietor to provide his guests with dance music at hours of the day when it would not be profitable to employ an orchestra for the purpose. In some cases the amplifier is used to supplant the orchestra entirely, and in other cases it is used in conjunction with the orchestra, thus permitting continuous music throughout the busy evening hours. Group-address amplifiers are also used in some large restaurants to provide music for the smaller or private dining rooms; in these cases the music may be picked-up with a microphone near the orchestra in the main dining room or a phonograph pick-up unit may be employed. Also, in restaurants the amplifiers are used as a coin-operated affair.

Small motion-picture theatres everywhere are beginning to use public-address amplifiers to provide music during the picture. By using an amplifier to reproduce phonograph records they are able to dispense with their pianist, organist, or small orchestra at a great saving of expense, and at the same time to provide *much* better music. Nowadays, even in the smallest theatres, one is able to listen to the best orchestras of the country.

Surprising as it may seem many factories have found it very profitable to provide their employees with music, not only during lunch hour, but throughout the entire day. In this connection Mr. Cotton of the Samson Electric Company writes, "We have tried in our factory, the proposition of using amplified music on the assembly help, mostly girls, and have found that when running music the production is increased. The music has a tendency to cut out talking among the girls and keeps their minds off the clock. As a result all hands seem to move faster." This same scheme is used in other factories and the same results are reported in each case.

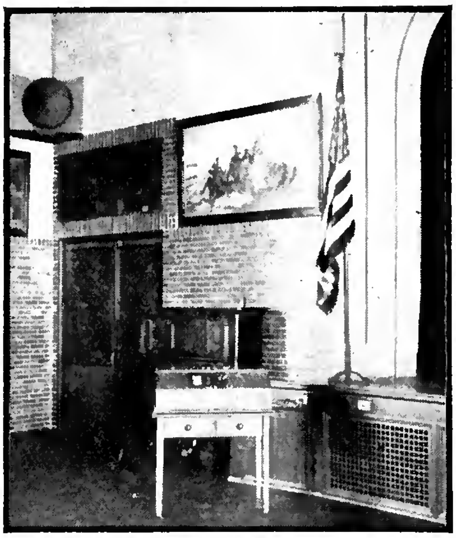
There is at present a fast growing tendency to use amplifiers for the instruction of pupils in public schools. Many special programs designed especially for schools are now being broadcast regularly and for this reason most school amplifiers are provided with a radio tuner. However, amplifiers in schools are also arranged for use with a phonograph pick-up unit as phonograph records have been found helpful in the instruction of music, languages, etc. In many cases a school installation consists of a combination public- and group-address system. A group of loud speakers are installed on the platform of the auditorium for the instruction of the school as a group, and in addition a small loud speaker is located in each class room.

A number of cases are on record where churches and funeral parlors have made use of public-address systems. In funeral parlors they may be used for reproducing phonograph records of a nature suitable to the occasion when the people holding the service have been unable to afford a quartet or musician. Churches as well as funeral parlors have also used amplifiers to permit an overflow crowd in another room of the building to hear the services. In particular, several Christian Science churches have found public-address amplifiers very helpful during special lectures.

Selling Group-Address Amplifiers

THERE are just as many persons interested in group-address amplifiers as in public-address installations, but the different uses for the former are slightly more limited. Apartment house landlords are probably the largest group interested in these systems. In the modern radio-equipped apartment house a radio outlet is provided in each apartment and this is supplied continuously with radio music from a group-address amplifier located in the superintendent's apartment. Also, in some apartment houses a duplex system is used to furnish a choice of two programs at the same time. In order to receive the programs it is only necessary for the tenant to plug the cord from his loud speaker in the jack of the outlet plate.

Many hotels and clubs are beginning to provide the same radio service that the apartment house landlord is giving. However, in hotels a much larger amplifier is used, as it is usually employed for public-address work in the main dining room as well. Hospitals, veterans' homes, and charitable institutions of various kinds are also making use of group-address systems but in these cases headphone outlets are often provided in the various rooms instead of loud-speaker outlets.



—Samson Electric Company

A large amplifier is used for instructing pupils at the Frank A. Day Jr. High School, Newtonville, Mass.

Amplifiers For Special Events

IN ADDITION to the places where permanent amplifier installations may be used there are numerous cases where amplifiers are required for special events; in fact, a wide-awake radio dealer should be able to rent his public-address system several times each week. This business, which is just as profitable as installing and servicing public-address amplifiers, also provides excellent publicity. It should be unnecessary to mention all of the places where such apparatus may be leased, as the necessity for a public-address system will occur to the dealer when he hears of the event. However, it may be stated that amplifiers are used constantly during banquets, for intensifying the speaker's voice in remote corners and alcoves of the dining room as well as in other small rooms where guests may be assembled. Private dances, which are held in homes or in rented ball rooms, may also use public-address amplifiers to provide orchestra dance music in the same manner that they are used by restaurants. At regular annual events such as automobile shows, motor boat shows, music carnivals, etc., public-address amplifiers may often be leased for an entire week. During the football and baseball seasons newspapers often find a need for public-address amplifiers to permit them to announce scores and news to the crowds assembled in front of their buildings. In addition there are numerous advertising stunts where large amplifiers may be used to advantage.

The suggestions given in the above paragraph are of greatest value during the winter months. However, contrary to most branches of the radio business, there is just as much need for amplifiers during the summer as during the colder months. At county and state fairs a radio dealer may find it possible to rent several amplifiers for one or two weeks at a time. Other times when amplifiers are really needed are during pageants, church festivals, water carnivals, horse races, automobile races, beauty contests, baby parades, etc. In fact, the demand for amplifiers could be made great enough, by proper sales promotion, to make the summer weeks very profitable for the radio dealer as other business is slow and he would be able to concentrate his entire attention on this work.

The charge which may be made for the rental of a public-address system varies with the use to which it is placed. For strictly commercial purposes where the apparatus is required for several days or a week the dealer may ask as much as fifty per cent. of the cost of the equipment. For semi-commercial events where the amplifier is needed only for one evening, twenty per cent. of the cost of the amplifier is a fair charge. On special occasions, such as election eve, on the night of a presidential broadcast, etc., amplifiers may be rented at a very handsome profit to motion-picture theatres, men's clubs, banquet halls, and other places of amusement where people assemble. For church affairs a very low charge, if any, must be made. However, in such cases the dealer or serviceman can afford to provide the equipment free in return for publicity received.

Technical Considerations

THE space available for this article is not sufficient to permit an adequate discussion of the technical side of the public- and group-address problem. However, a few of the important questions will be considered briefly. Readers who are interested in a more detailed description of the type of apparatus required are referred to constructional and technical articles which have appeared in previous issues of RADIO BROADCAST ("A Dual Push-Pull Public-Address Amplifier," January, 1929, RADIO BROADCAST, page 195, "An Efficient Push-Pull A. F. System," by Kendall Clough, February, 1929, RADIO BROADCAST, page 241). In addition, several manufacturers (Silver-Marshall, Inc., American Transformer Company, Samson Electric Company, General Radio Company, The National Company, etc.) have prepared excellent literature describing the type of apparatus required and the method of making installations. In particular, Silver Marshall's house organ, *The Radio Builder*, and their book, *Manual for Authorized Service Stations*, contain much practical and technical data on the subject.

The question regarding which there seems to be the greatest lack of information concerns the size amplifier required for various types of installations. In general it may be said that each magnetic-type loud speaker requires approximately 500 milliwatts (0.5 watts) for normal volume in the average size home living room. In halls or auditoriums where high volume levels are required one or a group of several dynamic loud speakers provide most satisfactory results. Dynamic-type loud speakers of standard design should not be called upon to handle more than three and one-half watts of power. Where a distribution system with headphone outlets is being planned about 14 milliwatts (0.014 watts) per pair of phones must be allowed.

The usual public-address amplifier employs three or four stages with two 250-type tubes in the output circuit. Such an amplifier has an output of approximately 15 watts. Larger outputs may be obtained by connecting two or more push-pull output stages in parallel.

Advantages and Disadvantages of

THE CONDENSER-TYPE LOUD SPEAKER

By JOSEPH MORGAN

International Resistance Company

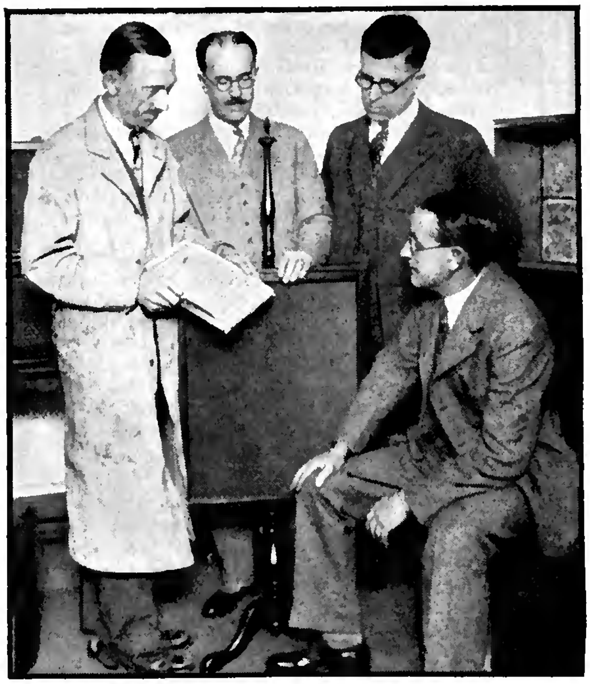
IN 1881, Professor Dolbear announced the first condenser receiver for telephone systems. This was the fore-runner of the condenser loud speaker which is being introduced into radio to-day. While the principle is interesting and may very well yield important results, there is nothing essentially new in the idea. It is to be noted that the magnetic and condenser types of loud speakers are about equally old in principle and, therefore, we must examine the condenser loud speaker with great care before we pronounce a verdict. It must be evident, therefore, that the condenser loud speaker is no more nearly ideal in its basic principle than the magnetic.

In this article the principle of the condenser-type loud speaker will be set forth together with its advantages and disadvantages. Also, a brief account of some typical loud speakers which are now being manufactured will be given together with a description of the method of application of such loud speakers.

When two conductors of electricity are separated in space by a non-conductor of electricity, we have what is called an electrical condenser. If these two conductors are charged with electricity of like sign, they tend to repel each other and if they are charged with electricity of unlike sign, they tend to attract each other. Suppose that these two conductors are large, flat, metallic plates of equal area, separated by a thin film of air. (See Fig. 1A.) If a difference of potential or voltage is applied to these plates, a force will be exerted tending to draw these plates together, and the force will be proportional to the area, A, of one side of one plate; it will be proportional to the square of the voltage between the two plates; and it will be inversely proportional to the square of the distance, D, between the two plates.

From the above paragraph it is seen that the greater the voltage the greater the force, the larger the size of the plates the greater the force, and the smaller the distance between the plates the greater the force. If we make one of these plates quite heavy and stationary and the second plate very light and movable (see Fig. 1B), the application of a varying voltage to these plates will tend to draw the light movable plate to the heavy stationary plate with a force which will increase as the square of the voltage. If an alternating voltage, for example, the usual 60-cycle, 110-volt house current, is applied between the two plates, the movable plate will tend to move in and out at double the frequency of the applied voltage which, in this case, would amount to 120 times per second. This result would be obtained since the plates tend to pull together both on the positive and on the negative halves of the alternating-voltage cycle (see Fig. 2, diagrams A and B). Thus instead of obtaining a 60-cycle tone by virtue of the motion imparted to the surrounding air by the movable plate, we would obtain a 120-cycle tone. This is a perfect instance of complete distortion, since the original tone is absent and is replaced by one of entirely different frequency.

Suppose that this alternating house current be replaced by the voice current from the output of a broadcast receiver. It must be obvious that the light movable plate, which we shall henceforth call the diaphragm, would produce a hopelessly distorted sound since it would move in accordance with the square of the voice voltage and at double the voice frequencies.



Colin Kyle (left), inventor of the Kyle condenser loud speaker, is demonstrating his invention to three authorities on radio and acoustics. In his hand he is holding a section of the loud speaker, and standing on the floor is a completed model

> *As has been predicted in these pages, the condenser-type loud speaker is apt to attract a great deal of attention in the industry during the coming season. What is it? How does it work? How does it compare with other types? These and other questions, Mr. Morgan, of the International Resistance Company, whose previous articles on loud speakers in this magazine have been so well received, attempts to answer. The device is not a panacea; it will not "revolutionize" the industry. Here is a straight-forward analysis of the whole question.*
>
> —THE EDITOR.

Minimizing Difficulties

LET us see how these essential difficulties are minimized. Suppose that we place a high direct voltage, for example 500 volts, across the plates of our crude condenser loud speaker. There will be a strong constant attraction between these plates, due to this constant direct voltage. If now we superimpose a much smaller 60-cycle sine-wave voltage upon these same plates, this alternating voltage will tend to increase and decrease slightly the direct potential which we have already established between the plates. In other words, the force will alternately become a little greater and a little less than the initial force due to the direct voltage (see Fig. 2, diagrams C and D).

It can be shown mathematically, that the motion of the diaphragm under these conditions will be approximately in accordance with, and proportional to the alternating voltage applied between the plates. The smaller the ratio of the alternating voltage to the constant applied direct voltage, the more accurately the diaphragm will follow the alternating voltage variations. It is exceedingly important to note that there will always be a component of the motion which is *twice* the frequency of the original voltage and also that the motion will never be *exactly* directly proportional to the applied alternating voltage. In other words, in this type of loud speaker, as well as in the magnetic and electrodynamic types, there is always some inherent distortion. A mathematical analysis of the condenser loud speaker shows that the greatest response is obtained when the plates are as close as possible together and both the constant direct voltage and the alternating applied voltage are as great as possible.

We have just shown that the alternating voltage must be a small fraction of the direct voltage in order to minimize distortion. This, therefore, is our first limitation. Second, the direct voltage, which we shall henceforth call the polarizing voltage, must not be increased beyond 500 or 600 volts because of the danger of break-down between the fixed plate and the diaphragm. Further, it is not safe nor practicable to generate much higher voltages than 600 for such a purpose. Third, the distances between the plates cannot be made indefinitely small for several reasons: (a) because the polarizing voltage would tend to puncture the insulation between the two plates (in this case, air) if the distance were too small; (b) there must be sufficient distance so that the diaphragm may move back and forth in order to impart a mechanical wave motion to the air in front of it; (c) if this distance were too small, the diaphragm might actually strike the stationary plate causing a short circuit if too great a voice voltage were applied or if resonance obtained either in the electrical circuit or in the mechanical construction of the loud speaker. Hence, it is seen that compromises must be effected throughout the design of this type of loud speaker just as in the case of the magnetic and electrodynamic loud speakers considered in previous articles.

As a result of these compromises, the sensitivity and efficiency of the condenser loud speaker is, in general, low. Due to the small permissible distance between the diaphragm and the back plate the large amplitudes of motion necessary for the adequate radiation

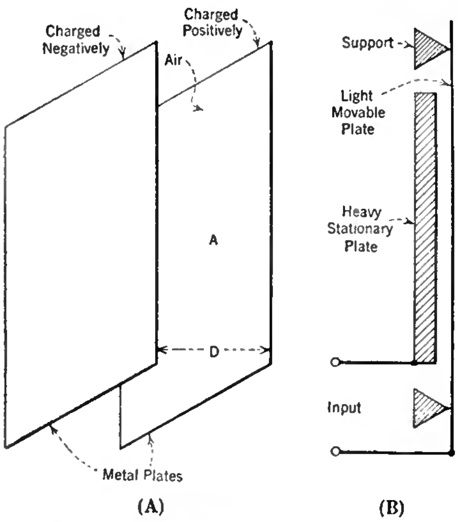


Fig. 1—(A) An electrical condenser; (B) A simple condenser-type loud speaker

of low tones is not practicable. Consequently, it is difficult to obtain adequate response at the lower audio frequencies.

Points of Superiority

AFTER this more or less discouraging introduction, let us now discuss the points of superiority inherent in the condenser-type loud speaker. Chief amongst these is the great simplicity of construction. The loud speaker has but one movable part and contains no coils nor elaborate magnetic field construction. In addition to its simplicity, it can be made to be exceedingly compact. One model of this type is scarcely more than one quarter of an inch thick. A second important advantage is to be found in the fact that the diaphragm is attracted as a whole over the greater part of its surface, instead of being actuated at a point, as in practically all magnetic and electrodynamic constructions. This reduces effects due to complicated modes of vibration of the diaphragm with resultant multiple resonances, and makes possible a smooth frequency-response curve, reasonably devoid of marked peaks and depressions. The third important advantage is the practicability of using exceedingly thin, light, non-magnetic diaphragms of great flexibility and low inertia, thereby making possible the radiation of the high audio frequencies which are so necessary to faithful and intelligible reproduction of speech and music. Another advantage is gained by the use of a large flat diaphragm as contrasted with the small magnetic diaphragms and the conical paper diaphragms used in other loud speakers, since a large, flat surface is better adapted to the radiation of sound.

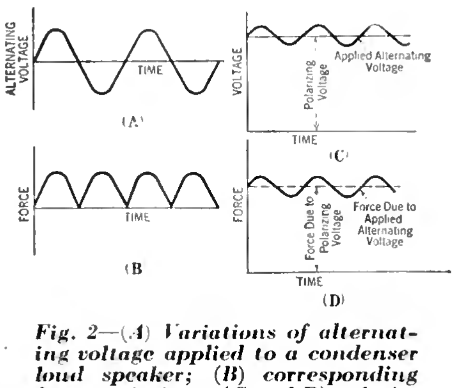


Fig. 2—(A) Variations of alternating voltage applied to a condenser loud speaker; (B) corresponding force variations; (C and D) polarizing voltage eliminates double-frequency effect of (B)

Some features of condenser loud speaker design will now be discussed. The back or stationary plate of the condenser loud speaker must be exceedingly rigid and can be made of any stiff metal. In practice, either iron or aluminum is generally used since they combine the requisite stiffness with low cost. The back plate is usually perforated to permit free passage of the air between it and the diaphragm in order to minimize the loss due to air damping between the plates. A compromise must be secured since too few perforations will allow excessive air damping and too many perforations will cut down the effective area of the plate and hence the force between the plates, thus materially reducing the sensitivity of the device (see Fig. 3).

The diaphragm itself may be made of exceedingly thin, tough metal such as certain of the alloys of aluminum. When so constructed, it is usually very tightly stretched in order that its fundamental natural frequency shall be higher than the highest audio-frequency which it is desired to reproduce. In this way, the natural frequency of the diaphragm will lie entirely outside of the usual audio-frequency range and, therefore, will not cause serious distortion. In one loud speaker designed by Hans Vogt, the metal diaphragm for a 14-inch diameter loud speaker is only 0.015 inch in thickness and weighs less than 0.14 ounce, and is stretched to have a fundamental natural frequency above 15,000 cycles per second.

Push-Pull Design

IN LOUD speakers constructed on this principle, the insulation between the diaphragm and the stationary plate is usually a film of air. In the speaker designed by Vogt,

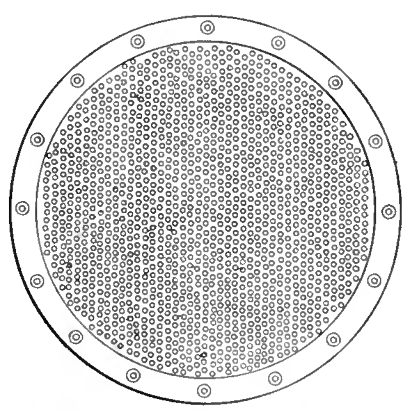


Fig. 3—Perforated stationary plate reduces air damping in condenser loud speakers

the push-pull principle is used as shown in Fig. 4, i.e., the diaphragm is placed between two stationary plates, the diaphragm is under no initial stress with respect to the back plates, and second-harmonic distortion is eliminated. A possible objection to this form of construction which occurs to the writer is to be found in the fact that there is no free passage for the sound from the diaphragm since both surfaces are masked by stationary plates. However, it is claimed by the inventor that this form of condenser loud speaker is quite sensitive and has a long, flat frequency-response curve. The diaphragm sometimes consists of thin, flexible insulating material such as india rubber, gelatine or paper, coated on the outside with gold or aluminum leaf or painted with a conducting material such as graphite. This type of construction has several advantages. In the first place, such a diaphragm is exceedingly light and has no pronounced natural frequency of its own. Second, since it does not have to be tightly stretched, the

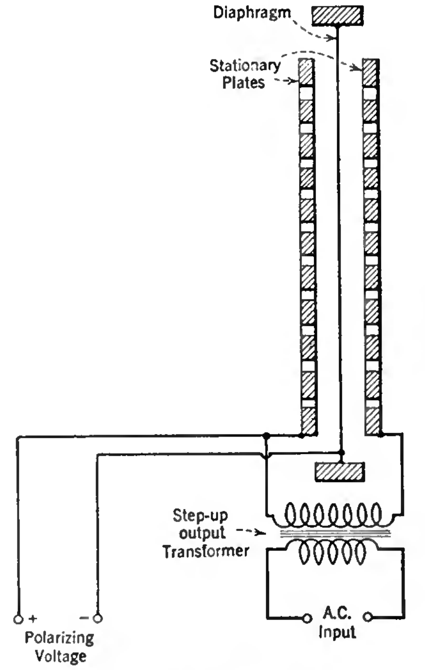


Fig. 4—Schematic drawing of a push-pull condenser-type loud speaker

sensitivity of the apparatus is increased. Third, the insulating material has a property which is known as the dielectric constant and for most insulators, this is greater than for air. Since the force between the plates for a given voltage is proportional to this dielectric constant, a greater force is obtained with such a loud speaker than with one in which air is the sole insulating material.

In one condenser loud speaker recently designed by Colin Kyle, the back plate is perforated and ribbed. Over this back plate is stretched a rubber-like material, called *Kylite*, on the outer side of which is cemented a thin, flexible conducting coating which serves as the diaphragm, as shown in Fig. 5. There are wedge-shaped air spaces between the diaphragm and the back plate. Under the action of voltage applied between the diaphragm and the back plate, these wedge-shaped air spaces tend to become narrower, hence the whole diaphragm behaves as if constructed of a multiplicity of small diaphragms acting in synchronism. It is claimed by the inventor, that this construction yields good sensitivity and a good frequency-response. While it is claimed that the dielectric material used in the Kyle loud speaker has a long life, certain experimenters have found that non-conducting diaphragm materials are apt to change their properties with changes in weather conditions and age. The thickness of the dielectric material in the Kyle loud speaker is 0.005 inch and has a dielectric constant of 3. However, reference to Fig. 5 will show that the force for the given voltage is not equal to three times that of the air-insulation loud speakers since, in this instance, the actual dielectric is a combination of Kylite and air. Therefore, the force is somewhat greater than for air dielectric, but not nearly as great as if the dielectric was Kylite solely. The loud speaker is constructed in units 8 inches by 12 inches. Any number of these units may be connected in parallel in order to give a large surface from which to radiate the sound. As many as 96 of these units have been used together. When a large number are employed at the same time, it is usual to place them on a slightly curved surface in order to prevent the radiated sound from being too directional. The capacity of each section of the Kyle loud speaker is 0.004 microfarads.

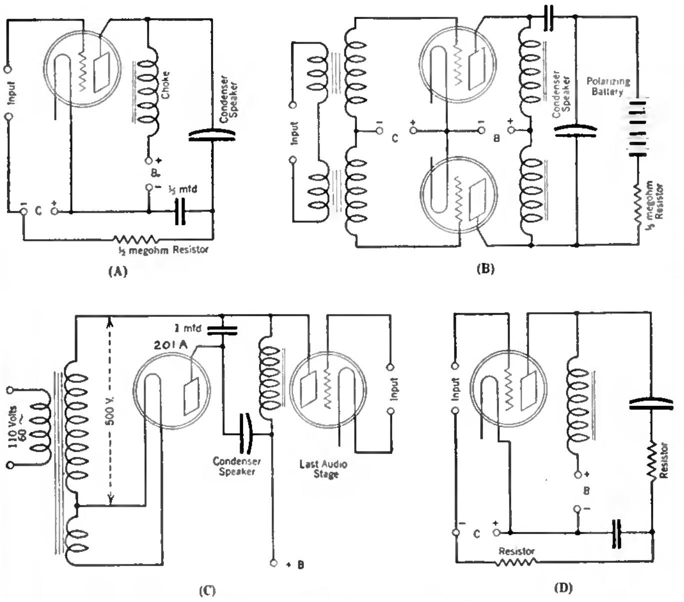


Fig. 6—Circuit arrangements employed for connecting a condenser loud speaker with various types of a.f. amplifiers

Baffleboard Required

JUST as with loud speakers of the electrodynamic type, it is necessary to use a baffleboard or baffle cabinet in order to radiate the lower audio-frequency tones. The same rules apply to the calculation of baffles for this purpose as in the case of electrodynamic loud speakers.

The radio set and associated audio-frequency amplifier must have the same properties as those required for good reproduction with magnetic and electrodynamic loud speakers with the exception of the arrangement of the circuit for the output of the last audio-frequency stage, and the provision of a suitable polarizing voltage. Whereas the impedance of the electrodynamic-type loud speaker is usually very low, averaging approximately 25 ohms at 1000 cycles, and the impedance of the average magnetic-type loud speaker is about 5000 ohms at 1000 cycles, the impedance of the condenser-type loud speaker is very high, that is of the order of magnitude of 50,000 ohms at 1000 cycles. It is, therefore, evident that circuit arrangements must be somewhat different in the case of the condenser loud speaker in order to obtain the proper impedance relationship. If a transformer is used to couple the loud speaker with the output tube of the audio-frequency amplifier, it must have a step-up ratio instead of a step-down ratio such as is usually employed for other types of loud speakers. Such an arrangement is shown in Fig. 4. The last tube may be impedance coupled as shown in Fig. 6A. However, if a low plate impedance power tube is used in the last stage, this is a very inefficient method of connection. A method for connecting this loud speaker with the push-pull amplifier is shown in Fig. 6a. Where the last tube in the set is a power tube, such as the 210 or 250, the B voltage may also be used as the polarizing potential for the condenser loud speaker, as shown in Fig. 6A. Sometimes it is desired to use a separate source of polarizing voltage in which case a step-up transformer, a 201A-type tube, and a 1-mfd. filter condenser are connected as shown in Fig. 6C to provide the polarizing voltage.

Since the impedance of the condenser-type loud speaker is inversely proportional to the frequency, the division of voltage between the resistance of the last stage tube and the condenser-type loud speaker will change with the frequency; the voltage across the loud speaker being greatest at low frequencies and smallest at high frequencies. This quality can be compensated by proper design of the coupling transformer or by the introduction of resistance in series with the condenser-type loud speaker as shown in Fig. 6D. The resistor used must be of the best quality in order that no extraneous noise shall be introduced into the loud-speaker circuit. This latter method improves the frequency-response characteristic at the expense of the sensitivity of the loud speaker, hence, a compromise must be effected between the two. In Fig. 7 are shown curves of the voltage

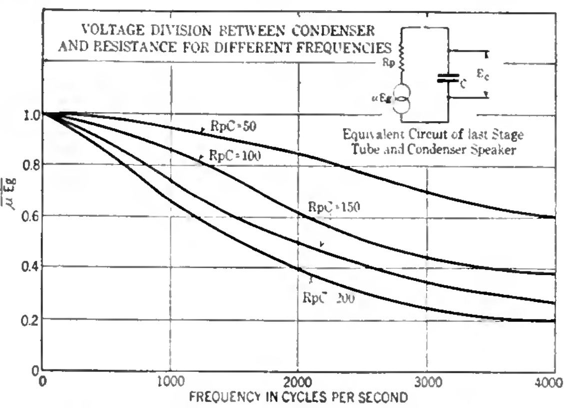


Fig. 7—Curves showing voltage ratio of condenser and tube resistance at various frequencies

ratio for different values of resistance. R_pC in these curves is the product of the resistance in ohms and the capacity in microfarads. Kyle recommends the value of $R_pC = 65$ for a single section; $R_pC = 100$ for a four section; $R_pC = 180$ for a twenty-four section loud speaker of the Kyle type. It is, of course, possible to design the audio-frequency amplifier in such a manner as to have a rising frequency-response characteristic which will compensate the falling frequency-response characteristic of the condenser-type loud speaker. In this way, a maximum response may be obtained with a very flat frequency-response characteristic. It is not possible to give the details of such design unless the precise characteristics of the loud speaker to be used are known.

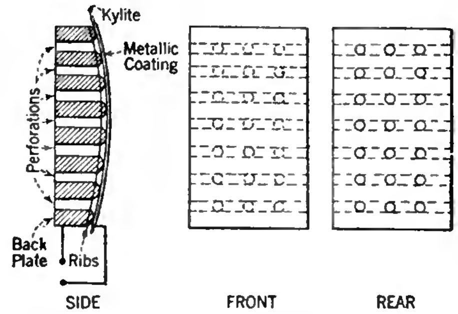
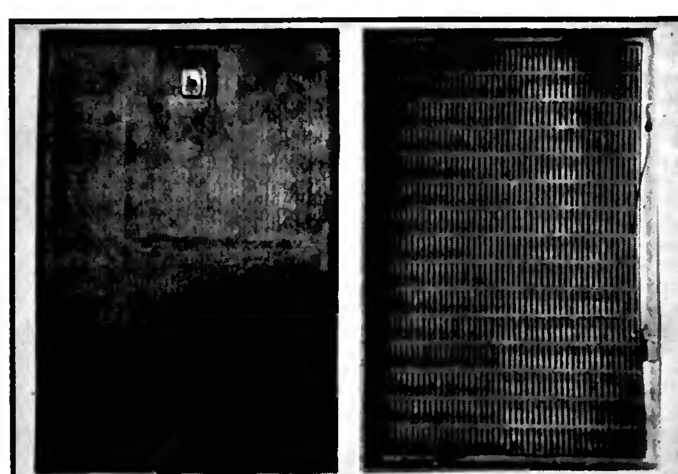


Fig. 5—Schematic drawing of the Kyle condenser loud speaker

Conclusions

IT MAY be seen from the above discussion that the condenser-type loud speaker has many advantages and disadvantages. It is impossible, at this time, to make a valuable prediction as to the ultimate survivor in this field. With present-day power amplifiers, the questions of sensitivity and efficiency are second to that of good frequency-response and if it can be shown that practical condenser-type loud speakers are capable of better frequency-response characteristics than magnetic or electrodynamic types, at least for the time being, this type of loud speaker should find a ready market. However, it is only fair to say that the issue is not a simple one and neither type has as yet been proved to outclass the other. It is hoped that within the near future it will be possible to publish frequency-response characteristics together with the efficiencies of condenser-type loud speakers manufactured for broadcast reception. Until this can be done no reasonable final judgment can be made for or against the condenser-type loud speaker as compared with the standard types now available.

[*Editor's Note:* This is the third article on loud speakers which Mr. Morgan has written for RADIO BROADCAST. The two preceding articles discuss the relative merits and disadvantages of other types of loud speakers and readers desiring further data on the subject of reproducing devices will find them of interest. The first, "All About Loud Speakers," appeared in August, 1928, RADIO BROADCAST, page 188, and the second, "All About the Dynamic Loud Speaker," appeared in January, 1929, RADIO BROADCAST, page 159.—*Editor*]



A close-up view of the front and rear of a section of the Kyle condenser loud speaker. The perforated plate is to the rear

The MARCH OF RADIO

A Well-Balanced Federal Radio Commission

THE nomination of Arthur Batcheller, Radio Supervisor for the Second Zone, to succeed O. H. Caldwell as Federal Radio Commissioner for the First Zone, and of Cyril M. Jansky, Jr., to the Fourth Zone Commissionership, both of whom probably will receive recess appointments from President Hoover before this issue is off the press, is one of the most encouraging indications of better federal regulation of radio which has occurred during the last few months. Both of these men possess high technical qualifications and long and intimate experience with allocation problems. Their addition to the Commission will make it a well-balanced body, both from the technical and legal standpoints. We look forward to greater progress from now on and regret that these men inherit a situation so complex that it prevents them from exerting their fullest effectiveness.

The testimony before the House Committee on Merchant Marine and Fisheries on the radio bill extending the life of the Federal Radio Commission as an administrative body brought forward little that is new to those well informed on radio broadcasting. With respect to the continuance of the Commission, only Commissioner Caldwell, who has already left the body, effective February 23, raised a voice in protest against the commission form of regulation. The remaining members of the Commission are convinced that so many of their problems are unsolved that the present tenure of the Commission should be continued. Broadcasting interests, in general, were indifferent as to whether the machinery of regulation functioned through the Commission or through the Department of Commerce.

As this issue goes to press, Congress passed a bill continuing the Commission until December 31, 1929. There is every hope that President Hoover will seek competent men, who have some understanding of broadcasting problems, to fill any future vacancies.

HIGH-CALIBRE MEN NEEDED

While broadcasting is paramount in public attention, the allocation of high frequencies presents even more difficult technicalities which make it all the more necessary to appoint Commissioners with considerable specialized knowledge, as is the custom with other commissions like the Interstate Commerce Commission. Congress has shown a disposition to meddle with the details of radio regulation and the past record of the Commission, of failure to tackle its problems actively and aggressively, makes it difficult to secure men familiar with the situation and competent to deal with it. The recent nominations, however, indicate that men of high calibre can still be attracted to the onerous duties of Federal Radio Commissioner.

The loss of Commissioner Caldwell, whose firm adherence to principle often led him into difficulties, is one which will be felt most seriously by those who regard broadcast allocation in its broad national aspects rather than from the viewpoint of individual stations or political districts. Caldwell has a better understanding of broadcast allocation as a national and engineering problem than any other member of the Commission, past or present, and he has done more to educate the public and the politicians in the actual difficulties with which the Commission is faced than any other Commissioner. May his shoes be filled by an equally nationally minded commissioner with an equally good engineering background and fully possessed of the diplomatic ability to make that knowledge effective. We hope that Mr. Batcheller will waive his natural reluctance to accepting this appointment.

Adolph F. Linden, president of the American Broadcasting Company which operates the ABC Western Network

Sam Pickard, Commissioner for the Fourth Zone, submitted his resignation to the Commission in order to become Vice-President of the Columbia system. He has risen rapidly from chief of the radio service of the Department of Agriculture to Secretary of the Commission, to Commissioner, and finally to his present position. The congested conditions of the Fourth Zone made his position as Commissioner especially difficult and frequently necessitated reversals of policy, invariably bringing him new difficulties. He faithfully represented the interests of his zone and succeeded in making himself liked by the broadcasters in spite of the problems which his duties entailed.

Congress Considers the Commission's Record

THE allocation of forty high-frequency channels to the Universal Wireless Communication Company was quite severely criticised before one of the committees in these same hearings. Judging from the testimony, little evidence was obtained by the Commission as to the competence of the company in making good use of the vast allocation made to it. If the Universal people ever do get under way with actual commercial communications, they have at least had the benefit of nationwide publicity which should attract business to their channels.

The broad question of whether radio competition with established wire systems of communication is desirable or not is a delicate one to discuss. It has been established quite definitely as a general principle that communication systems are most efficient as monopolies but, as such, should conduct their operations strictly in the public interest without discrimination and at a carefully regulated rate of profit. The Radio Corporation of America is desirous of establishing a nationwide radio-telegraph network for the distribution and collection of its foreign trans-oceanic message business. The Universal Wireless Communication Company is seeking to compete directly with the telegraph companies.

RADIO VS. WIRE AND CABLE

Radio is equipped to handle such a small proportion of the total wire message business that all the fussing about competition with wire communication is still considered a matter of insufficiently significant importance to the wire companies to be worth opposing actively. Radio is, however, a severe competitor to the transoceanic cable systems and has been effective in substantially cutting cable rates. It is for this reason that the overland wire services, with their extensive cable affiliations, have not particularly welcomed the Radio Corporation and have rebuffed its overland message business, making it almost imperative for the R. C. A. to establish a competitive radio distribution service.

Single radio links over long distances can be maintained at lower cost than corresponding wire links. Therefore, a small independent communications company could readily compete with a telegraph system between a few particular points. But the small total volume of traffic and the comparatively few cities which could be taken care of under present conditions would not warrant the scrapping of telegraph systems in part or in whole, while any channels which might be so used would ultimately be required for greatly increased foreign communications. The technicalities and economics of the high-frequency allocation problem and the relation of independent radio and wire systems is altogether too complex for brief annual consideration by Congress. The more competent the men who serve on the Commission, the sooner such problems will be left to it.

IN HIS appearances before the House Committee on Marine and Fisheries, Henry A. Bellows, former Federal Radio Commissioner, now Manager of WCCO and Chairman of the National Association of Broadcasters' Legislative Committee, testified that the Association favored a gradual rather than a drastic re-allocation of frequencies. In such reports of the Association's deliberations as were circulated officially, there was no evidence of any formal declaration to this effect by the membership of the Association, but Bellows, undoubtedly, in his position as Chairman of its Legislative Committee, must have spoken with authority.

A BILL, seeking to appropriate $50,000 for the erection of a standard-frequency station somewhere in the center of the United States, has been placed before the House. Such a station would be extremely valuable to laboratories calibrating crystal oscillators for use in the broadcast band But who knows how to maintain the standard station on its standard frequency?

More Discussion on Frequency Control

A SERIES of questions were submitted to various associations in the radio field by Dr. J. H. Dellinger, Chief Engineer of the Federal Radio Commission. None of these was more interesting than those concerning the regulation of frequency stability and regulation of synchronizing experiments in the broadcast band. The Institute of Radio Engineers Committee reported that the maintenance of a station on its frequency within fifty cycles is quite possible and commercially feasible. The National Electrical Manufacturers Association Committee, however, stated that the Commission should content itself in maintaining 500-cycle stability, because that would affect as great economy in channels as 50-cycle regulation.

These differing opinions seem to us quite accountable in view of the sources of information. The engineers' viewpoint is that of the laboratory physicist who has demonstrated under laboratory conditions and expert supervision that an oscillator may be maintained within 50 cycles of its average frequency. On the other hand, the manufacturing people know that it is next to impossible to grind a crystal to the precisely correct frequency or to determine accurately just what its frequency is. It must be remembered that the objective of maintaining a station within 50 cycles of its frequency is to enable stations to share the same channels with reduced mileage separation, not to prevent overlapping of carriers on neighboring channels, that objective being satisfied with the obviously feasible 500-cycle regulation.

A 50-cycle deviation produces a maximum heterodyne of 100 cycles which is not heard as a carrier whistle in the loud speaker. But a sub-audible beat, even as little as 15 cycles, has the unfortunate result of producing a ragged effect by modulating the audio-frequency carrier component. While it is possible to maintain two oscillators which happen to be in step for some time, experience has proved that sooner or later a fundamental change takes place in one or the other crystal and the two oscillators cannot be kept in step thereafter. Were any advantage taken of approximate synchronization by closer geographic spacing of stations on the same channel, then such deviations, suddenly occurring without apparent reason, would have the disastrous effect of ruining the service on that particular channel. The fact that 50-cycle stability might be possible under experimental conditions is no immediate indication that any relief can be obtained or more channel space uncovered.

PRECISION OF MODERN STATIONS

The suggestion made by the manufacturers that the Commission first strictly regulate frequency deviations under the present 500-cycle limit is very constructive. This rule has been in effect for over a year, yet the most flagrant violations are tolerated by the Commission. Some difficulty was experienced in obtaining satisfactory crystals when the order first went into effect, but certainly there has been time for the technical staffs of stations to solve the problem of maintaining their carriers within 500 cycles. A good example of license revocation would be a most desirable stimulant to engineering carefulness in this respect.

H. B. Richmond of the General Radio Company states that the cost of a temperature-controlled crystal for monitoring by the beat-frequency method is about $1000, but that control of a station by amplification of the crystal-controlled oscillator is worth about ten times that much. It is doubtful whether the present plan of ten-kilocycle separation can be maintained in full operation without any inter-channel heterodyning unless automatic control of station carriers becomes the rule. Reliance upon the beat-frequency method is the principal cause of the widespread disregard of the 500-cycle regulation.

Regulation of Allocations Attempted

THE New Jersey State Legislature is considering the advancement of radio legislation supplementary to Federal statutes in the effort to "relieve conditions existing since the new allocations," according to J. K. Woods of the New Jersey Broadcasters Association. Since radio communication is distinctly an inter-state function, certainly no state legislation is possible which would interfere with or direct Federal regulation. The State of New Jersey is afflicted with many very small broadcasting stations in the metropolitan area of New York, necessitating considerable time sharing. The leading New Jersey station, WOR, is not considered by the Association as a New Jersey station, because it obviously serves the entire metropolitan area. The Commission has shown clearly that New Jersey stations are receiving the consideration which is their due under the Davis Amendment and only by moving the State of New Jersey into the Fifth Zone can the present discontent be alleviated. The southern and western part of the State could use the smaller New Jersey stations to much greater effect than the over-served metropolitan area of New York.

In the World of Broadcasting

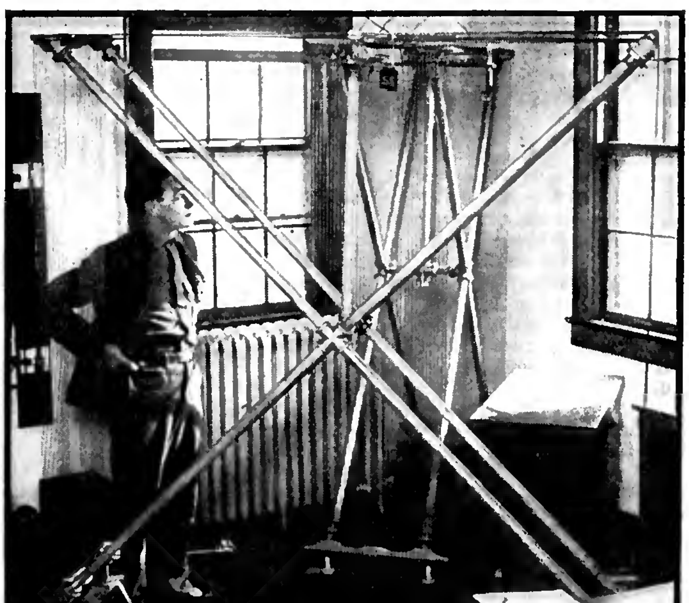
THE American Newspaper Publishers Association has made a survey of the radio situation. Its report states that radio lineage in twenty cities increased but 29.8 per cent. from January to October. This ought to satisfy any reasonable publisher that the editorial space devoted to radio is worth while, but many publishers nevertheless express the opinion that radio programs ought to be classified advertising, paid for by the radio stations themselves. The newspaper publishing business is immensely profitable and we feel inclined to offer the ingenious publishers some other suggestions which may serve to increase their revenues. News of the courts should be paid for as classified advertising by the community; police news should be paid for by municipalities at a classified rate; each stock exchange listing should be charged for at so much per line; death notices should certainly be charged to the estates of the deceased because they cannot protest; news of disasters could well be paid for by the War Department, and huge revenues could be collected from such gentlemen as the handsome Grover Whalen and the stylish Jimmy Walker. The publishers really have not scratched the surface; if they had any imagination, they could so increase the revenue of newspapers that people could be paid to read them.

THE tendency to regard broadcasting as a public utility is further strengthened in the brief of the Federal Radio Commission in the WOK case which states that "broadcasting stations, either partly or wholly, contain all four of the elements usually found in public utilities. By reason of the laws of nature, they serve the entire public within their area without discrimination; if they attempted discrimination by employing a form of transmission which could be received only with a patented device and could not be received with the ordinary receiving set, the Government would soon put an end to the practice. That they are under an obligation to give service during all hours at which the public usually expects to receive broadcasting has already been recognized by the Commission."

This is a clear statement of the obligation of a broadcasting station assigned to a channel to utilize that channel, but there are nevertheless some important differences between radio and recognized public utilities. There are technical limitations which strictly define the amount of traffic which can be handled in broadcasting or high frequencies. A public utility must prepare itself to meet all reasonable public demands for the service which its franchise covers. Public service commissions may order railways to purchase more cars or to extend service while, with radio communication, such extension cannot invariably be made and the time will come when it will become next to impossible. Certainly the obligation of public utility regulation, requiring service to all who apply and can afford the service under reasonable conditions, cannot possibly obtain in radio communication.

THE effectiveness of the chain broadcasting order, limiting the radiation of chain programs to points more than 300 miles apart, has again been postponed by the Commission. So long as the non-chain stations assigned clear channels are of comparatively low power, chain programs are bound to dominate the clear channel region.

A STATEMENT by the National Broadcasting Company, analyzing the programs offered through their key stations, WJZ and WEAF, indicates the still further reduction of the percentage of time devoted to jazz music. The analysis shows 15 per cent., or 36 hours a week, devoted to that type of music,



By means of two 6-foot loop antennas, the U. S Navy are taking cross bearings on static between Anacostia, D. C., and Lakehurst, N. J. In this way they are able to forecast the direction and intensity of storms

28 per cent. to classical, 10 per cent. to novelty and ballad, 4 per cent. band music, 2 per cent. radio drama, 14 per cent. to what is described as balanced features, involving orchestral music, artists, and featured speakers, that is, the typical commercial variety program, 8 per cent. religious, 6 per cent. educational, 6 per cent. women's programs, 4 per cent. health material, and a varying percentage, from 5 to 25 hours a week, to national events. The leading broadcasting systems in foreign countries employ a much larger percentage of their time in spoken and educational features. The tendency in the United States is to appeal to the entertainment demand of the radio public rather than to present the less broad appeal to the educational feature.

THE final breakdown of the opposition of vaudeville business to broadcasting was accomplished when the Radio-Keith-Orpheum hours were inaugurated as regular N. B. C. features. An obvious broadening of radio's appeal is accomplished as a result of recent mergers of the theatrical and concert fields by the consolidation of Radio-Keith-Orpheum and Victor. This is the practical consummation of a trend predicted in past editorials.

Circulating energy at radio frequency, when handled in large amounts, sometimes goes astray. The picture shows the result of an r. f. feedback flashing from the tank circuit of a 50,000-watt broadcast transmitter (WJZ).

A GREAT deal of publicity attended the experiments of KLCN of Blytheville, Ark., which transmitted special programs from one to four a. m. on 1290 kc., using only seven and a half watts power. At the particular hours involved, freak reception over great distances is possible. This, however, is so far short of reliable program service that it is of no great practical value. Short-wave amateur communication to all parts of the world on very small powers is in the same category. Reliable broadcast reception and reliable commercial radio communication must be successful not only under extraordinary conditions but must be of service value at all hours and seasons. It is to be hoped that the successful freak reception of a little Arkansas station in various parts of the country is not regarded as evidence that much lower powers in broadcasting are desirable.

STATION KFAB announces that it will broadcast a news service from 9 to 9:30 a. m. and from 6 to 6:30 p. m., the news to be gathered by its own reporters, stationed throughout the State of Nebraska and at neighboring points. Legislative news will be reported directly from the floor of the legislature. This is the first instance of a broadcasting station relying upon its own news-gathering force.

THE resumption of international broadcasting on a much more advanced technical standard was offered as a surprise to the radio audience through the N. B. C. networks on February 1, when a program picked up from 5SW, the B. B. C. short-wave transmitter at Chelmsford, England, at Riverhead, Long Island, was put on the air through that broadcasting system. The noise level was high, but otherwise the experiment was entirely successful and promises an increase of international program exchange.

Amateur and Commercial Radio

ARISTIDE BRIAND opened the first direct radio telephonic communication between Paris and Buenos Aires early in February. This span of 6870 miles represents the longest commercial radio telephone link, although this record will be exceeded when the New York–Buenos Aires link is put into final operation.

AN INTERESTING instance of the use of transatlantic picture transmission occurred when sketches of a damaged rudder were sent from England to the United States. The cargo liner *Silver Maple* damaged in a storm and awaiting repairs in Bermuda, was saved more than a week's time, estimated at a value of $7000, because the transmission of the sketches by radio enabled a shipbuilding company in Pennsylvania to begin work on the needed parts that much sooner.

ALTHOUGH the conference, held in Canada for the allocation of high frequencies to stations in the North American continent, did not reach a final conclusion, it was agreed that Canadian amateurs shall be permitted to exchange messages with amateurs of the United States and the Philippine Islands of a nature which would not normally be transmitted by any existing means of electrical communication and for which no tolls are charged, for communication with isolated points, having no regular means of message exchange, and for special transmissions of any essential character in emergencies and floods. This is strictly in accordance with the International Radio Telegraph Convention.

THE Mackay Radio and Telegraph Company is soon to place in operation its transoceanic radio service, utilizing the re-conditioned station at Sayville, operated before the war by the Telefunken interests. Several transmitters have been installed, including one with power up to 100 kilowatts. At the time the announcement was made, the Mackay people were still waiting for a license from the Federal Radio Commission.

THE rescue of the crew of the *Florida* by the *America* emphasizes again the value of the radio compass. Due to drift and the difficulty of determining bearings by navigating instruments under difficult conditions, those ships relying on the *Florida's* statement of position searched for it in vain. The *America*, radio-compass equipped, was successfully guided to the spot. Some consideration is being given to making compass equipment compulsory.

GEORGE R. PUTNAM, Commissioner of Lighthouses, suggests that ships bearing SOS calls triangulate their compass readings so that the exact position of the distressed vessel may be determined more accurately than is possible when bearings are taken from a single point.

A 100-watt radio transmitter, suited for installation on all types of aircraft, has been announced by the Radio Corporation of America. The standard equipment includes a wind-driven generator, although the transmitter may be powered from a dynamotor, energized from the usual 12-volt battery system aboard the craft. It has a 150- to 200-mile telephone range and a 500- to 800-mile range with continuous-wave transmission. The total weight is 89 pounds. Means are provided to use the amplifier for an inter-phone equipment. The Radiomarine Corporation has also developed a special beacon receiver, covering a range from 580 to 1100 meters.

The above illustration shows the quality of pictures which are now being sent over telephone wires by the American Telephone and Telegraph Company. It is actually difficult to detect a difference between the original and the reproduction

RADIO RETAILING'S annual survey of radio sales predicts a $650,000,000 business for industry during 1928.

—E. H. F.

AT THE January meeting of the Board of Directors of the Radio Manufacturers Association, Joseph L. Ray, General Sales Manager of the Radio Corporation of America, B. J. Grigsby, President of the Grigsby-Grunow Company, and Allan G. Messick, Chairman of the Board of the U. S. Radio and Television Corporation, were elected directors, succeeding three who had previously resigned. It was announced that the Trade Show at Chicago, starting on June 3, this year will embrace the Blackstone and Congress Hotels as well as the Stevens. This may prevent non-RMA members from securing exhibit space adjacent to the Stevens this season as has been customary in past years. An arrangement has been made for the sponsorship under RMA auspices of broadcasting features presented by certain members of the association. A tentative schedule for fourteen weeks of RMA programs has already been arranged for. Progress was reported on numerous other activities.

THE ROUTINE TESTING OF RECEIVERS

By JOHN S. DUNHAM

Q R V Radio Service, Inc.

THE value of an efficient, logical routine in testing radio receivers of all makes, models, and social standing can hardly be over-emphasized. The *Oxford Dictionary* defines the word routine as: "Regular course of procedure, unvarying performance of certain acts, performed by rule." No matter what sort of work one does, any part of which is purely mechanical repetition of the same acts day after day, even though intelligence is required to watch, tabulate, and draw conclusions from the results obtained, much time may be saved and energy conserved by developing an unvarying system of performance of those acts. Fundamentally, there is little difference between radio receivers, and it is entirely practical to devise a routine which may be used universally for the efficient testing of virtually all of them.

Use of Diagnoser

IF THE routine of testing used is to be equally applicable to all sets, then testing equipment must be used which may be applied to all sets with equal facility. The socket contacts of the average modern receiver cannot be reached when the tube is in the socket, and that remains true in some sets even after the chassis has been removed from the cabinet. As it is highly desirable to make some of the essential tests under load conditions, it becomes necessary to use a set-diagnoser ("analyzer" or "tester") to attain that end. If for no other reason, that application alone would be ample justification for the use of such a device.

Fortunately, the set-diagnoser has *many* other advantages which make its use by all servicemen imperative if they are to approach closely the maximum efficiency in doing service work. The set-diagnoser has three distinct and important advantages. It permits a number of essential tests which either are impossible or would consume a totally unjustified amount of time with lesser equipment. It makes all the tests that can be made with ordinary single meters, in much less time. And it has an exceedingly beneficial effect on the customer's impression of the efficiency and ability of the serviceman.

Cost of Equipment

THERE are a good many servicemen and service organizations who are of the opinion that the cost of the manufactured set-diagnoser is prohibitive. We believe a small amount of simple arithmetic can effectively dispel that myth. Five minutes is a conservative estimate of the time saved on the average service call by the use of a good set-diagnoser (we are assuming that the serviceman knows his business, makes all the tests he ought to make, and is thoroughly familiar with his equipment). It is also conservative to assume that the average serviceman can make an average of six service calls per day. Multiplication of six calls by five minutes per call gives a product of thirty minutes saving per day. The serviceman ought to bring in *at least* two dollars per hour for his organization, or for himself if he is working alone. At that rate, the saving of a half hour per day would represent a saving of one dollar per day. The cost to a service concern of a good set-diagnoser is not over $75.00. Paid for at the rate of one dollar per day, three 25-working day-months would accomplish that object. For the remainder of the life of the instrument, the daily saving would be clear profit. The foregoing computation considers only the saving in time, while the money value of the other advantages, added together, is certainly equal to that of the time saved. In the opinion of the author, two months is a fair estimate of the maximum length of time required for a set-diagnoser—properly used by an intelligent, well-trained serviceman—to pay for itself.

> *A question many dealers and servicemen frequently ask is, "What is the best order of procedure in servicing receivers?" Each service problem is at once the same as every other and different from others. Mr. Dunham, head of one of the largest New York City service organizations, here discusses some of the outstanding phases of this question, and, while he does not attempt hard and fast rules, his thoughts should interest and help those doing this work.*
>
> —THE EDITOR.

Even some of the radio set manufacturers have begun to realize the value of their use, and when manufacturers generally come to the conclusion that any particular thing would be advantageous in performing service on their sets in the field, then you may be certain that progressive service organizations came to the same conclusion about two years previously. The American Bosch Magneto Corporation says, in part, in their dealer service manual: "With the introduction and almost universal approval of the a.c.-type radio receiver by the public, the use of some standard and approved radio test set is absolutely essential."

Logical Routine Tests

THE ability of a radio serviceman to thoroughly and quickly discover the troubles in any receiver is largely a function of his ability to think logically and to approach the problem, serenely, as one which may *always* be solved by a process of orderly elimination and orderly reasoning out of cause from effect. Every action, whether mechanical, electrical, or chemical, which takes place in a receiver or its associated equipment, is governed by known laws, and any variation from normal action can be determined by known methods. There is nothing *mysterious* about any radio or any radio trouble, except to the man who is not familiar with them. Every trouble in every radio can be found without the aid of spiritualism, psycho-anal-ism, or guess-ism.

Present-day radio receivers are composed primarily of tubes, and secondarily of circuits employed to couple and supply those tubes. As the tubes are the heart of the machine, and the coupling and supply circuits both arteries, veins, and nerves, so are the tube sockets the nerve centers, at which most of the needed information about what is going on in the rest of the system may be obtained. Therefore, any logical system of testing must start at the sockets. More information may be obtained there, far more quickly, than at all other points. One end of each plate, grid, and filament circuit terminates at a socket, *and the other end of each of those circuits terminates at the same socket.* At the sockets one may get plate, grid, and filament voltages, and plate and filament currents.

Tube Tests

TUBES are at once the most important and fragile of the things that comprise a radio receiver. They are the most prolific source of trouble, and, as progress is made by manufacturers in the elimination of other troubles, the ratio of tube to other troubles increases. The serviceman's first object in testing a receiver should be to get as quickly as possible to the business of testing the tubes. They cannot be tested properly, however, unless the voltages applied to them are approximately correct. One must, therefore, test filament, plate, and grid voltages at each socket before the tube may be tested, a statement which requires a degree of modification depending upon the type of set.

Obviously, one does not get grid voltage reading at a detector employing a grid condenser and leak, for no grid voltage is applied when that method of detection is used. Even if it were, the drop caused by the very high resistance of the leak would be sufficiently great to overcome the small applied voltage. Neither is it feasible to test tubes from other sockets to which no grid voltage is applied.

In old battery-operated sets which remain guiltless of a C battery—of which, fortunately, there are few left—the only recourse in testing the tubes is to abandon the set entirely, connect the batteries, and one of the 4.5-volt C

There is nothing mysterious about any radio. Every trouble in radio can be found without the aid of spiritualism, psycho-anal-ism, or guess-ism

Any logical system of testing must start at the tube sockets

batteries which every serviceman should carry, to the prongs at the end of the diagnoser cable—by means of clip-ended test leads which should also be carried by servicemen—and make the usual I_p-E_g test with the tube in the diagnoser socket. In sets not quite so senile, which have grid bias on the last audio tube or both audio tubes, all of the tubes in the set may be tested from one of those sockets. In more modern apparatus, most of the tubes have grid voltage applied to them, so that those tubes may be tested properly in the diagnoser from their own sockets. Detector tubes employing a grid leak and condenser, oscillator tubes, and sometimes the first detector in a super-heterodyne, must be tested from some other socket. Whatever the type of set, however, *all* of the tubes should be tested, at the earliest possible moment in the routine which is possible without duplication of effort.

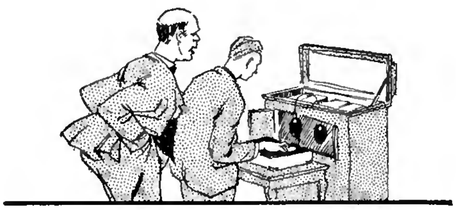
It is well to keep always in mind that approximately normal I_p *alone* does not invariably indicate a good tube. For example, there is such wide difference between the I_p ranges of different tubes of the same make and type, that a tube whose I_p range is higher than normal, but whose emission (and therefore mutual conductance) has fallen off just enough, can have a remaining I_p which, at normal voltage values, is approximately the normal *average* for that type of tube. It is also possible for a tube whose emission has fallen to a much lower point, but to the grid of which the normal bias is not applied, by reason of an internal open grid circuit, to continue to show normal average I_p.

Measuring Merit of Tubes

THE measure of merit of one tube against another of the same type is its mutual conductance. Mutual conductance is the *rate* of variation of I_p with variation of E_g over the straight portion of the I_p-E_g curve. A determination of that rate is the only method by which we may know accurately whether a particular tube is doing all it ought to do. All good set-diagnosers possess a means of changing the grid bias, applied to the tube placed in its socket, from the normal value to zero. The amount of I_p change caused by that change of E_g is a rough but sufficient indication of the condition of the tube. Obviously, that change will vary with different applied voltages, and with different types of tubes. It becomes necessary, therefore, for the serviceman to know definitely what the amount of that change should be for different tubes and different plate and grid voltages. While the author does not know of any printed source of such information (which doesn't prove there is none), it is not a difficult fund of knowledge to acquire in the field, and to anyone who is the fortunate possessor of a technically inquisitive mind, the gathering of that data is rather interesting.

It should be remembered that the grid-voltage reading obtained by even a 1000-ohm-per-volt instrument is less than the voltage applied to the tube when no meter load is in the grid circuit, by the amount of voltage drop across the secondary of the preceding transformer. This drop is equal to the current drawn by the meter, multiplied by the d.c. resistance of the transformer winding. The drop across the secondary of an r.f. transformer, with its small d.c. resistance, is so little that it can be neglected, but that is not always true of the secondary of an a.f. transformer. For example, let us assume that the grid-voltage reading obtained when testing a tube from the first a.f. socket is 10 volts on a 50-volt scale. Assuming a one milliampere meter movement, its current drain would be one-fifth of a milliampere, or 0.2 mA. Assuming the d.c. resistance of the secondary to be 10,000 ohms, that value times 0.2 mA equals 2 volts, the drop across the secondary, so that the actual grid voltage applied to the tube with the meter load removed would be 12 instead of 10 volts.

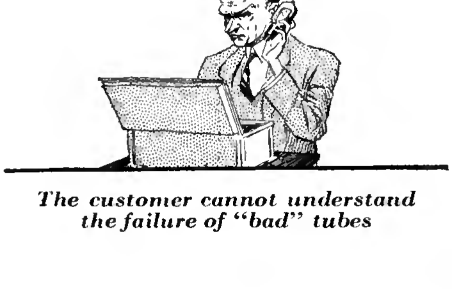
Let us take another example, of an output tube. Suppose it is desired to test a 171-type from its own socket. Assume the grid-voltage reading to be 40 volts on a 50-volt scale. The current drawn by the meter is, therefore, four-fifths of one milliampere, or 0.8 mA. Assume the d.c. resistance of the secondary to be the same as that in the previous case, 10,000 ohms. Then the product of the resistance by the current gives an 8-volt drop across the transformer, so that without the meter the voltage at the grid of the tube would be 48 instead of 40 volts. The drop in each of the two examples given is approximately 16 per cent. of the no-load applied voltage. The percentage drop will increase with increased d.c. resistance of the transformer, and with decreased resistance of the meter. In the case of the 171-type tube test, with a secondary whose resistance is 15,000 ohms, and a meter requiring 2 mA. for full-scale deflection, assuming a no-load grid potential of 48 volts, the drop with the meter load would be 18 volts, or more than 37 per cent. of the applied voltage.



Using a set tester has an exceedingly beneficial effect on the customer's impression of the ability and efficiency of the serviceman

The important point about this grid voltage discussion is that, if the serviceman does not know those factors and does not take them into account when testing the audio tubes of a set from their respective sockets, he may be led to very false conclusions about the tubes and the grid voltages actually applied to them. And the difference between a serviceman who has and applies enough technical knowledge to discover such things, and the serviceman who is devoid both of technical knowledge and desire to acquire it, is usually a large proportion of the difference between a really good serviceman and one who might possibly be a very good plumber.

From a practical business standpoint, tubes whose emission, or mutual conductance (I_p change with E_g change), has fallen appreciably below normal should always be replaced with good tubes. Putting a fairly good tube in some other socket, where it *may* perform practically as well as a new tube, very often results in a no-charge return call within a few days, to replace that tube. When the emission of a tube starts to fall off appreciably, it usually continues to do so at a fairly rapid rate. That is especially true of thoriated filaments. You may expound to the customer the fragility of tubes, the rapidity with which they can become inoperative, and the fact that the manufacturer does not guarantee them, until you are reduced to whispers, but, while he is usually willing to pay for new tubes, he is rarely willing to pay for a return call made within a short time, and no amount of eloquence will thoroughly convince him that such a return call is not due to the negligence or inexperience of the serviceman. And in that belief, *the customer is usually right.*



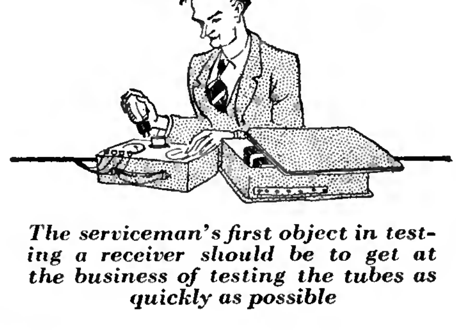
The customer cannot understand the failure of "bad" tubes

Microphonic Tubes

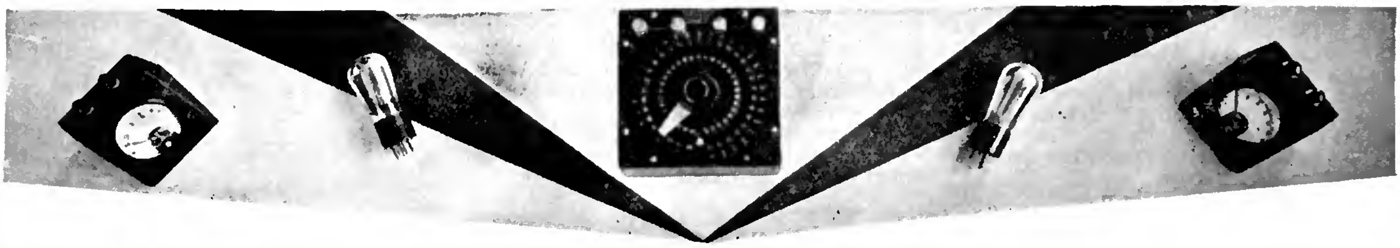
NEXT to tubes whose emission has fallen off, microphonic tubes give the most trouble. The detector tube is normally the worst offender, because the audio-frequency variation of plate current set up by mechanical vibration of the tube elements is amplified through all of the audio system. While that same tube may not appear to be microphonic to the degree that it produces a howl, when placed in the first a.f. socket, it is *not* wise to do so, because the condition usually grows worse and within a short time the amplitude of vibration can become sufficiently great to produce sound from the loud speaker when amplified by only the second transformer and last tube. If the microphonic condition in a set is to be remedied by shifting tubes, it should, therefore, never be done by simply exchanging the detector and first a.f. tubes, but always by selecting a quiet tube from one of the r.f. sockets,

Sometimes proximity of the loud speaker causes a degree of additional vibration. In these instances moving the loud speaker farther away also removes the microphonic condition which existed. In cases where a separate loud speaker is used, that remedy is always worth trying. In some cases, when neither moving the loud speaker nor shifting and replacing tubes will effect a cure, the placing of lead weights—manufactured for that purpose—on top of the detector and first a.f. tubes may be effective. If none of those remedies cures the patient, the only remaining one is to re-mount the socket on sponge rubber, or other shock-absorbing material, and make flexible leads. In normal cases, when it is simply a case of tubes themselves, no tube should be left in either of the two critical sockets if the ring caused by tapping the tube sharply with the forefinger is sustained for more than two seconds.

There are few things more exasperating to a serviceman than to put into a set one of the tubes he has with him, and find it to be open, shorted, or paralyzed. The remedy for having poor tubes turn up on the job is to have each man turn in for test, *at least* once a week, every tube he has been carrying, and to enforce rigidly the rule that no tube shall ever be returned to stock, even if it has been out only half an hour, without first having been tested properly. If we may be permitted to digress briefly, in closing Part I of this article, it has always seemed to us that the word *paralyzed* is the most fitting word in the English language to express, for practical purposes, the condition of a radio tube whose emission has become very low. Some years ago a radio engineer of our acquaintance took violent exception to our use of the word, and we were unable to convince him that Webster's definition describes the tube's condition perfectly, insofar as its ability to work goes, which is, after all, the thing in which we are chiefly interested.



The serviceman's first object in testing a receiver should be to get at the business of testing the tubes as quickly as possible



STRAYS *from* THE LABORATORY

Vacuum Tubes as Fuses

IT IS COMMON knowledge that when the A and B batteries on a radio receiver are mixed up, the tubes are ready for the wastebasket. It remains for the General Electric Company to make use of this sad phenomenon which frequently has expensive economic aspects. A tungsten filament which will pass 10 amperes at 15,000 volts is placed in a vacuum. When the current in the circuit rises to 45 amperes the filament burns out, and, therefore, the tube acts as a fuse. If a fuse operating in such high power circuits is opened in air, an arc forms and it is difficult to extinguish it. Even when the arc is broken, strong surges are created in the line which are difficult to control. In the vacuum tube fuse, however, there are enough electrons escaping from the ends of the broken filament to carry the current for a short period and prevent a heavy surge, and yet the circuit is positively opened.

Output Vs. Voltage Amplification

SOME READERS have difficulty in distinguishing between power output and voltage amplification. The power output of a receiver depends entirely upon the final tube in one's amplifier and the load it works into. With a given load it requires a certain a.c. voltage on its grid to produce this power output. (See "Home-Study Sheet No. 14"). Now if one has a strong signal from a local station the voltage amplification between antenna and grid of the power tube needs to be only of low value to produce this a.c. voltage on the grid of the power tube. If one lives twice as far away he must have four times the voltage amplification to produce the same voltage on the tube's grid, and if he lives several hundred miles he must provide much more voltage amplification. The power output has not changed at all—but the voltage amplification of the entire reciever may become many thousand times as great.

Suppose a receiver is so sensitive that with a field strength of one microvolt per meter across the antenna, it provides 50 milliwatts of undistorted output from the power tube. To deliver this much power the tube may require an a.c. potential of 7 volts, r.m.s. on its grid (A 171 working into twice its plate resistance). If the antenna is four meters high, the antenna-ground voltage is 4 micro-volts. The overall amplification of the receiver under these conditions is $7 \div 4.0 \times 10^{-6}$, or approximately 2×10^{6}, or two million.

If, however, the listener lives within a mile of a 50-kw. station, he may get a voltage across his antenna-ground coil of 2 volts. He needs only a voltage amplification of $7 \div 2$ or 3.5 to get the same power output.

Possibly power output and voltage amplification are related but they are not synonymous.

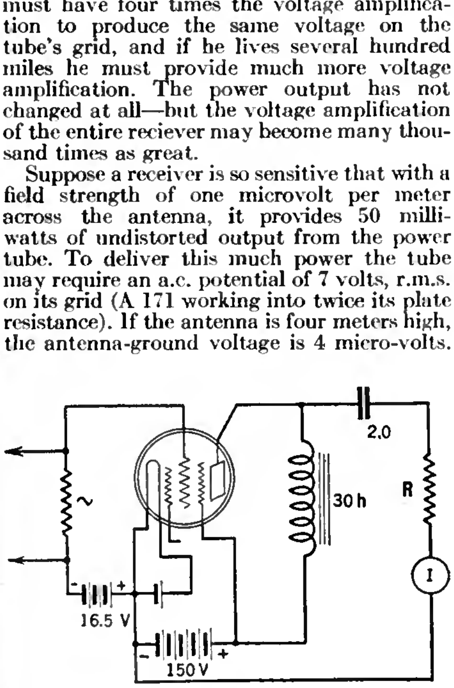


Fig. 1

The following are among the Subjects discussed in "*Strays*" this Month:

Cause of Winter Static

MR. H. C. JACKSON, of Brooks, Iowa, sends us an interesting account of "snow static." Static in the winter is not uncommon; it must be something of the same phenomenon which causes static in a shipboard receiver when the "old man" blows the whistle in a fog. However, Mr. Jackson's letter gives some data on the subject. "We are in the midst of an electrical snow storm which I think will interest you. It is of the hard dry variety driven by a strong wind, and is of the type which the Middle West designates as a blizzard. The storm began by a heavy snowfall without wind but accompanied by heavy static of the steady crashing variety. That was about 12 to 15 hours ago (Last evening). This morning no static was noticeable on a Hammarlund-Roberts "Hi-Q Six" receiver with the volume well advanced, but about 9:00 a.m. I noticed the regular putt-putting usually associated with a faulty grid connection. As the first step in locating the trouble I removed the antenna wire, and, while holding the bare tip of the wire in my fingers, I chanced to touch the chassis of the set. The result was a considerable shock. Upon holding the antenna wire a half to three quarters of an inch from the chassis (which is grounded) a distinct corona appears which may on occasions be drawn out to one and one quarter inches, accompanied by a faint hissing. Upon coming within three eighths to one quarter of an inch of the chassis, sparking occurs, which becomes a continuous flame at one sixteenth of an inch. As I have not connected the set to the antenna to attempt operation for more than an hour, I do not know whether there is static or not at the present time. The strength of the corona varies with the intensity of the wind and when the sparking at one quarter of an inch is permitted, it produces the putt-putt which first attracted my attention. My antenna is a stranded enameled copper wire 100 feet long plus a 45-foot rubber-covered 14-gauge lead-in wire dropping direct from a height of 40 feet. The ground wire is connected to a lightning rod. I am not using a lightning arrester during winter."

Experiments With the Pentode

WE HAVE already mentioned the Pentode, a new tube that has, as yet, not been manufactured in this country, but which has attracted considerable attention in England and on the Continent. George Uzmann gave us the opportunity to take a Phillips type B-443 valve into the Laboratory to see what would happen when we put a.c. voltages on the grid. The circuit is shown in Fig. 1 and the output power as the load resistance was varied with constant input voltage is shown in Fig. 2. The output power at various input voltages with a constant load of 25,000 ohms is given in Fig. 3.

These figures are very interesting. With a plate potential of only 150 volts, a plate current of only 10.0 milliamperes, and with an a.c. input potential (r.m.s.) of only 12 volts, we were able to get 725 milliwatts into a 25,000-ohm load. Compare this with a 171-type tube which, to produce 700 milliwatts of power into a 4000-ohm load, requires an input r.m.s. potential of about 27 volts, a plate battery of 180 volts and a plate current of about 20 milliamperes.

This tube requires 0.15 ampere at 4.0 volts for its filament. Whether or not this tube would stand up in practice we cannot say. There is one distinct disadvantage—the high plate resistance. When a 540-AW loud speaker was placed in the output of this tube, the quality was poor because of the comparatively low impedance of the loud speaker at low frequencies. With an output transformer of proper characteristics, the transmission of good quality from tube to loud speaker should be possible.

There is this difference between our power tubes and this Pentode—which has three grids, one attached permanently to the filament, one attached to the B plus, and the third corresponding to our signal grid—and it is the fact that its much higher plate resistance implies that much smaller plate current variations are necessary to supply a given amount of power. For example, the 171-type tube with a steady plate current of 20 milliamperes,

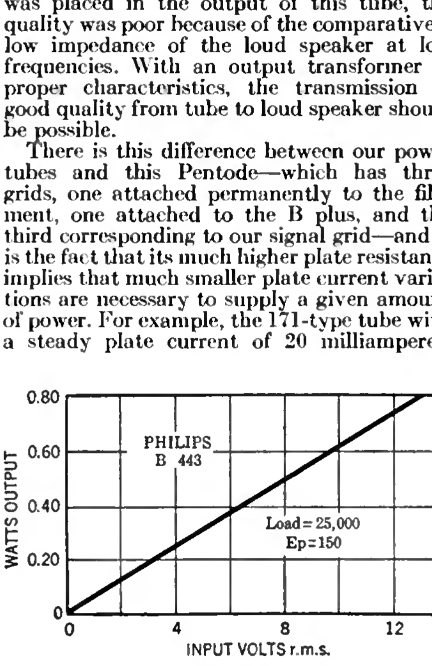


Fig. 2

must have a maximum a.c. plate current at times of this order, i.e., 20 mA. This a.c. current into the load of 4000 ohms gives us the power output. The Pentode with a steady plate current of 10 mA. will deliver the same power into its 25,000-ohm load with an a.c. current that is much smaller. In other words, the filament need not be so heavy nor consume so much power.

The Pentode is distinctly a battery tube. Its filament and plate power to deliver a very respectable power output is less than required with present-day 112-type tubes.

The characteristics of the tube as given by the manufacturer are presented in Table 1, and a characteristic curve in Fig. 4.

Table I

Filament voltage	4.0
Filament current	0.15
Plate voltage	50 to 150
Screen-grid voltage	50–150
Amplification factor	100
Internal plate resistance	87000 ohms
Mutual conductance	1500 micromhos
C bias	16 volts
Normal plate current	10 mA.

Will we have Pentodes in this country? We don't know. We shall take more characteristics in the Laboratory and present them in this department in the near future.

"Phantom" Power Tubes

THE FOLLOWING letter from Albert Allen Ketchum, of Coulterville, Illinois, describes a phenomenon that has been observed by many users of oxide-coated-filament power tubes. It is a kind of fluorescence which takes place when certain substances, usually organic salts, are exposed to visible or ultra-violet radiations or cathode rays. During this exposure these substances give off a light which is of different color than that color they reflect, and is related to the color they absorb most readily. The organic substances are in the oxide coating and do not indicate, as some believe, that the tube is defective or short lived.

"I have a "Phantom" power tube, in the form of a deForest 171A. At least, there occurs in it a phenomenon the like of which I have never seen before in my several years of experience with radio, and I thought perhaps you could explain it to me, or perhaps it may be new to you.

"I discovered this freak ghost to-night for the first time. As I turned on my set and tuned in a station I happened to be looking at the power tube and noticed a shadow moving on the plate. First I thought it was reflection from my clothing but upon more careful observation I noted that the shadow moved in cadence synchronous with the speaking and music, up and down along the outside face of the plate. Then I began to study it. When the music or speech stopped it stopped, when bass notes were played it made a deep jump and when banjoes or lighter instruments were playing it danced a merry little jig up and down in short quick movements. It was not a reflection from a brightening or dimming of the filament of the tube, for I studied it and it seemed as near as the eye can tell to remain constant. Besides the plate is opaque and it would be impossible for the filament rays to pierce it. This shadow had the appearance of a phosphorescent glow, and seemed to be more greatly agitated with the human voice than with music.

"Can you explain it? This is the first time I have ever had the privilege of seeing at least a part of radio at work!"

Novel Dynamic Baffle

WE HAVE often mentioned the unsightly baffle-board which seems necessary for dynamic loud speaker operation. At least three square feet of baffle is necessary if notes as low as 100 cycles are to be reproduced. One way to solve the difficulty is disclosed in the following letter from A. A. Abels, of Dumont, New Jersey.

"Being the proud possessor of an NH-10 Newcomb-Hawley dynamic loud speaker, I was particularly anxious to take advantage of

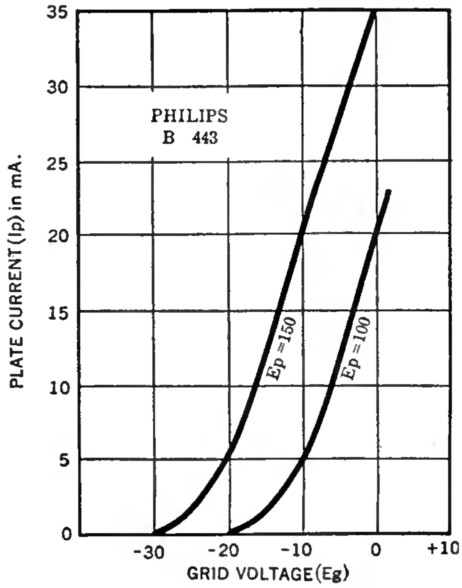


Fig. 4

the utmost of its excellent frequency characteristic.

"I occupy a rented house, and could not, therefore, secure the infinite baffle effect obtained by placing the loud speaker in the wall, as described in the excellent article in your January issue. The wife's ideas of interior decoration were an uncompromising barrier, when I suggested a 4-foot square baffleboard.

"I studied the interior architecture of the house for a week before I concurred a plan which proved both effective and in accord with the wife's decorative scheme.

"I placed the loud speaker on the top of the piano, which stands "kitty-corner" in the corner of the room. I consider that the piano forms the lower half of the baffleboard, so that by placing the loud speaker in a baffleboard about 4′ x 2′, the 4-foot dimension being horizontal, I have in effect a 4-foot baffle. I used a piece of Upson Board with a reënforcing framework. With rounded corners and painted to match the walls, or covered with tapestry, or with drapes, or relieved with Dutch wall paper, such as can be bought in the form of panels; the decorative possibilities are great.

"In combination with my Fada special 265-A set, my audio results are as fine as I have ever heard"

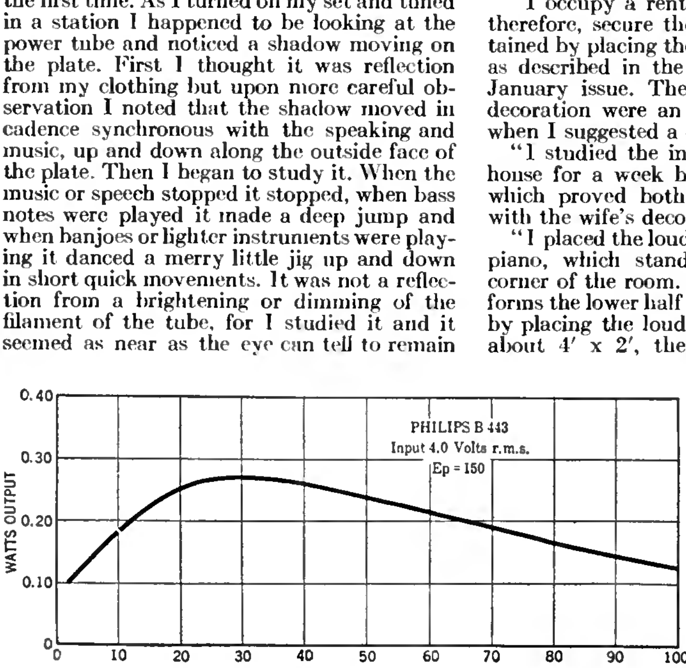


Fig. 3

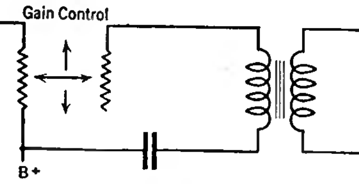


Fig. 5

Life of a.c. Radio Tubes

READERS STILL complain that their a.c. tubes seem to have shorter life than tubes which operate from batteries. This may be so, but have these readers actually checked up the number of hours they operate their receivers now that battery troubles no longer worry them? An estimate made recently by a prominent tube manufacturer indicates an average of nearly nine hours a day for receivers which operate from a lamp socket. A combination of good programs more hours of the day and freedom from worry about charging the battery is responsible for this estimated increase in receiver service. All the old estimates on tube life were made on the basis of three hours operation a day—and so an apparent short life in tubes is only *apparent* after all.

The following release from the Arcturus Radio Tube Company is pertinent in this connection: "On the twenty-first of April, 1928, twenty-five tubes were placed on life test in a special test rack installed in the office of the sales manager. With the exception of such occasions when the tubes have been removed from the test rack for laboratory measurements, they have been burning constantly for over ten months. This is equivalent to almost seven years of average home reception service. No tubes have burned out to date. The tubes under test are Arcturus 2.5-volt a.c. detector tubes (type 127)."

Approved Amateur Intermediates

BEGINNING January 1, 1929, amateur stations started a somewhat different system when calling each other. The old "intermediates" were abolished, and the following list approved by the respective governments was the substitute on January 10. It was sent to us by A. L. Budlong, of the A. R. R. L.

United States (territorial)	W
United States (possessions)	K
England	G
Germany	D
Mexico	X
Salvador	YS
Portugal	CT
Denmark	OZ
Canada	VE
New Zealand	ZL
Australia	MH-VK (?)
Cuba	CM
France	F
South Africa	ZS
Great Britain	G
Ecuador	HC
Panama	RX
Austria	UO

By the international convention the old system of calling and signing is changed to conform with the universal practice of using the intermediate "de".

A Correction

AN UNFORTUNATE error occured in the diagram of the constant impedance resistor in the article on "An inexpensive audio oscillator," page 187 January RADIO BROADCAST. The correct diagram of the apparatus is shown in Fig. 5.

Manufacturer's facetiousness: The Clarostat Manufacturing Company has announced a variable center-tapped resistor to be used across tube filaments. The name of this new device is the "Hum-Dinger."

—KEITH HENNEY

THE REAL SIZE OF THE RADIO MARKET

COLD figures on the sales of the two chief products in the radio industry—receivers and vacuum tubes—are of great importance because they furnish a guide to the history of the months past and they give an excellent measuring stick for the future.

We present below figures on the receiver and tube sales for 1927 and 1928 which should prove of wide interest. They are of especial interest because they include accurate figures of the tube and set sales of the Radio Corporation and its licensees for these two years, years in which the radio industry was passing through what may be regarded in the future as its most critical period.

Previous estimates, while most useful as a general guide to the progress of the industry, have been incomplete because of the unwillingness of key manufacturers to give out their sales figures. These companies, notably the Radio Corporation and its various licensees, are probably responsible for far and away the largest sale of receivers, as in this group alone are more than 30 of the biggest company "names" in radio.

The figures which follow were gathered by the Editor in an independent survey in order to provide the most accurate possible basis for examining the radio industry tube and set sales. They were presented during a recent action in the Federal Court at Wilmington, Delaware, in which certain tube manufacturers sought to secure a permanent injunction restraining the Radio Corporation from enforcing Clause 9 of their license contract with set manufacturers requiring the purchase of RCA or Cunningham tubes for each socket of each set sold.

GENERAL SUMMARY

Radio Sets

Sets in use, Jan. 1, 1929	*11,000,000*
Sets in use, Jan. 1, 1928	*8,080,359*
Sets in use, Jan. 1, 1927	*6,352,419*
Sets acquired, 1928	*2,919,641*
Sets acquired, 1927	*1,727,940*

Radio Tubes

Tubes sold, 1928	*61,552,846*
Tubes sold, 1927	*33,662,247*
Tubes sold, 1928 for new sets	*20,472,487*
Tubes sold, 1927 for new sets	*10,332,640*
**1928 Tubes sold for replacements*	*41,080,359*
**1927 Tubes sold for replacements*	*23,339,607*

**new and old sets*

TABLE I

1928. Set Sales Requiring New Tubes.

Sets sold by RCA	569,641
Sets sold by RCA licensees	2,025,000
Total sets sold by both	2,594,641
All other set sales	340,000
Total sets sold	2,934,641

Note: "Other set sales" estimated and included non-licensed sets and kits, home-assembled sets and transmitting and receiving amateurs. RCA licensee sales were 843,614 sets for first three months. Of estimated total sets sold, RCA sold 19.3 per cent., RCA licensees, 69.05 per cent., and both a total of 88.35 per cent. of all sets.

TABLE II

1928. Original Installation and Replacement Tube Requirements.

Initial Installation		
RCA and licensees (2,594,641 sets, av. 7 tubes ea.)		18,162,487
All others: complete sets, kits, etc., (340,000 sets at average varying: 7, 6, and 3 tubes ea.)		2,310,000
Total tubes required		20,472,487
Replacements (required in sets sold during this year)		
RCA and licensees	2,594,651 sets	
All others	325,000 sets	
Total	2,919,641 sets	
*Replacement tubes required		8,758,923
Old Sets		
**Sets in use as of Jan. 1, 1928	11,000,000	
Sets acquired during 1928	2,919,641	
**Sets as of Jan. 1, 1928	8,080,359	
† Replacement tubes required		32,321,436
Total Tubes Sold For All Purposes		61,552,846

* At 3 tubes per set
**Estimate of Daniel Starch
† At 4 tubes per set

TABLE III

1928. Tube Sales.

Tubes sold by RCA to set licensees	7,122,123
*RCA tubes for RCA sets	3,987,487
	11,109,610
Other RCA sales	19,552,510
**Total RCA tube sales	30,662,120
Sales by other tube manufacturers (est.)	30,890,726
Total tube sales	61,552,846

*569,641 sets, 7 tubes per set
**Including Cunningham

Note: RCA tubes sold to licensees were 11.6 per cent. of year's sales; RCA sets required 6.5 per cent. of the above grand total; other RCA sales, 31.8 per cent. and all other manufacturers sold 50.1 per cent. of total tubes during the year. In above, "sales by other tube manufacturers" is necessarily estimated with Table VI as basis. For derivation of total tube sales, see Table II.
RCA (and Cunningham) sales first 6 months, 7,802,324; second 6 months 22,859,796.

TABLE IV

1927. Set Sales Requiring New Tubes.

Sets sold by RCA	324,878
Sets sold by RCA licensees	966,542
Total sets sold, RCA and licensees	1,291,440
All other set sales	436,500
Total sets sold	1,727,940

Note: "Other set sales," estimated and includes non-licensed sets and kits, home-assembled sets and transmitting and receiving amateurs.
RCA and licensees sold 74.8 per cent. of sets (18.8 per cent. RCA, 56.0 per cent. RCA licensees); 25.2 per cent. of total was sold by all others.
First RCA set license granted Mar. 10, 1927, and some 24 others at different times following, so that total of 966,542 sets does not represent entire sales by makers during 1927 who at end of year were licensed; their sales included in estimate "other set sales."

TABLE V

1927. Original Installation and Replacement Tube Requirements.

Initial Installation		
RCA and licensees (1,291,440 sets av. 6 tubes ea.)		7,748,640
All others: complete sets, kits, etc. (436,500 at average varying: 6 and 3 tubes ea.)		2,574,000
Total tubes required for initial installations		10,322,640
Replacements (required in sets sold during this year)		
RCA and licensees	1,291,440 sets	
All others (est.)	421,500 sets	
Total (at 2.5 tubes each, replaced)	1,712,940 sets	4,282,350
Replacements (required in old sets)		
Sets as of Jan. 1, 1928	8,080,359	
Sets acquired during 1927	1,727,940	
Sets as of Jan. 1, 1927 (at 3 tubes per set to be replaced)	6,352,419	19,057,257
Total tubes sold		33,662,247

TABLE VI

1927. Tube Sales.

Tubes sold by RCA to set licensees	5,719,710
*RCA tubes for RCA sets	1,949,268
	7,668,978
**Other RCA tube sales	14,583,097
Total RCA sales	22,252,075
Sales by other manufacturers	11,410,172
Total tube sales	33,662,247

*324,878 sets, 6 tubes each
**includes Cunningham

Note: RCA tubes sold to licensees were 16.9 per cent. of year's sales; RCA sets required 5.8 per cent. of the above grand total; other RCA sales were 43.3 per cent. of the total and all other manufacturers sold 34.0 per cent. of the total. For derivation of total tube sales, see Table V. In above, "sales by other manufacturers" is necessarily estimated with Table V as basis.
RCA (and Cunningham) sales first 6 months 7,116,747; second 6 months 15,-135,328.

In the tables above, the RCA set sales and set sales by RCA licensees are grouped and all others are estimated and given separately in order to make it perfectly clear what figures were known and what were estimated. When the entire radio industry releases its sales figures each year, under proper control, it will no longer be necessary to make estimates. All in the industry agree on the necessity of reliable figures, and the manufacturers are not least among these, but as yet it is impossible to secure all figures necessary for the most accurate report of a year's business.

The estimates given in the tables were arrived at by what is thought to be the best means possible: the accurate figures of set sales by RCA and RCA licensees and the tube sales for licensees' sets and for RCA sets were used as the basis. In addition, the total tube sales by RCA (and Cunningham) was known. It was necessary then, to estimate the sets sold by all others which are responsible for installation of new tubes. This estimate (in skeleton form only) appears in Tables II and IV. The derivation of the other figures is apparent from a study of the Tables.

Meaning of the Estimate

IT TAKES no gift of prophesy to read in these figures, concentrated under the heading "General Summary," the record of astounding development in the radio market and, behind that, the remarkable, and growing public acceptance of radio broadcasting. The number of sets in use by the first of January 1929 had increased by 37.5 per cent. over the number in use at the same time the previous year. And the number of sets in use on the first of

(Continued on page 384)

Discussing 60-Cycle Filters

THE EXPERIMENTER'S ARMCHAIR

By ROBERT S. KRUSE

THE radio operator has his static room, the adventurer his camp fire, and the chauffeur the gas station. We Experimenters have been without a place in which to tell of our adventures and this one is now opened to us.

Gentlemen, if you are all settled comfortably, we can begin our first meeting. We will not be formal about it, for these meetings are open to any experimenter, whether he be scientist, engineer, laboratorian, operator, serviceman, or plain tinkerer.

In order that no one will be embarrassed by having to make the first talk, I will read an anonymous paper. It is on the subject of filters, concerning which there is so much bilious mathematics and so few easily applied facts. While the writer of the paper speaks from the transmission viewpoint his ideas apply to any filter used on the output of a rectifier fed from a 60-cycle supply. Notice that he does not agree with our general use of the "brute-force" type of filter.

FILTERING WITH SMALL CHOKES

Listening to some of the 60-cycle growls we still hear on the air makes it evident that in some transmitting filters the growl was weighed against the price of 30-henry chokes capable of carrying 200 mA:—and the chokes lost. Another, and very potent, argument, against the use of big chokes, is the fact that their d.c. resistance is high; nobody wants to waste 200 to 300 volts in a filter when those volts might better be keeping the oscillator plates warm. Neither does anyone care for a plate voltage that swoops wildly up and down as the load changes.

How can we make a filter which will do the work well enough to give us a "fairly d-c." note, and at the same time, cost little and waste very few of our precious volts? This problem was taken up from a laboratory standpoint; a rectifier unit was built, as in Fig. 1, and the output of alternating voltages at the various harmonic frequencies was measured by means of a special vacuum-tube voltmeter capable of indicating the value of any one frequency in the presence of others, this being accomplished by means of resonant circuits tuned to the frequency being measured. Calibration was accomplished by means of a single-frequency current of known value flowing through a known resistance, the voltmeter being calibrated at each frequency to be measured. An accuracy of plus or minus one per cent. is obtainable by this arrangement.

The power unit used in the tests comprised an ordinary step-up transformer with a split secondary and two 281-type tubes as rectifiers (see Fig. 1). With this unit working into a 7500-ohm resistance load, no filter being used, output voltages were measured; the result of the analysis is shown in column A of Table 1. The presence of the 60-cycle and other odd harmonic voltages is due either to one transformer secondary having a slightly higher voltage than the other, or to a higher plate-filament resistance in one of the rectifiers.

The magnitude of the 120-cycle voltage explains the growl to be heard in an unfiltered supply; it also shows that our greatest problem in designing a filter will be to get rid of this voltage.

For the next test the simplest type of filter (a condenser across the output of the rectifier as in Fig. 1B) was used. This produced a drop in the harmonic output voltages for the following reason. The greater part of these harmonics is due to the leakage reactance of the transformer. The addition of the condenser, C_3, reduces (in effect) this leakage reactance and thereby reduces the harmonic output. At the same time the d.c. output potential increased from 530 to 750 volts, due to the increase in voltage on the tube which is limited by the leakage reactance voltage, and—as said above—the addition of a condenser reduces the effective leakage reactance. (The same effect as to d.c. voltage rise may be obtained by connecting 0.1-mfd. directly across the transformer secondary but this has almost no filtering action and is not recommended.) The value of the condenser C_3 was varied from 1 to 10 mfd. More than 3 mfd. gave very little increase in filter action. (The subscript 3, as in C_3, indicates a condenser of 3.0-mfd. capacity. Thus, in diagram C of Fig. 1, C_{10} has 10.0 mfd. capacity.) The results for this test (as shown in the table) make it quite evident that we cannot afford to omit condenser C_3 from our circuit, even if that is all the filter we have.

> *As the title of this contribution of Mr. Kruse's indicates, the main content deals with the experimental side of radio. Mr. Kruse has been given the widest latitude in the selection and treatment of the material that appears under this heading. In our judgment, all those who are interested in experimenting with a practical aim will find these pages each month of benefit to them. Contributions are invited and will be paid for if acceptable.*
>
> —THE EDITOR.

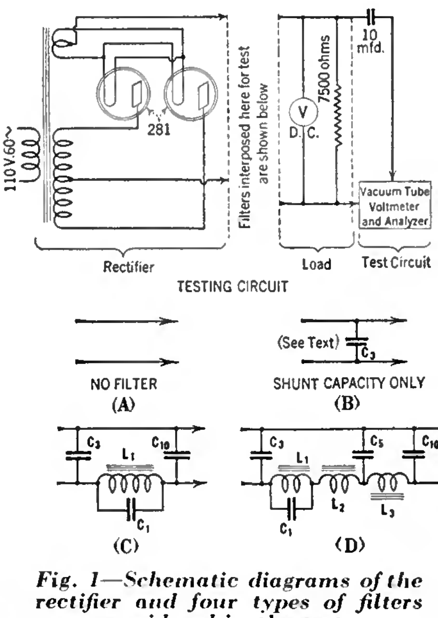


Fig. 1—Schematic diagrams of the rectifier and four types of filters considered in the tests.

RESULTS WITH 120-CYCLE TRAP

For the next test a trap, tuned to 120 cycles, was placed in the negative lead and beyond that another condenser, C_{10}, was connected across the circuit, giving the arrangement shown in diagram C of Fig. 1. The trap was made up of a choke having 12 ohms resistance and an inductance in the neighborhood of 1.2 henries. It was tuned to offer maximum impedance to the flow of 120-cycle current by connecting various condensers across it until the 120-cycle voltage at the load was a minimum. Approximately 1.1 mfd. was required to do this. *Low-voltage* condensers were used and since the trap was in the negative side of the line it could be "worked hot" as the greatest potential encountered is 50 volts or so at 120 cycles. The d.c. drop through the choke is insignificant, and with this connection the output is pretty fair d.c. The total r.m.s. alternating voltage at the load is less than 2, which is less than $\frac{1}{3}$ of 1 per cent. of the direct voltage.

This should be sufficiently smooth for any c.w. transmitter, likewise for a number of other purposes—and we did it with a single choke having a resistance of only 12 ohms! The final condenser, C_{10}, may be reduced to as low as 2 mfd. and maintain a fairly smooth output. Here, then, is a good c.w. transmission filter; one small choke, 4 or 5 mfd. of high-voltage condenser (C_3 and C_{10}) and about 1 mfd. of low-voltage condenser.

A still smoother output for phone work, or other purposes, may be obtained by using the circuit shown in diagram D of Fig. 1. The coils L_1, L_2, and L_3 each have an inductance of approximately one henry and a resistance of 10 to 15 ohms. The condenser, C_5, in the center branch has a capacity of 5 mfds. The analysis of the output of this filter is given in the table under D. It can be seen that the total r.m.s. alternating voltage at the load is now only 1.2. volts (less than $\frac{1}{4}$ of 1 per cent. of the d.c.) and that is mostly at 60 cycles where it will not be particularly troublesome to a phone transmitter. The total series resistance of the filter is less than 50 ohms, so that for ordinary load currents the voltage drop will not be more than 10-15 volts, or 2 per cent. of the d.c. voltage. This should help the "yoop" problem of the c.w. amateur who wants a smooth tone. Part of this difficulty is occasioned by large voltage changes when the key is opened and closed. Of course, no filter can prevent the rectifier from charging the condensers to a value near the peak voltage of the transformer when the load is off but that is avoided easily enough by a resistance permanently connected across the filter output. There is no exact value for this resistance and it must be determined by trial, using the highest value that will still prevent the rise of voltage when the load is off. Where a high-voltage d.c. meter is connected across the circuit no other drain is needed. Incidentally, such a shunt is useful in another way. It prevents one from taking hold of a filter condenser and discovering that the brute is still loaded.

At any rate the 10–15-volts drop is quite an improvement over the common 150–300-volt drop. In one case which was tested a set had

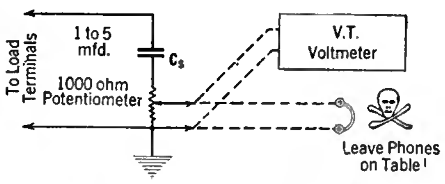


Fig. 2—Test circuit for trap tuning

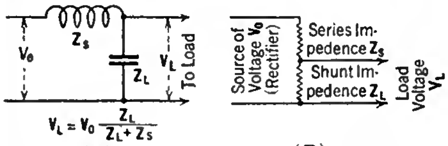


Fig. 3—Method of calculating voltage reduction. (A) Actual circuit, (B) Equivalent circuit.

an annoying "yoop" when keyed with a "brute-force" filter. The drop through the choke was 175 volts. Filter circuits such as shown here cured this almost completely without any change in the r.f. circuits.

TUNING THE TRAP

The question will naturally be asked, "How am I going to be able to tune the trap without some sort of analyzer?" Fortunately this is simple. If you have, can make, or will borrow, a vacuum-tube voltmeter, connect it to the output of the *loaded* filter as shown in Fig. 2 and juggle the trap condenser until the vacuum-tube voltmeter shows a minimum. The 1000-ohm potentiometer is used as a sensitivity control and enables you to keep the meter deflection within reason. The isolating condenser C_s must be capable of withstanding the full voltage of the output. Always do the testing with the rectifier and filter operating at their normal load as the inductance of the chokes vary with the d.c. flowing through them.

If a vacuum-tube voltmeter is not available, a pair of phones may be used and the filter adjusted for minimum sound. *Leave the phones on the table*; the condenser C_s *might* puncture and electrocution is reported to be unpleasant.

The rectifier shown is of the "centertap" variety. If the "Bridge" connection is used for any reason a larger 60-cycle voltage may appear and may call for a 60-cycle trap in addition to the 120-cycle trap. Such a trap will require about 4 times the capacity (in the trap circuit) as is necessary for 120 cycles.

No tests were made on a half-wave rectifier but in this case also a 60-cycle trap is necessary, although the 120-cycle trap may probably be omitted. Incidentally, in the full-wave rectifier discussed some 60-cycle voltage appears because of an unbalance. If for any reason it is objectionable a 60-cycle trap is the cure.

Some measurements of the harmonic currents flowing in various parts of the circuit were made by inserting a resistor in the circuit and measuring the alternating voltage drop across it.

The 120-cycle current flowing in the branch C_3 of diagram C, Fig. 1, was 120 milliamperes. This is practically the total 120-cycle output current of the rectifier, since the 120-cycle current flowing through the trap to the load was only about 4.7 milliamperes. From this latter current and the voltage across the trap it is easy to calculate the impedance of the trap to 120 cycles:

$$Z = \frac{E}{I} = \frac{0.53}{0.0047} = 11{,}300 \text{ ohms.}$$

The impedance of C_{10} to 120 cycles is 132 ohms, hence we should expect a 120-cycle voltage at the load of $\frac{53 \times 132}{11{,}300 + 132} = 0.64$ volts. The voltage measured was 0.60, a fairly close check. The method of calculating the last voltage is explained in Fig. 3.

The combination of series and shunt impedances may be considered as a potentiometer, which permits a fraction of the impressed (or rectifier) voltage to appear across the load. The ratio of these two will be the ratio of the total impedance, $Z_s + Z_l$, to the shunt impedance, Z_L, which latter is made up of the load and the last condenser, in parallel. By varying these impedances we can make the a.c. voltage reduction in our filter anything we please. For instance, suppose that the final condenser, C_{10}, is reduced to 1 mfd. Its impedance will then be 1320 ohms, and the 120-cycle voltage appearing at the load will be (neglecting load impedance)

$$\frac{53 \times 1320}{11{,}300 + 1320} = 5.5 \text{ volts}$$

This simple way of looking at filter action permits you to calculate quickly what reduction of voltage you may expect from a given set of impedances. The impedance of a choke coil is given approximately by

$$Z = 6.3 \times (\text{inductance in henries}) \, (\text{frequency})$$

The impedance of a condenser is given by

$$Z = \frac{160{,}000}{(\text{capacity in mfd.}) \, (\text{frequency})}$$

The impedance of the trap was discussed before.

Of course, the method of calculating drops does not work out if any choke is in resonance with one of the harmonic frequencies by reason of its distributed capacity or if one of the chokes and one of shunt condensers makes a series resonant circuit.

COMMENT AND SUGGESTIONS

The difference between this filter and the "brute-force" type is that it does a very neat piece of work for the particular conditions to which it is adapted, while in the "brute-force" case we squirm out of the necessity of adjustment at the expense of tolerating rather bad voltage drop and rather large expenditure for apparatus.

Probably everyone has found it out before now that choke inductances and paper condenser capacities usually vary considerably from the marked values so that a little cutting and trying is useful. This means changing the condensers around and adjusting the air gap of the choke.

A 1.2-HENRY CHOKE

In Fig. 4 are shown a pair of suggested chokes which can be varied from about ½ to about 1.2 henries by changing the air gap. In both forms (A and B) the core legs are 1 inch square and butt joints are used throughout. The air gap is adjusted by laying different thicknesses of cardboard in it after which the core is again clamped or taped to reduce humming. About 1½ pounds of No. 24 enameled wire will fill the winding space of A while No. 23 enamel may be used for B. The chokes will handle about ½ ampere without saturation and may, of course, be wound for any other inductance, keeping in mind that this changes approximately with the square of the number of turns and that the ampere turns must not exceed 800.

Table I

ANALYSIS OF FILTERING ACTION OF CIRCUITS SHOWN IN FIG. 1

Frequency	Voltages at Load A	B	C	D
d.c.	530.0	750.0	750.0	750.0
NOT WANTED: 60	25.0	7.4	1.6	1.1
120	245.0	53.0	0.60	0.3
180	1.2	1.06	0.01	0.01
240	17.6	14.2	0.90	0.075
300	0.16	—	—	—
360	12.5	1.9	0.13	0.01
480	7.5	1.0	0.075	—
600	6.7	0.67	0.05	—
720	3.5	0.156	0.02	—
840	1.25	0.19	0.15	—
900	0.51	0.085	—	—

A blank means that the voltage was less than $\frac{1}{100}$ volt.

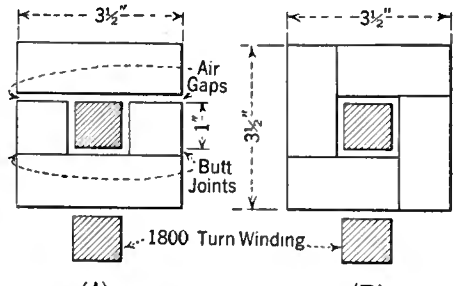


Fig. 4—Details of an efficient filter choke. (A) Usual form, (B) Simplified form with all legs alike.

Unlucky New England

It has been said that if a set will work through the static at New Orleans it will work anywhere except in the Caribbean. To this let us add that if a receiver will give a good account of itself in southern New England it will be an amazing success elsewhere. Here at Hartford we sit in the world's largest nest of high-power radio stations and with rather decent receivers hear materially less than does the Kansan with the most ordinary of home-made apparatus. WEAF is not amazingly strong here, though only 90 miles away over seemingly favorable country, and this is the cause of disparaging comments from our Kansas relatives, who, at 1000 miles, are accustomed to hear the station comfortably in daylight. WGY's high-power commission-defying transmitter fades horribly and is of little use to us, while WJZ fluctuates in a ratio of as little as $\frac{1}{50}$ or as much as $\frac{5000}{500}$ if one speaks of audibilities. As to other stations, and other types of signals, matters are not materially better. Television and rayfoto signals have a rather terrible time of it. Altogether one is not surprised that the American Radio Relay League was organized here to relay messages over the 27 miles to Springfield while at the same time amateurs in Illinois, Ohio, Kansas and Missouri conversed freely and easily over distances well up toward 700 miles.

From Here Forward

Our time for this month is up.

The Editors are leaving the nature of the future material to our judgment. This is not as reckless as it seems—for the copy passes under the blue pencil before reaching these pages!

Since this encouraging "department" was suggested a pleasant number of letters have arrived, bringing material and comment of the most varied sort. We can, so to speak, take from stock a conversation on vacuum-tube voltmeters, variable a.c. supplies, an extremely queer short-wave effect, some ingenious tuning devices, or several other things.

These letters assure our immediate future but they are not a "preferred list." Whatever you have done, are doing, or may be planning is of interest. Do not be too serious about it, this being neither a literary society nor the Franklin Institute. The main thing is to learn of each other's doings, whether they concern a simple mechanical makeshift, an odd effect or large plans for investigation of one of the two score unsettled problems.

Letters—or informal papers—will be welcome. They should be addressed to Robert S. Kruse, care RADIO BROADCAST, Garden City, New York, and should refer to these pages by title.

Part II of a Series

GRID-LEAK POWER DETECTION

By FREDERICK EMMONS TERMAN

Stanford University

IN DETECTING, or what is the same thing, in rectifying large signals, it is generally considered that C-bias detection is necessary if good quality of output is to be maintained. The common grid leak-condenser rectifier, so sensitive with weak signals, is found to overload with only moderate input voltages and to be entirely impossible.

The unsatisfactory results generally obtained with grid leak-condenser power detection are not an inherent shortcoming of this mode of rectification; they are merely a consequence of using grid detection improperly. Under suitable conditions the grid leak-condenser method of detection will give *less distortion when the applied signal voltage is large than when it is small.* This perhaps surprising result is obtained by analyzing the causes of distortion in the grid rectifier and then adjusting the circuits and battery voltages to eliminate the trouble. The result is a power detector giving good quality, and having a high degree of sensitivity on both strong and weak signals.

There are two kinds of distortion introduced by detectors. The first type is frequency discrimination, that is, the reproduction of some audio frequencies better than others. The second type is non-linear or amplitude distortion which is caused by the detector output not being proportional to the size of the signal voltage. Non-linear distortion causes the production of audio frequencies in the detector output which were not present in the original sound. Both kinds of distortion are, of course, undesirable.

> *Power detection! Not so many months ago we called the attention of* Radio Broadcast's *readers to the tendency toward the use of a single stage of audio amplification, and thereby got ourselves into controversy with manufacturers of audio equipment. In this article, Professor Terman tells how it is possible for a detector to deliver enough output rectified voltage to "load up" a power amplifier tube. Such a detector is used in the Radiola 60 series, the Sparton receiver, the new Crosley Jewelbox, the R. F. L. airplane receiver, and there may be others whose names we don't recall at the moment. Power detection is coming into its own, evidently.*
>
> *The author is Assistant Professor in charge of Communication at Stanford University. He has another article or two on detection in preparation for us.*
>
> —The Editor.

Distortion With Weak Signals

THE fundamental basis of grid-leak detection of small signals was considered in the first of this series of articles on detection, and the problem of selecting grid-leak and grid-condenser values to avoid frequency discrimination was taken up at length. In general, it was found that in order to reproduce all audio frequencies equally well the grid-leak resistance should not be too high and that the grid condenser should be as small as possible. At the same time if either the grid condenser or leak resistance is less than certain rather critical values there will be an excessive loss of sensitivity.

Proper attention to these circuit details will eliminate almost completely frequency discrimination when the grid leak is handling small voltages. At the same time, and no matter how well adjusted, the grid leak-condenser detector, like all other known detectors, introduces amplitude distortion with weak signals. This is true because the output of all rectifiers is proportional to the *square* of the signal voltage when this voltage is small (i. e., less than approximately 0.25 volt for grid-leak detection and only a few volts with plate detection).

Over this range of signals for which the detector follows a square law the amplitude distortion is such as to introduce distortion audio frequencies which are twice the frequency of the sound to be reproduced, and also distortion audio frequencies which have frequencies that are all the possible combinations of sums and differences of the frequencies actually present in the original sound. Thus if the modulated signal voltage is simultaneously carrying audio frequencies of 1000 and 1500 cycles, the detector in addition to reproducing the desired 1000- and 1500-cycle currents will produce weaker double-frequency distortion currents of 2000 and 3000 cycles and will also produce a sum distortion-frequency current of 2500 cycles and a difference distortion-frequency current of 500 cycles.

Fortunately, these various distortion frequencies are usually weak in the detector output compared with the output currents of the undistorted frequency. The amount of distortion is proportional to the degree of modulation of the radio-frequency signal voltage, and for this reason it is not always desirable for the transmitting station to modulate its carrier more than 20–25 per cent. With such a degree of modulation the distortion currents will be about 5 per cent. as strong as the main signal currents. When the degree of modulation is 100 per cent. the distortion may run as high as 25 per cent. but will never exceed this value.

The cause of these distortion frequencies in the detector output can be understood readily from the following explanation. Assume that the carrier wave of the transmitting station is 1,000,000 cycles, and that this wave is simultaneously modulated by the 1000- and 1500-cycle frequencies mentioned above. Then the wave actually transmitted from the broadcasting station consists of waves of the following frequencies:

Upper side band	1,001,500 cycles
	1,001,000 cycles
Carrier	1,000,000 cycles
Lower side band	999,000 cycles
	998,500 cycles

The carrier wave is much stronger than any of the side-band frequencies. Now when several waves of different frequencies are applied simultaneously to a square-law detector each frequency present heterodynes with each other frequency present to produce a component of detector output that has as its frequency the difference between the heterodyning frequencies. The amplitude of this difference frequency is proportional to the product of the amplitudes of the two waves producing it.

Applying these principles to the example at hand, the carrier heterodynes with the first frequency in the upper side band and produces a difference frequency of 1500 cycles. It also heterodynes with the second wave of the upper side band giving a difference frequency of 1000 cycles. The carrier in heterodyning with the two waves in the lower side bands also results in output currents of 1500 and 1000 cycles, which add in with the output of the upper side band to give the undistorted component of the detector output.

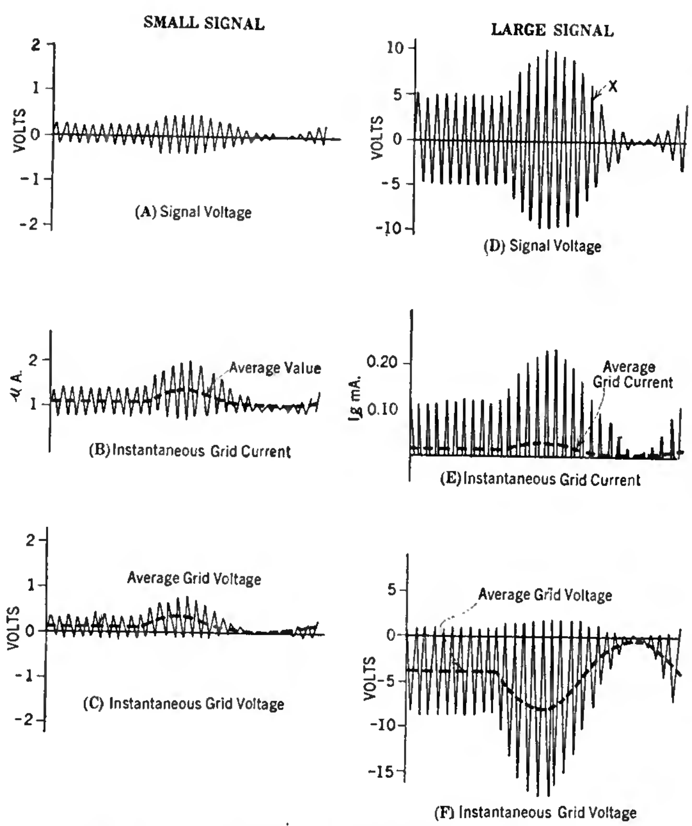


Fig. 1—Comparison of grid action with grid leak-condenser detection of large and small signals.

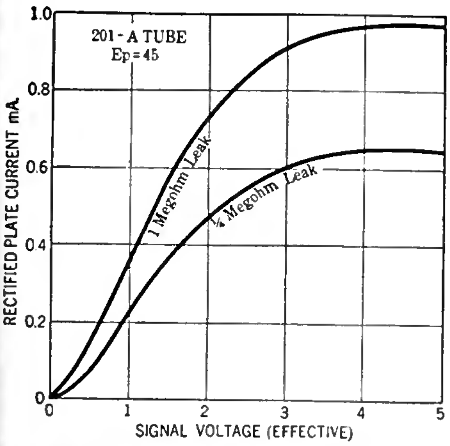


Fig. 2—Rectified plate current of a typical grid leak-condenser detector as a function of signal voltage.

While this is going on the first component of the upper side band heterodynes with each of the other side-band components, resulting in difference frequencies of 500, 2500, and 3000 cycles, while the second component of the upper side band heterodynes with the lower side-band components to produce difference frequencies of 2000 and 2500 cycles. These numerous output frequencies due to side-band components heterodyning with each other are distortion frequencies, but are relatively weak as long as the carrier wave is strong. This is because the undistorted components are obtained by heterodyning of the side bands with the strong carrier, while the distortion frequencies result from the heterodyning with each other of relatively weak side-band components and so are not very strong relative to the useful part of the output.

Small and Large Signals

THE mechanism of grid leak-condenser detection when the signals are strong is entirely different from the action taking place with weak signals. In both cases the radio-frequency signal voltage is rectified in the grid circuit by virtue of the non-linear relation between grid current and grid voltage, but when the signals are weak the grid current flows continuously while when the signals are strong grid current flows only when the signal voltage is at or near a positive crest.

The difference in the two cases is shown in Fig. 1. With small applied radio-frequency voltages the variation in grid current caused by this small signal is not great enough to reduce the grid current to zero. It is to be remembered that in the grid-leak detector there is always a small but very definite grid current flowing, and that this current is necessary for the functioning of the detector. The effect of the radio signal voltage, such as shown at (A) in Fig. 1 is to cause this current to vary with the signal as shown at (B). The dotted line in (B) indicates the average value of grid current, which is seen to vary in amplitude in accordance with the modulation of the signal. This varying average value of grid current must flow through the grid leak-condenser combination, and in doing so produces across the combination an audio-frequency voltage drop that, being applied between the grid and filament of the detector tube, is amplified by the detector acting as an audio-frequency amplifier. The effect of this audio-frequency voltage drop is shown in (C) of Fig. 1, where the dotted line represents the average grid voltage, which is seen to vary in value in accordance with the signal amplitude and with the rectified grid current.

When a large radio-frequency voltage is applied to the grid the situation is changed because with this large voltage the grid potential goes negative sufficiently to stop the grid current for the greater part of the cycle. This is shown in Fig. 1 where (D) represents the radio voltage and (E) shows the grid current, which now flows only for a short time each cycle. The grid voltage during detection of the signal is shown at (F). The average value of this voltage, indicated by the dotted line, is seen to vary in accordance with the signal modulation, and is an audio-frequency voltage that is amplified by the detector tube acting as an audio-frequency amplifier. The average grid voltage becomes more negative as the signal increases in amplitude because the pulses of grid current at each positive crest of the signal then become larger, charging the grid condenser with more electrons and making the average grid voltage more negative. When the detector is adjusted properly some of the charge leaks off the condenser through the grid leak during the part of the cycle when no grid current is flowing. The quantity of charge leaking off the condenser in this way between the impulses of grid current is just equal to the charge supplied by the impulse, and at the same time the amount the average grid potential goes negative is proportional to the size of the impulses of grid current shown at Fig. 1 (E).

In a properly adjusted power grid detector the average grid potential goes sufficiently negative to keep the grid from ever getting very positive, as shown in Fig. 1 (F). This is because the impulses of grid current become very large when the grid becomes a few volts positive. Thus with large signals the average grid potential stays sufficiently negative to allow the grid to become only slightly positive each cycle, and as the signal strength varies the average grid potential varies so that this stays true all the time. Of course, when the signal is extra large the grid becomes slightly more positive during the crest of the cycle in order that the impulses of grid current may be larger, as shown in (F), but in any case the amount of positiveness is small compared with size of the signal voltage because only a small positiveness will cause the grid current impulses to be very large.

Amplitude Distortion

ONE of the first difficulties that has been experienced in the past with power grid-leak detectors was that the audio-frequency output of the detector was far from being proportional to the radio-frequency signal voltage. For example, the solid lines of Fig. 2 show the rectified plate current of a certain grid-leak detector as a function of signal voltage, for the case of an unmodulated signal voltage. It is apparent that the output of the detector is far from proportional to the signal voltage for both high and low grid-leak resistances. When the signal voltage exceeds about $1\frac{1}{2}$ volts effective value, non-linear or amplitude distortion becomes pronounced. As has already been explained, the result is then the introduction in the detector output of audio frequencies which were not present in the original sound.

The cause of the non-linear relation between

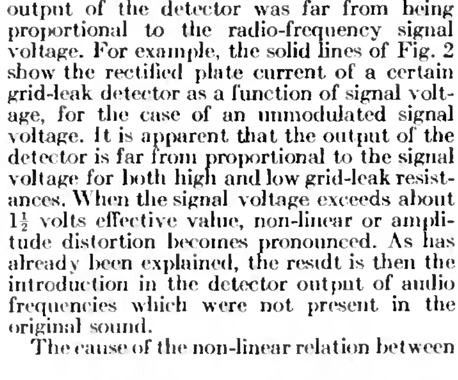


Fig. 4—Rectified plate current of a 210-type tube as a function of signal voltage, showing the possibilities of power detection under suitable conditions.

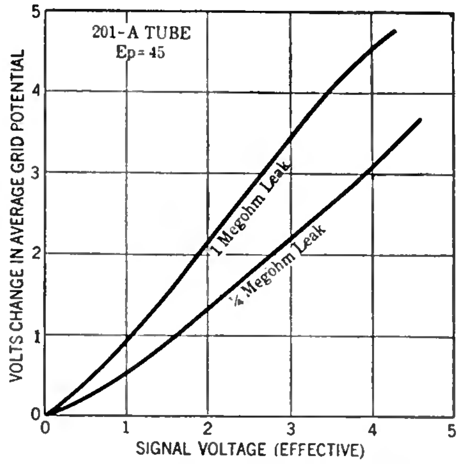


Fig. 3—Change of average grid potential as a function of signal strength for the same condition as Fig. 1.

signal voltage and output for the case of Fig. 2 is not far to seek. If we measure the change of average grid potential from the grid potential with no signal, as a function of signal voltage, we get the result shown in Fig. 3. The average grid potential is seen to vary in almost exact proportion to the signal amplitude even for very large signals. *The reason the average plate current does not also vary in proportion to the average grid potential is due to rectification of the radio-frequency signal voltage in the plate circuit by plate detection.* Plate circuit detection takes place with increase of plate current while grid rectification is characterized by a decrease of plate current. Unless the operating conditions are correct, the plate rectification at large signal amplitudes will be sufficient to neutralize the effects of grid rectification to a serious extent, as in the case in Fig. 2.

In order to prevent amplitude distortion in the grid leak-condenser power detector it is necessary to eliminate all plate detection. Reference to Fig. 1 (F) shows that distortionless power grid rectification can be obtained only when the detector tube gives distortionless amplification of grid potentials ranging from approximately zero to a negative value of twice the crest amplitude of the radio-frequency signal voltage. This is true because Fig. 1 (F) shows that during detection the grid potential varies from about zero to a negative value approximately equal to twice the crest amplitude of the signal—twice the amplitude of the signal measured from its average value shown by the dotted line in Fig. 1 (F)—and distortion will be present unless this variation of grid potential is over a straightline part of the plate-current characteristic. That is to say, plate rectification can be avoided only by operating on a straight line part of the plate characteristic.

The requirement for avoiding amplitude distortion in the grid-leak power detector is, therefore, that *the power capacity of the detector tube at the plate voltage being used must be sufficient to amplify the radio-frequency signal voltage without distortion.* Since the grid of the detector tube is at approximately zero potential when there is no signal voltage present, the mu of the detector tube must be sufficiently high to keep the plate current of the tube within safe limits for continuous operation with full voltage on the plate, and with the grid at zero bias. Power detection obviously requires a power tube operated at a high plate voltage, and it is absurd to expect more undistorted power output from a particular tube at a given plate voltage when acting as a power detector than one could expect to get out of the same tube operating as an audio-frequency amplifier with the identical plate voltage.

The undistorted audio-frequency power

which can be put out by a grid leak-condenser power detector is theoretically just *one fourth* of the undistorted power which the same tube can put out as an audio-frequency amplifier, the plate voltages being the same in the two cases. This can be seen from Fig. 1 (F), where it is evident that the average grid voltage (which is amplified in the plate circuit and becomes the audio-frequency output of the detector) swings through only half the range of voltage that the radio-frequency signal goes through. As power is proportional to the square of the voltage, the audio-frequency power output is one fourth the power capacity of the detector tube acting as a distortionless amplifier.

The maximum allowable carrier voltage of the radio-frequency signal that can be applied to the grid of the grid-leak power detector is approximately *one half* the audio-frequency voltage that may be applied to the same tube when acting as an audio-frequency amplifier. This is because during moments when the carrier is fully modulated the radio signal voltage reaches an amplitude twice that of the carrier, and the detector must be capable of handling input voltages of this size.

Of the standard tubes available for grid-leak power detectors the moderate mu 112A, 226, and 227 types can be operated at plate voltages from 90 to 135 volts without drawing excessive plate current, and under these conditions will put out enough power to run a 171A- or a 210-type power tube, or even two 171A-type tubes in push-pull. The 171A-type tube is not suitable as a power detector because its low mu allows the plate current to become too high.

By going to higher power tubes it is possible to operate a dynamic-type loud speaker directly from the detector output, and *to dispense entirely with the audio-frequency amplifier*. In order to do this it is of course necessary to go to very large tubes and high plate voltages. By using a 210-type tube at a plate potential of 250 to 300 volts it is possible to supply from 110 to 250 milliwatts of undistorted audio-frequency power directly to the loud speaker from the detector tube.

That real undistorted power can be obtained from a grid leak-condenser power detector under favorable conditions is shown by Fig. 4 which gives the measured rectified plate current in a 210-type tube as a function of radio-frequency signal voltage. It is evident that rectified output is almost exactly proportional to the signal up to an applied potential of about 10 or 12 volts effective. The curves given in Figs. 1 (D), 1 (E), and 1 (F) are actual curves drawn to scale showing the measured performance of this 210-type tube under the same conditions as in Fig. 4.

Eliminating Distortion

IT HAS been shown that adjusting a power grid leak-condenser in such a way as to eliminate plate-circuit rectification will eliminate amplitude distortion, but the problem of reproducing all audio frequencies with equal sensitivity still remains. The general tendency of a grid-leak detector is to be less sensitive on the high notes than on the low, and this is even more so when the signals are large than when they are small.

When the modulation frequency is high the average grid potential may not be able to follow the rapidly varying amplitude of the signal, as is the case in Fig. 5. Here the grid-leak resistance and grid-condenser capacity are too high, and as the signal amplitude decreases the charge on the grid condenser is not able to leak off fast enough through the grid leak to reduce the average grid potential as fast as the signal is changing amplitude, with the result shown in Fig. 5. A correct value of grid-leak resistance and grid-condenser capacity will give the conditions of Fig. 1 (F), in which the distortion is at a minimum.

The rate at which the average grid condenser charge can change is inversely proportional to the product of leak resistance, R, times grid condenser capacity, C. Analysis shows that when the signal voltage is modulated completely, as shown in Fig. 1 (D), and is at the point "X" indicated in Fig. 1 (D), the average grid potential can just barely decrease as fast as the signal is decreasing when the relation $2\pi f = 1/RC$ is satisfied, in which f is the frequency of modulation, R denotes the grid-leak resistance in megohms, and C is the grid condenser capacity in microfarads. Modulation frequencies for which $2\pi f$ is greater than $1/RC$ will not be reproduced as well as the lower notes.

It is evident that to reduce frequency distortion to a minimum it is desirable to have

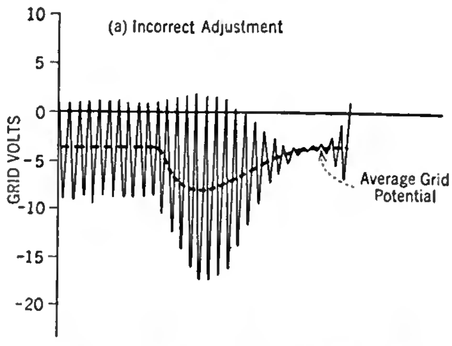


Fig. 5—The grid action of the power detector with a grid leak too large.

small grid-leak resistances and small grid-condenser capacities. At the same time, however, it is undesirable to go to extremes. A grid condenser capacity of 0.0001 to 0.000125 mfd. is about right for a power detector. A condenser much smaller than this will cause serious loss of signal voltage, since the voltage drop in the condenser of the radio-frequency signal voltage will be large enough to make the actual voltage reaching the grid of the tube considerably less than the voltage supplied by the tuned circuit. Grid condensers much larger than the values suggested are undesirable because they make necessary an excessively low grid-leak resistance, which lowers the sensitivity of the detector, and makes the radio-frequency energy lost in the grid circuit unduly large.

If the highest audio frequency to be preserved in the output of the power detector is 5000 cycles, and if the grid-condenser capacity is 0.000125 mfd., a simple computation shows that the grid-leak resistance can not be higher than 0.255 megohms. If the grid condenser was the usual 0.000250-mfd. size, the grid leak would have to be about ⅛ megohms, an undesirably low value.

Summary

A GRID leak-condenser power detector will deliver approximately one quarter of the undistorted power output that the same tube with the same plate voltage (and suitable grid bias) will deliver when acting as an audio-frequency amplifier. This means that high plate voltages must be used with the power detector, and that the mu of the tube must be sufficiently great to prevent excessive plate current at this plate voltage when the grid potential is zero. If the power detector is overloaded, rectification will take place in the plate circuit and will cause amplitude distortion.

The power detector will reproduce all frequencies equally well only if the grid condenser and grid leak sizes are smaller than the usual values best suited to small signals.

The potential of the grid-return lead of the power detector is unimportant. It can be brought back to either the positive or negative leg of the filament with about equal results. The decision as to whether the grid return should go to the plus or minus filament, or to a plus or minus grid-bias battery should be made so as to give the greatest sensitivity with very weak signals, and can be determined by experiment, or by the principles given in the first article of this series.

In conclusion, it is easy to see why the ordinary grid leak-condenser detector used for weak signals is so unsatisfactory for large signals. The plate voltages usually employed are absurdly small for power work, the usual grid condenser is too large, and the customary grid-leak resistance is about ten times the value best suited for handling large amounts of energy.

THE REAL SIZE OF THE RADIO MARKET

(*Continued from page 379*)

January 1928 increased 27.3 per cent. over the number in use on January 1, 1927.

In the tube market an equivalent increase is noticeable. Total tube sales jumped 82.5 per cent. in 1928 over 1927. The increasing size of the replacement business fairly shouts at one in the summary. Tubes sold for replacements in 1928 increased 74.8 per cent. over the year previous while the number of new sets sold, sets which are in part responsible for the replacement sales, increased in 1928 69.7 per cent. over the year before.

No one can say what the sales in 1929 will be, but there is no prohibition on forecasts. Certainly not less than 3,000,000 receivers will be sold in 1929. Almost that number was sold in the year just closed. It is fair to assume that with the increasing number of sets becoming obsolescent, the year, 1929, will see a tremendous sale of new sets to what one might call old radio customers. Users who have tired of the inconvenience of their antiquated battery set, its poor fidelity, which cannot compare with the reproduction of the best of to-day can be sold new sets. They need not be sold on radio, but what a sales story radio dealers have for them in the product they now have in their shops!

The number of battery-operated sets which can be replaced with the modern socket-powered set is very large. In 1927, not more than 500,000 "electric sets" were sold. Even if every set sold during 1928 were an "electric" set, there would be hardly more than 3,500,000 sets of this type in use. That means on January 1, 1929 there were 7,500,000 sets not of the modern self-contained type. If 2,000,000 sets be subtracted from that total to allow for those in use in districts where a central station power is not available, there are five and a half million sets which are obviously not modern and which can be replaced with the excellent products the market affords to-day.

Yet the battery set market is by no means inconsiderable—and it is evidence of the astounding vitality of the radio market—as covered at length in an article on page 331 of RADIO BROADCAST for March, 1929.

What this examination of the market means for all in the industry is not difficult to see: in the manufacturing field, tube and set companies have announced plans for great expansion; mergers and combinations have all been calculated toward greater production to meet the 1929 demand which these wise companies anticipate. In the retail field it means that the set market will be greater than ever in 1929, that the sale of tubes for original installation and for replacement will be much larger than last year. Some tube manufacturers who ought to know do not hesitate to say that 100,000,000 tubes will be sold in 1929. The radio dealer can make quickest capital out of this analysis of the probabilities for his sales and service staffs are in direct contact with this public we are talking about. Here is a rich and profitable field for all who purvey to the public who see now in radio, if not a necessity, an almost essential adjunct to the home.

SOUND MOTION PICTURES

BY CARL DREHER

Sound Attachments for Standard Picture Projectors

IN THE March issue of this department the general construction and operating principles of standard motion-picture projectors were described. Nothing was said in that article about the motive power for the machine. This is normally an electric motor drive through a system of gears on the left side of the head, a flywheel being provided to steady the speed. The projector may also be operated by means of a hand-crank from the right side, as shown in the accompanying cut (Fig. 1) of a Simplex (International Projector Corporation) machine, where the crank is seen with the handle over the lower magazine. This is feasible only with silent pictures, and then the crank is used only in the rare event of failure of the driving motor.

When sound pictures are projected the speed must be kept constant at 90 feet per minute (24 pictures per second) with a regulation of about 0.2 per cent. in order to hold the pitch. Unless an a.c. source with reliable frequency control is available this requires special speed stabilizing circuits of the type described by H. M. Stoller, "Synchronization and Speed Control of Synchronized Sound Pictures," in the *Transactions of the Society of Motion Picture Engineers*, Vol. XII, No. 35. A synchronous motor operating on a constant frequency a.c. supply is the simplest means of securing the proper speed, and can generally be used in large cities. In projecting silent films a variable speed control is desirable, which means the addition of another motor if a synchronous motor is used for the sound-picture drive.

The lower sprocket of the projector, in the absence of a sound attachment such as is described below, delivers the film to the lower magazine, where it is wound up at a constant rate, as the diameter of the roll increases, by a device known as the "take-up." This is usually an arrangement utilizing a split pulley and tension spring to allow loss of speed as the reel is filled up with the film, with a constant speed drive.

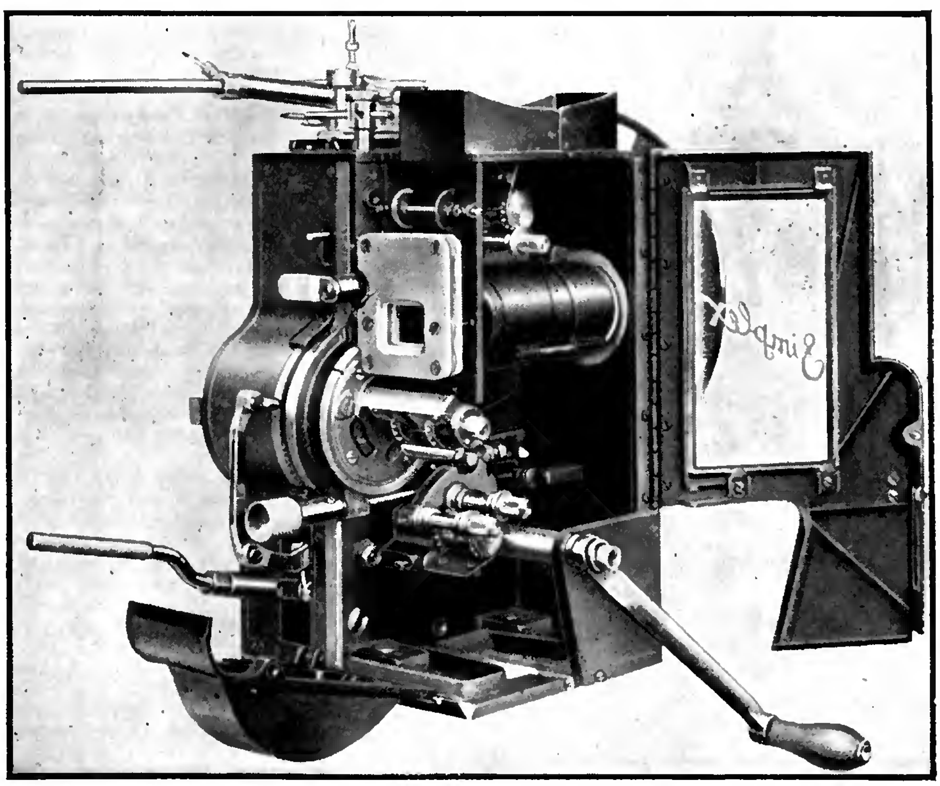
The sound-head attachment shown in Fig. 2 below the picture head is that of the Movietone type, which has been widely illustrated. The optical principles have been described in October and November, 1928, RADIO BROADCAST. The principal problem in the sound head is that of preventing the intermittent movement above from influencing the continuous motion of the film past the point where the sound is taken off. This is accomplished in the mechanism shown, by means of a sound-head sprocket which revolves at constant speed (special mechanical filters to smooth out pulsations usually being applied) and drags the film through a gate similar to the picture gate, containing a spring tension pad which holds the film firmly as it slides through. This sound gate presents intricate problems to the designer. The tension pad must not scratch the film or take off the emulsion; on the other hand, it must not allow the film to vibrate or buckle in the sound gate, even when it has been subjected to the heat of a high intensity arc in the picture gate a few inches above. As soon as the film is allowed to move out of the plane of focus in the sound gate, the output quality deteriorates—high frequencies drop out, "fuzz" and extraneous tremolos come in, etc. This is because the sound track, instead of passing through a sharply defined rectangle of intense light, the dimension of which in the direction of film motion is less than the wavelength, on the film, of the highest frequency to be picked off, runs instead through a relatively wide spot with irregular edges. It must be remembered that at the standard sound film speed of 18 inches per second, a 6000-cycle note, for example, is recorded in a space of 0.003 inch for each oscillation, and it does not take much to spread the light beam, which is designed to cover 0.001 inch, so that it will overlap more than one peak or line of the record. Much, therefore, depends on the construction of the sound gate. As shown in the figure, idler rollers are provided above and below to further control the motion of the film.

Synchronism is maintained by setting up the film with the proper loops, so that when a given picture is at the picture aperture the appropriate portion of the sound track will be at the light aperture in the sound reproducing section of the projector. An error of one or two frames is allowable; beyond this the defect in synchronism becomes noticeable to observers. The proper separation of the picture and sound elements is taken care of in the printing of the film, the sound preceding the picture (since the sound head is below and a given point on the film reaches it *after* it has passed the picture aperture) by such an interval (19 picture frames, or about 14.5 inches) that scene and sound are projected simultaneously.

The Technique of Wax Recording

HALSEY A. FREDERICK'S paper on "Recent Advances in Wax Recording," printed in the *Transactions of the Society of Motion Picture Engineers*, Vol. XII, No. 35, 1928, contains material of much interest, not only to the sound-motion picture specialist, but to students of applied acoustics in general. Mr. Frederick is an engineer of the Bell Telephone Laboratories. His paper is concerned with lateral cut records, in which the groove is of constant depth and undulates about a regular spiral on a flat disc.

After some preliminary discussion, the author refers to a curve, here reproduced in Fig. 3, which shows a typical frequency characteristic for a commercial electromagnetic recorder. The response is allowed to fall off below 250 cycles as a commercial compromise between quality of reproduction, the necessity for getting a certain amount of music onto a disc of reasonable size, and the amount of energy in the form of sound oscillations which it is desirable to get off the record when it is played. The intensity of the sound, in playing a lateral cut record, is a function of the velocity imparted to the needle, and that is the product of the amplitude of the oscillation and the frequency. With the characteristic shown in Fig. 3 constant velocity is secured from about 250 to 5500 cycles, with constant amplitude below 250 cycles. Were the amplitude to be increased below 250 cycles to keep the output constant, the cutter would break



Close-up view of the picture head of a Simplex motion-picture projector

through from one groove to the next in the wax, or, if the pitch of the spiral were increased to allow for a wider swing, the amount of entertainment which could be put on a given disc would be much less. The loss in low frequencies introduced by adhering to constant velocity cutting only as low as 250 cycles may be compensated in reproduction, if desired, by means of corrective net-works, or in the characteristic of the electric pick-up employed.

Of course the amplitude of the cut as a whole can be reduced, and the loss in output made up by increased amplification in reproduction. In this way the constant velocity relationship could be maintained down to a considerably lower frequency, but when this is attempted another limiting factor is encountered—needle scratch or surface noise, caused by the nature of the record material. It is desirable to keep the oscillations corresponding to the speech or music large in order to keep the disturbance caused by the needle scraping the record relatively low. Before the general amplitude of cutting can be reduced, therefore, improvements in record material must be effected.

Frederick states that wax records can be made with special recorders flat to within 1 DB from 250 to 7500 cycles, and not deviating more than plus or minus 4 DB between 30 and 8000 cycles. Such a characteristic, or even the characteristic shown in Fig. 3, can be secured only by flat amplifier design and by constructing the cutting mechanism mechanically on principles analogous to the electrical ones now generally employed. One of these principles, in telephone transmission practice, is to terminate the system with an impedance of such a value as to avoid reflection of energy. In modern electrical recording this is accomplished, in the mechanical portion of the system, by not using the rather variable load imposed by the wax on the cutting stylus as a termination, but instead supplying a relatively large mechanical load in the form of a rubber rod, which dissipates the energy. The work done at the stylus is then incidental mechanically, although functionally it constitutes the whole purpose of the machine.

The actual cutting takes place on what is essentially an accurate lathe with a vertical shaft. The groove cut is generally between five and six mils wide, and 2.5 mils deep. The space between grooves is of the order of four

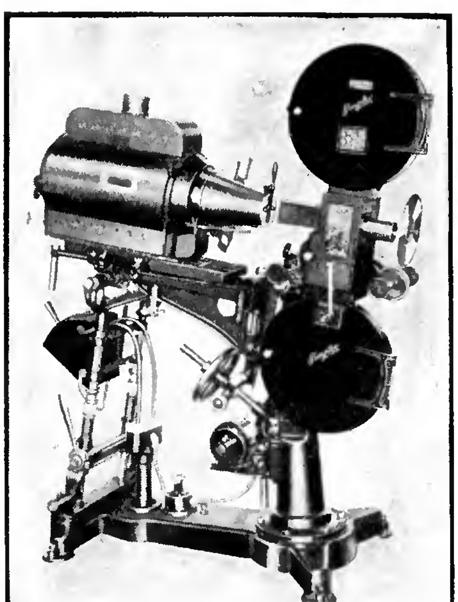


Fig. 1—General view of the Simplex projector

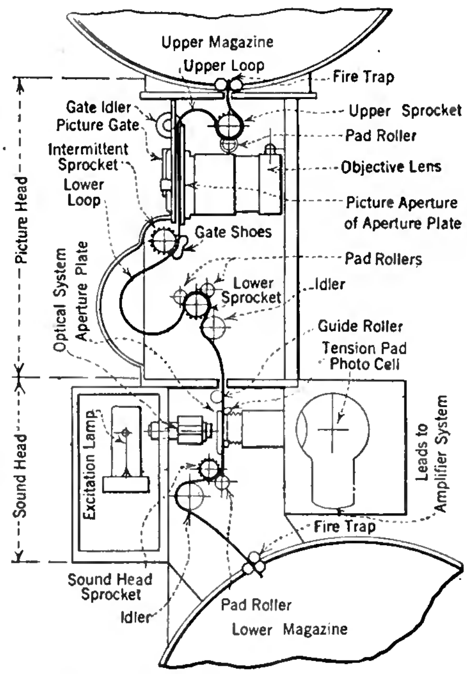


Fig. 2—Schematic diagram of mechanism in a standard motion-picture projector with sound adjunct

mils. The number of grooves per inch varies between 80 and 100 in normal practice, with 90 as the average. This gives a pitch, or distance between turns of the smooth spiral, of 0.011 inch, (11 mils). Since the space between grooves is 4 mils, the permissible amplitude of oscillation is not over 2 mils. If this limitation, for the reasons stated above, is set at 250 cycles, then for a constant velocity cut (amplitude varying inversely with frequency) the amplitude will be 0.0001 inch (0.1 mil) at 5000 cycles. These are microscopic dimensions, and the work is, indeed, best done under a calibrated microscope, which moves across the disc with the recorder stylus.

It is interesting to note that in wax recording and reproduction the linear speed of the record past the cutter or reproducing needle varies between 70 and 140 feet per minute, a figure of the same order as sound film speed (90 feet per minute). For a minimum linear speed and fixed groove spacing, there is an optimum relation between the size of record, rate of rotation, and playing time. This may be mathematically expressed and drawn as a family of curves, here reproduced as Fig. 4.

By means of a special "playback pick-up," which is lighter and more elastic than the usual electrical reproducing pick-up, the newly cut wax may be played immediately through an amplifier and loud speaker system, with quality sufficiently close to that of a hard record to allow an accurate judgment of the performance. This is a valuable feature both in phonograph recording and sound-motion picture applications.

The material of the finished record, or "pressing," has to be hard, in order to afford a sufficient number of playings, and it must contain enough abrasive material to grind a new needle quickly (in 10 to 30 seconds) to fit the groove. Most of this wear is in the starting spiral, in which no sound is recorded. Since pressure is force divided by area, the pick-up, with a weight of about 4.5 ounces, exerts an enormous pressure through the microscopic area of a new needle, and even after the needle is worn to a fit the pressure is of the order of 50,000 pounds to the square inch.

Contrary to a general impression, the finished pressing is a faithful copy of the wax record and loses practically nothing in essential frequencies. Its defect is in the addition of surface noise. By improvements in the material, as well as in the electro-plating process by which the wax is copied, Mr. Frederick states that a reduction of 3 to 6 DB in surface noise has been secured during the last two years. Further improvements may be expected in this line, without change in the present size of records and amplitudes of recording.

By an interesting calculation, Mr. Frederick shows that the diameter of the bearing portion of existing commercial needles used in electrical reproduction is not too great to follow the groove undulations at 7000 or even 10,000 cycles, with standard methods of recording, so that this factor is not a limitation in reproduction of high frequencies by this method.

Advances in electrical pick-up design have been in the direction of reduced mechanical impedance at the needle point, elimination of resonances in the tranmission chain, and reduced weight. These factors combine to secure better reproduction of the higher notes and less wear on the record.

The comment of an engineer who is not a specialist in the wax recording field, based on observation in theatres, would probably be that Mr. Frederick's paper shows interesting and important improvements, but that much still remains to be done before an entirely satisfactory technique is evolved.

Mils, and What They Are

THE theatrical papers are certainly the snappiest on earth, but in technical matters, however simple, they are about as ignorant as one can be without trying. Last summer there was considerable speculation among the Broadway savants regarding standardization of sound track width on talking films, and the trade papers found numerous occasions to write about 80-mil sound tracks, 100-mil sound tracks, and so on. But they hardly ever printed it "mil." Frequently it became "mile." Again it was "mill." And "millimeter." But a mil is neither a mile nor a millimeter. A mil is a thousandth of an inch, and nought else.

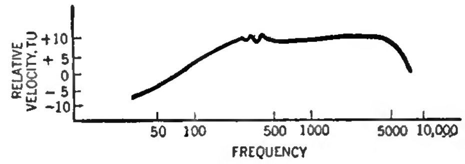
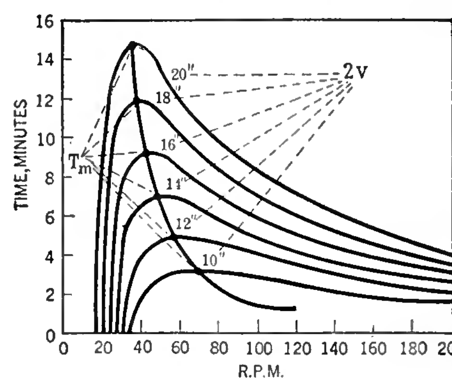


Fig. 3



$$T_m = \frac{\pi N R^2}{24 V_0}$$

T_m = Max. Playing Time, Mins.
N = Grooves per Inch.
R = Outside Groove, Radius, Inches.
V_0 = Min. Linear Speed-Ft. per Min.
V = Inside Groove, Radius Inches
R = 2v

Fig. 4

One Method of Matching Coils and Condensers

PRODUCTION TESTING WITH OSCILLATORS

By RICHARD F. SHEA

VARIOUS different types of apparatus have been devised and tried by the author in order to obtain accurate matching of coils and condensers with a minimum maintainence cost. These types have included aural and visual tests of all sorts, and the final system has been an adaptation of the beat-frequency audio oscillator. In a preceding article ("A Simple Unit for Measuring Impedances," September, 1928, RADIO BROADCAST) the importance of closely matching the individual coils and condensers in a radio receiver was stressed.

In the beat-frequency audio oscillator we utilize two radio-frequency oscillators, one having a fixed frequency and the other a frequency varying from the fixed frequency up to any desired difference. For instance, one oscillator might be fixed at 500 kc. and the other vary from 500 to 510 kc. This produces a frequency difference between the two varying from zero to 10,000 cycles, and if these two oscillators are loosely coupled to a detector this beat will appear in the output as a variable audio frequency. This system has been used extensively to produce a compact audio oscillator with a continuous range and fairly constant output. The maximum frequency is obviously dependent only upon the frequencies of the two oscillators and the size of the variable tuning condenser. If both oscillators are tuned to very short waves and a large variable condenser is used, the beat can be made to go from low audio notes to radio frequencies far above the broadcast band. The lowest obtainable note depends entirely upon the degree of coupling between the two oscillators. If they are coupled closely they will "pull in" at comparatively high frequencies, and that will set the lowest obtainable note. To lessen this tendency it is customary to set one oscillator at a harmonic of the other. For instance, one might be fixed at 500 kc. and the other vary from 250 kc. to 255 kc. (the second harmonics being 500 to 510 kc.), thus producing a 10,000-cycle maximum beat.

To adapt this device to production testing in a manufacturing plant we see that the audio beat note will pass through zero when the two oscillators are identical in frequency. To match two condensers we merely need to make up two oscillators whose frequencies depend upon the capacities of the condensers under test, and if they match we will get a zero beat. This is the principle of this system applied to condenser matching.

The apparatus (Fig. 1) consists of two oscillators, a detecting system, and an audio amplifier. One unit of the condenser gang is connected to one oscillator and the other oscillator is connected alternately to each of the other units of the gang by means of switches. A small compensating condenser, C_4, is connected across the tuned circuit of one oscillator and a variable midget condenser, C_3, across the other. These are adjusted so that when the vernier, C_3, is set at mid-scale and the two condensers under test are equal, a zero beat will result. If the condenser C_2 is greater than C_1, the dial on the vernier C_3 will have to be moved to one side of mid-scale to reëstablish zero beat. The amount of motion necessary is a measure of the unbalance between C_1 and C_2. The vernier, C_3, should be about 35 mmfd. maximum capacity, and for such a condenser one division on a hundred-division scale corresponds to approximately three-tenths of one mmfd.

Let us now take these parts and dispose them to make a satisfactory production tester. To fill this purpose the apparatus must be sturdy, reliable, and quick of operation. The whole should be mounted on a base of strong steel and should have a jig so that the condenser gang will mount quickly and securely on the base and always in the same position. This latter consideration is important as the position of the gang makes a great deal of difference in the stray capacities which are shunted across the gang. All the wiring should be of heavy bus to insure remaining in place and great care must be taken to make it uniform for all the units of the gang. The drawing of Fig. 2 suggests a successful layout.

> *Mr. Shea describes in this article an instrument suitable for use in the production testing of coils and condensers for use in manufactured receivers. The author has been connected with the radio division of American Bosch Magneto Company.*
>
> *Obviously the sensitivity and selectivity of a modern single-control receiver depends to a large degree on the accuracy with which the coils and tuning condensers are matched.*
>
> —THE EDITOR.

The coils L_1 and L_2 must be identical, and to insure this fact they should be measured for inductance in the shields. The capacities of the tubes can be compensated by the adjustment of C_4, so that the matching of L_1 and L_2 and the uniformity of leads are the only strict requirements.

To adjust this device place the condenser gang on the jig and set it at zero, i.e., minimum capacity. Set the vernier, C_3, at 50° (on a 100° scale) and adjust C_4 until you get a zero beat. To check this and also the uniformity of the wiring, test about ten gangs and note the readings on all three switch positions. If it is found that the average in all cases is 50° then the adjustment is correct. If, however, all averages are off the same amount from 50° then C_4 should be changed to bring them to 50°. If the average on any one switch position is off it means the wiring is non-uniform, and it can be fixed by pushing the bus wire nearer to or farther from the base. When the tester is correctly adjusted the average of a larger number of gangs should be very close to 50° on C_3.

We are now ready to set limits. If our gang has a capacity of 20 mmfd. at minimum, 200 mmfd. at mid scale, and 500 mmfd. at maximum, and we wish to hold units to within 1 per cent., then our allowance is 0.2 mmfd. at 0°, 2 mmfd. at 50° and 5 mmfd. at 100°. In setting these limits it must be borne in mind that the strays also add to the capacity, and the total minimum will be 40 to 50 mmfd., so that 0.2 mmfd. is holding them much closer than 1 per cent. In such a case 0.5 mmfd. would be the proper tolerance at zero, 2.25 mmfd. at 50°, and 5.25 mmfd. at 100°. If our vernier has 0.3 mmfd. per division this becomes approximately two divisions at zero, 7 divisions at 50°, and 17 divisions at 100°.

Then in testing our gang we set it upon the jig and turn on switch S_1. This matches condenser one with condenser two. We set the gang at zero and rotate C_3 to get zero beat. Let us say it comes at 51°. Snap on switch S_2 and readjust C_3. This time we get 50°. Lastly turn on switch S_3 and here we get 49°. This gives us 50°, 51°, 50°. and 49° for the four units, and as no two readings differ by more than 2 divisions the gang comes within the limits specified above. A similar process at 50° and 100° gives us the deviations at those positions.

So much for condenser matching. Now let us turn to the application of such a system to coil matching. Here we have a much simpler problem and are able to obtain even greater accuracy for reasons which will soon become evident.

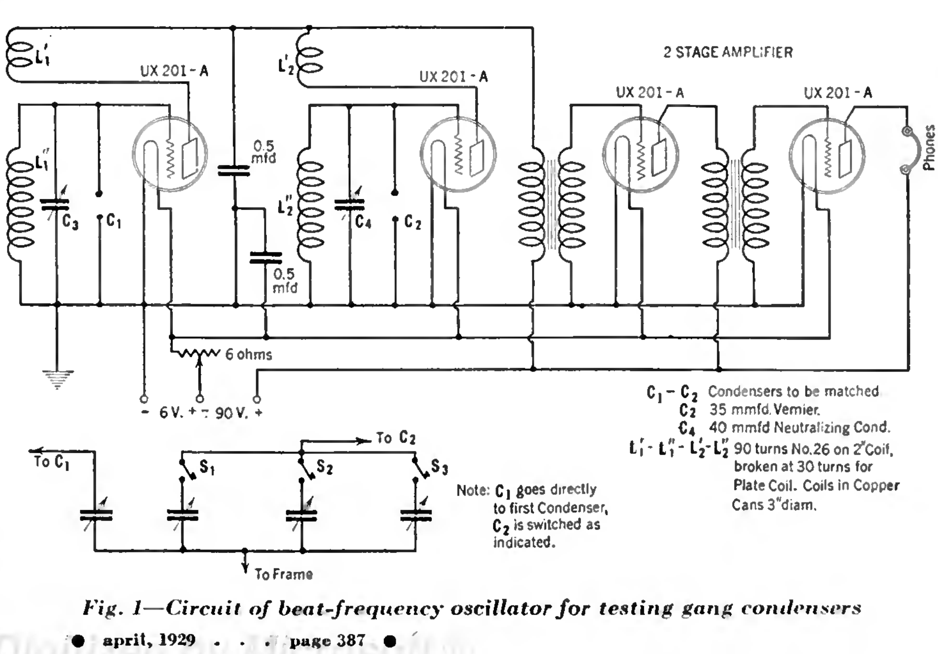


Fig. 1—Circuit of beat-frequency oscillator for testing gang condensers

Fig. 3 shows the set up of the coil tester. It comprises two oscillators and a radio receiving set. One of these oscillators is fixed, say at 300 meters, the wavelength to which the receiving set is tuned. The other's wavelength depends upon the inductance of the coil L_x under test and is brought to 600 meters by the vernier C_3. C_4 is a compensating condenser which can be adjusted to bring the reading of C_3 to exactly 50° when using a standard coil. It will be noticed that the second harmonic is used here for greater sensitivity and also that the coupling between the oscillators is extremely loose, as we have the r.f. gain through the receiving set to make up for it. Thus we are able to get a very sharp reading on this tester.

It will also be noticed that the two oscillators differ in wiring in this tester. The fixed oscillator uses a modified Hartley circuit, i.e., utilizing a coupling coil for feed-back, whereas the other oscillator gets its feed-back through a resistance which is common to both plate and grid circuits. This eliminates the need of a tickler coil, and the coil under test has only two connections made to its extremities. Also a filter is provided in L_F, C_F which reduces the coupling between the two oscillators. The two oscillators are shielded from each other by partitions and the only coupling is through the common batteries, as in the case of the condenser test, except that it is reduced still further in the case of the coil tester by the use of the filter.

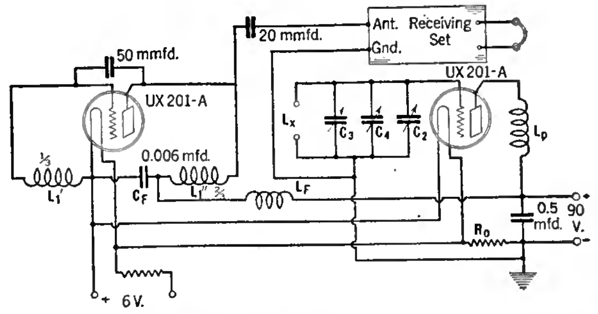


Fig. 3—Circuit of beat-frequency oscillator for testing coils

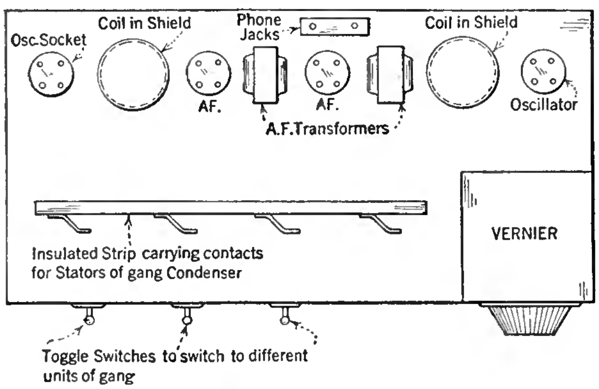


Fig. 2—Suggested layout for oscillator of type shown in Fig. 1

In using this tester set C_4 so that an average of a large number of coils will come at 50° on C_3. Limits may be obtained for C_3 by measuring the extremes of a large number of coils. For instance, if the average coil is 200 microhenries and a coil giving a reading of 60° is 195 microhenries, and a coil reading 40° is 205 microhenries, then ten degrees on the tester corresponds to five microhenries in 200 or 2½ per cent. If 1 per cent. tolerance is allowed this means 4 degrees. It has been found possible to hold coils to tenths of one per cent. with this tester, as it will easily show a difference of a few hundredths of one per cent. between two coils. In actual use the operation of this tester is very rapid if the coils are at all close, as an audible beat will usually be heard the minute the coil is placed in the jig, denoting that the coil is easily within required limits, so that in most cases it is unnecessary to adjust C_3.

A word of caution is proper here regarding the use of B-power units to operate these testers. While the testers themselves will operate satisfactorily on such devices they will usually cause considerable external annoyance to near-by receivers due to radiation through the power lines. If sets are being tested in the same building they are apt to pick up the beats when they are tuned to the same wavelength as the tester.

The foregoing discussion will no doubt show that the use of beat frequencies in inspection apparatus is much to be preferred to previous methods of aural and visual measurement, not only for accuracy but for speed as well, and consequently is well worth adoption in all plants when precision is desired at low cost.

BOOK REVIEWS

Advertising By Radio, By Orrin E. Dunlap, Jr. The Ronald Press Company, 1929. Price $4.00.

In this new volume on radio advertising appear figures for the returns of many recent commercial broadcast features. The author has had access to the sales-promotion material and tabulations of mail return of the National Broadcasting Company and its affiliated stations and also those of WOR. These are quoted liberally throughout his book and should make the volume of immediate interest to all solicitors selling time for broadcasting stations, because any shred of material giving tangible proof or suggestion of proof of the medium's effectiveness is welcome to them.

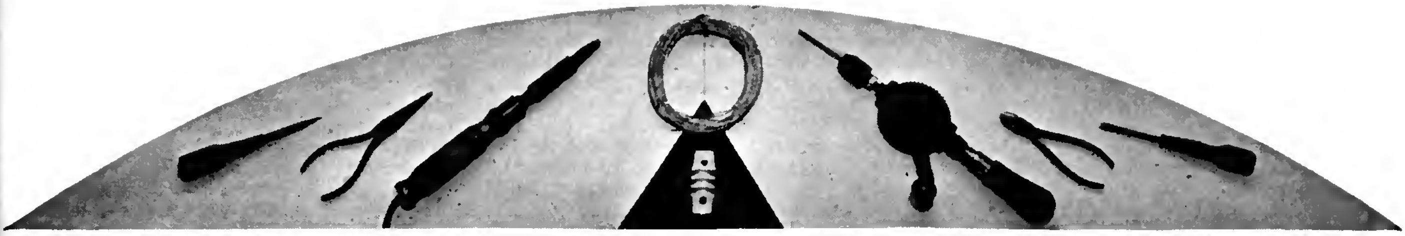
To one familiar with all the problems of commercial radio broadcasting the rather broad scope covered by the title of the book and the headings of the chapters is hardly fulfilled. But Dunlap provides the complete answer to the question, "Does commercial broadcasting bring mail response?" His observations on broadcast programs are those of any expert listener and critic. He levels a few richly deserved shots here and there at announcers for *faux pas* familiar to radio listeners. In common with the entire broadcast industry he sidesteps the most important point in appraising the value of the good-will program, namely, "Does broadcasting actually influence sales and at what cost?" Conclusive proof that thousands of people send for a cross-word book or a bridge score pad is only indirect and inconclusive evidence as to actual sales return.

Considering that commercial broadcasting is now entering its eighth year, the advertiser certainly has the right to expect some tangible proof that that warm feeling around the heart which the radio listener is supposed to have for those who sponsor programs has in one instance or another actually increased sales volume by a definite number of dollars and a definite cost per dollar increase in sales.

With reference to the practical utilization of broadcasting by an advertiser and such specific and relevant problems as the method of procedure for the selection of stations, programs, management of artists, methods of preparing script, personnel and organization required, and methods of tabulation of returns, little if any information is given. It is characteristic of the writer's style in this particular volume to use the primer method of asking a question and then attempting to answer it. "Of course if you were an advertiser seeking good-will on the radio, what would you send through the microphone to entertain a million listeners and hold them spellbound on a series of wavelengths until the program concludes? Would you contract for the Goldman Band, Will Rogers, Irvin Cobb, or would you link the name of your product with George Gershwin, Galli Curci, Al Jolson, a prize fight or Paul Whiteman's orchestra, or would you select an opera, etc., etc.?"

One chapter is devoted to selecting the broadcasting station for the commercial program. Dunlap calls attention to the fact that the station used must have a good wavelength and that it should reach an area which constitutes a market for the type of product involved.

The selection of broadcasting stations has become much more than a matter of merely selecting one with the best wavelength, covering the area desired. Many complex questions now enter such as chain affiliations, habitual program character and its effect in establishing a particular type of audience at different hours, transmission quality, conditions on the frequency to which the station is assigned, suitability to the particular type of program which the sponsor desires to present and numerous other factors, now habitual considerations when advertising agencies are called upon to select broadcasting stations for a particular client. It is obvious that Mr. Dunlap's rôle has been one of skillful and competent observer at the loud speaker rather than actual contact with the problems of managing directing and placing broadcast advertising features. He deals very fairly with his true subject, the returns obtained by radio advertisers, and the book is certainly enlightening to one interested in this subject. It falls short, however, of a complete study of radio advertising and a guide to the advertising manager who would use the medium of radio broadcasting.—E. H. F.



THE SERVICEMAN'S CORNER

THE quite numerous problems that beset the serviceman can be cleared up best by a general discussion of them by several workers who have encountered and solved similar difficulties. A half dozen or so suggestions on the elimination of categorical troubles are always better than the isolated experience of any one serviceman.

Six servicemen can give their brothers a better idea on how to go about curing a power pack that overheats than any one of them who may have run across only one of the several possible causes of hot transformers.

From month to month, as we scan our correspondence, we are going to pick out the more general attributes of poor reception, and put them before the serviceman for open discussion.

The topic this month is noise. The serviceman every day runs into complaints of this sort. Needless to say an objectionable noise should not be present in any receiver, and it is often the job of the local expert to eliminate it. Many things may cause noise in a receiver, from proximity to the lighting mains to an ageing rectifying tube. The cures for noise are as many and as varied as its causes.

What cases of hum have you run into? What is your general procedure in tracing and rectifying trouble of this nature?

Short articles on this subject of hum reduction will be welcome in "The Serviceman's Corner"—and paid for at our usual rates.

Service Equipment and Procedure

IDEAS on test equipment and the procedure of locating radio troubles are about as diversified as the possible ways of making stuffing for chicken. The tools and methods vary with the individual. It turns out that this business of fixing a radio set is rather a personal affair, and is cut and dried only in its fundamentals. This department has received many contributions from servicemen, describing their favorite equipment and their systems of using it. While, offhand, it might appear that the selection of the proper tools, and the knowledge of how to use them would be kindergarten stuff to the readers of these pages, so much interest has been displayed in the matter, as is evidenced by the many contributions on the subject, that we feel justified in publishing the more representative letters, and drawing from them such conclusions as we can.

SUGGESTIONS FROM KANSAS

RAYMOND E. SNODDY, of Leavenworth, Kansas, boils it all down in a few paragraphs:

"When I am making a service call this is the equipment which I use: a meter with a range of 0–50 volts and 0–35 amperes, a long and a short screw driver, two pairs of pliers, file, soldering iron, headphones, hydrometer, test leads, tape, pipe cleaners, spare wire, a large cloth, and a tube- and set-tester. The tube- and set-tester consists of a 0–8 d.c. filament voltmeter, 0–300 high-resistance plate voltmeter, a 0–15–100 milliammeter, and an a.c. voltmeter with a range of 0–15–150 volts. The tester is also supplied with a cable and tube bases to make the various tests. This equipment is all contained in a small carrying case, very compactly and neatly arranged. I designed and built this service kit myself.

"When servicing a radio receiver this is the routine I always go through: First, upon entering the house and while checking the battery connections, I ask the owner a series of questions as to how the set has been acting, how long it has been out of order, etc. This will often save a lot of trouble as the owner will generally give you some information that will point directly to the trouble. I then check the A- and B-battery connections, test the batteries, and then place the plug from the tube tester in the first radio-frequency socket and test all the tubes in this socket. I then remove the plug and place it in each socket and note the plate and filament voltages, and also the plate current which tells at a glance if the plate, filament, and grid circuits are all complete. Next I replace the loudspeaker with headphones and inspect the antenna and ground connections. Any further continuity tests are very seldom necessary."

ANOTHER SERVICEMAN'S IDEA

BOB BROOKE, of Minneapolis, Minn., goes into more details, and a bit of reminiscence.

"Here I am sort of down with the flu or something and I figured it would be an opportune time to scribble a couple of lines to you about the "Serviceman's Corner." Among other things I am a radio serviceman, and as some satisfied customers think I'm not so bad as a serviceman, I thought possibly I had a chance of getting a line into the "Serviceman's Corner." The other things I am are: amateur radio operator—w9DSH-w6AWR, commercial radio operator, WGDJ-NOG, salesman (house-to-house once when broke and in a small town on the Pacific coast while waiting for my ship to come in), broadcast operator, KNAC, radio engineer in a B-power unit manufacturing company. So now that I've explained myself I'll start on some ideas I have on radio service.

"First, I will give a list of what I consider about the minimum of tools for a serviceman out on the job:

1. A good test kit for a.c. and d.c. sets.
2. A flashlight (I find Burgess snaplights to be the handiest).
3. A kit of tools containing:
   a. several sets of good pliers and cutters of various sizes
   b. several assorted screw drivers
   c. a complete set of spintites
   d. a rat-tail and several small files
   e. a pair of phones
   f. a few line drills and a hand speed drill
   g. a box of assorted screw nuts and junk
4. A bakelite balancing stick with a hex hole $\frac{3}{16}$" across.

"The test kit has two uses, it gives the customer a higher impression of the serviceman from the start and it makes a positive and quick check of the set and nearly all the circuits in the set as well as testing tubes, voltages, etc. It is the best investment a serviceman can make for himself and often gives or loses you a job. I found mine handy once when I was stranded on the Pacific coast and didn't know when I would get a ship. I took my test kit and made house-to-house canvass in a district that was bound to be good. I offered free tests on the customer's tubes and batteries and told them truly just the condition of their set. In case they needed anything invariably they bought it from me. I also had a Sterling tube rejuvenator along and brought their tubes up for two bits apiece. I also sold several sets during the month I worked the district, and although it was hard work and very discouraging at times it was better than going hungry. I played the game fair and square, made a good many friends, and worked up a good little business that I passed on to a friend whom I had met—that was another example of the helpfulness of a test kit.

"The Burgess snaplight is the handiest little light for a servicemen that I have ever seen as it gets into small places and you hold it in your hand and work with the hand too. I buy them by the half dozen as I lose them or leave them all over town. They cost 26 cents apiece wholesale and last two weeks if you don't lose it in a day or two.

"As for the tools, that is another thing that a customer looks at when the serviceman arrives. A neat kit and a good clean set of tools makes a great impression on the average set-owner."

The Weston tube-checker is an excellent piece of shop equipment for the dealer-serviceman. Any 4 or 5 prong tube may be tested with this set

ANOTHER SUGGESTED ROUTINE

A few additional points are adduced by NEWELL N. WHITE, of Wichita Falls, Texas, who skims the milk of eleven years of servicing as follows:

"I have been in the game since 1917, doing service work on broadcast sets since 1921 with the exception of the two years I was with S. W. Bell Tel. Co. Therefore, I feel at liberty to tell the way I go about checking a set in the home of a customer.

"First I will give the routine I follow on battery-operated sets.

"First the A battery is checked. If it is an acid battery the test is made with a commercial current-drain tester (I find the Hoyt Cell-Check good enough). A hydrometer is never used in the home. A cell checker is sufficiently accurate and there is no danger of spilling acid. Next the B batteries are tested (with no set load) with a low-resistance pocket voltmeter, which puts a heavy enough load on batteries to cause a voltage drop if they are weak. The C battery is checked next. All batteries found defective are replaced before test continues, as all other tests require voltage to give meter readings.

"The next step is to remove tubes from set. When this is done all circuits should be open leading from batteries to set. A *high-resistance* voltmeter is connected in series with each lead from batteries. This will show up any shorted batteries, leads or filter condensers.

"The next and final step in testing the set is with a Jewell a.c.-d.c. box (would not trade it for all the rest of the equipment a serviceman could carry in a truck). This is done with all batteries connected and all tubes in their sockets, except socket under test. The Jewell box tests the filament, grid, and plate circuits of all sockets. In this test, open grid suppressor, open grid coils, poor ground connections, open plate coils, open audio transformers, etc., can be detected. If still no trouble is found the loud speaker is tested by placing it in series with an a.c. plug from a convenient outlet and the a.c. voltmeter of the Jewell test box.

"Next the antenna and ground are inspected. If none of these tests have located the trouble apparently the repairs will have to be made in the shop where I have an oscillator, stationary test board, output meter, etc.

"I might add that while the various sockets are being tested the tubes are also tested.

"In a.c. sets the troubles are less numerous as I find most calls are made on account of bad 227-type tubes or a noisy volume control. In testing these receivers the line voltage is first checked to give me an idea of whether the set voltages are high or low. After this is determined each socket is tested with the Jewell test box which shows the trouble very easily. Since the power pack should be under "set load" while it is being tested, I never like to test from the pack terminal strip. The antenna and ground are also inspected on electric sets.

"In this letter I also wish to comment on the article by Thomas Glose, in January, 1929, RADIO BROADCAST. Probably Mr. Glose was using a high-resistance voltmeter to make his continuity test. If so, the sensitive meter would still show full voltage, because no current to speak of was being passed through corroded contact.

"Now don't get me wrong. I would not start on a call or try to fix a set without my high-resistance voltmeter, but, fellows, you better watch the things. I will bet that a meter of low resistance that had a fairly heavy current consumption, as meters go, would have shown up that poor connection."

SUMMARY

The amount of test equipment the serviceman should carry with him is determined to quite an extent by just how much work he thinks he ought to do in the home of the set-owner. This too, is a matter of personal opinion, but a consensus would limit this to rather elementary tests and repairs. Actually it is a compromise involving convenience and economy. Major repairs can be effected more efficiently in the serviceman's shop than on the library table of the set-owner.

In summation, it would seem that the following equipment is adequate for making all the adjustments and minor repairs that should be made outside of the workshop:

One a.c. and d.c. tube test set;
Two screw drivers, one large and one small;
One diagonal cutter;
One six-inch pliers;
One long-nose pliers;
One small file;
One sheet emery cloth;
One piece of cloth;
One coil of wire;
One knife;
One roll of tape;
One Burgess snaplight;
One pencil with an eraser.

The procedure should be altogether logical. Spend two minutes in finding out the past history of the receiver—then proceed to diagnose the trouble. This will fall into one of four main classes: no reception at all, weak reception, noise, and distortion.

If there is no signal response, endeavor to localize the difficulty without immediate recourse to the test set. If the tubes light, hit the detector tube lightly with a pencil. A ring in the loud speaker shows the a.f. circuit to be o.k., locating the difficulty in the r.f. circuit. (No ring is, of course, indeterminate, and the usual systematic checking of power and tubes should follow.) If the trouble is in the r.f. end of the set, connect the antenna to the plates of different tubes in an endeavor to locate the faulty stage, and then go to work on it. Cases of weak reception should be similarly investigated. The possible causes of noise are many and are treated to some extent elsewhere in this department. If the trouble is distortion, the a.f. circuit should immediately be suspected, and tests made for emission, and incorrect A, B, and C potentials.

The point to be emphasized is that service time can often be cut by using a bit of common sense before resorting to a test set—invaluable as this may be. As John Dunham points out, in his article in March RADIO BROADCAST, a knowledge of radio engineering fundamentals is a servicing tool second to none.

Bad Tubes and Service Troubles

W. S. HARTFORD, of the Kellogg Switchboard and Supply Company, makes a concise and interesting observation: "You may be interested in knowing that 65 per cent. of the reported cases of no reception were traced to incorrect insertion of one or more tubes. About 15 per cent. of the cases were due to low B voltage. In consumer complaints, many owners felt that advancing the rheostat to the tubes will cause shortened tube life. The actual effect is to impair the selectivity and sensitivity of the receiver with a gradual weakening of the tubes."

The Arborphone Company broadcasts a somewhat similar warning on sheet 8 of their service manual: "We wish to call your attention to the fact that the greater percentage of power pack trouble may be attributed to defective tubes. After through tests and reports from various sections we find the following troubles are caused by defective tubes:

Lack of sensitivity, lack of volume, a.c. hum, noisy reception, and fading. However, the most serious of all the defects is that many of these tubes, after being in use a short time, will develop a short in the plate circuit, thereby frequently burning out the power transformer."

Miscellaneous

How Much Current Does My Receiver Consume?: The serviceman is often asked just how much current the particular a.c. set he is servicing consumes—a reasonable bit of curiosity on the part of the owner. MALCOLM CHASE of Taunton, Mass., suggests a simple way of determining just what it costs to operate any a.c. set, as far as current consumption is concerned.

"In order to determine the approximate cost of electricity consumed by an electric set without any accessories the following method may be used. A fifty-watt lamp which consumes five-hundredths of a kilowatt hour per hour should be turned on and, if a kilowatt costs say eight cents, multiply eight by five-hundredths. This will give you the cost per hour to operate a fifty-watt lamp. Now consult your electric watt-hour meter and count the number of revolutions the aluminum disc turns in one minute.

"Now turn on your radio set or battery charger. Suppose the disc makes one and one-half times as many revolutions as it did for the fifty-watt lamp in one minute. Obviously the radio set will cost one and one-half times as much to operate as the fifty-watt lamp. Make sure of course that the only load on the line is the device you are interested in computing the operating cost of."

Selling A.C. Tube Insurance: The Fordham Electric Company, dealers and service in the Bronx, New York, are selling the Ward Leonard Vitrohm Line-voltage Reducer, shown on page 391, to many clients in outlying a.c. districts where the line voltage often rises above safe limits. This is good business. The good will of the customer is more than worth the sale of replacement tubes.

The latest merchandizing scheme at this store will interest the small-town serviceman who is also generally the main source of radio supplies. Hundreds of burned out tubes are heaped in the window surmounted by a sign reading: "For Sale Cheap." A second sign tells the story of the line-voltage reducer as a means of preventing blown-out tubes. Dozens of customers have been brought in the store by this window display and sold on the spot. Many of them spent only two dollars for one of the line units the first time, but came back later to spend much more money for a set and accessory equipment.

Elimination of Noise

THE following trouble is quite common, although the first time it is encountered it might cause a lot of extra work. It starts out like a microphonic howl and grows to a roar of rather low pitch. The usual routine tests indicates everything o. k. except that when a certain 226-type tube is inserted in the set-tester the howl stops. However, when it is returned to the set the noise starts again. Upon examining the tube it will be noticed that the filament and grid are nearly touching each other.

When the tube is in the set the vibrations from the loud speaker cause the filament and grid to short, thus causing the howl. When the tube is inserted in the tester, which was away from the set the vibrations do not affect the tube and everything seemed o.k. The remedy is obvious. A good way to find the offending tube is to hold each tube with one hand and tap it lightly with the other. A defective tube will cause a prolonged scratchy noise in the loud speaker.

H. WEIMAR, Appleton, Wis.

DATA FROM KING MFG. CO.

The service bulletins of the King Manufacturing Company, of Buffalo, N. Y., contain some interesting "dope" on the elimination of noise.

"Some radio tubes are microphonic in action and when used will cause a ringing sound in the loud speaker. This will be especially noticeable when the set is jarred or when the lid is closed. Usually microphonic tubes cause the greatest trouble in detector and first-audio stage.

"To overcome this difficulty first try changing tubes into different sockets to isolate the microphonic ones. If this does not eliminate your troubles ballast the tubes mechanically. To do this either use the commercial devices marketed under the name of "Howl Arrestors," etc., or ballast with rubber tape.

"Wire-wound rheostats will at times, in spite of all precautions, become noisy and produce a grating sound when turned. This is due to the natural wearing of the resistance wire and can be overcome easily. Simply take a soft lead pencil and rub the lead over the wire winding of the rheostat. This slight application of graphite lubricates the rheostat and in no way changes its electrical characteristics."

INSULATION CAUSES NOISE

C. W. Mangold, of Richmond, Ind., sends along the following that is typical of the many exasperating cases of noise one encounters when the receiver is jarred.

"Just recently I serviced a Bremer Tully six-tube receiver. The only station that could be brought in was WLW and the signals were very weak. After checking the tubes, antenna, loud speaker and power supply, and finding them in good condition, I started to test the set.

"By moving the first a.f. tube, and getting it in a certain position the signals would come in very loud, but just as soon as the tube would go back to its normal position the signals would become weak again. I then removed the set from the cabinet and looked for a bad tube socket or connection to the socket but they were all right. In placing the tube back in the socket and moving it around, I found that the tube prongs were moving some wires that run to the r.f. coils which were covered with a metal shield. The insulation had worn off of one of the wires and was shorted on the shield.

"By moving the tube it would move the wire far enough to eliminate the short and of course the signals would increase. After the wire was wrapped with tape the set worked satisfactorily."

DETERMINING LOCATION

The Freshman service bulletin contains the following suggestions in reference to checking up on noise:

"Disconnect antenna and ground leads. If set becomes quiet, and signals, though now very weak, are heard, the trouble is in the antenna system or it is caused by electrical disturbances. If due to antenna system, repair same. The location of interfering electrical disturbances may be found with the assistance of the local power company.

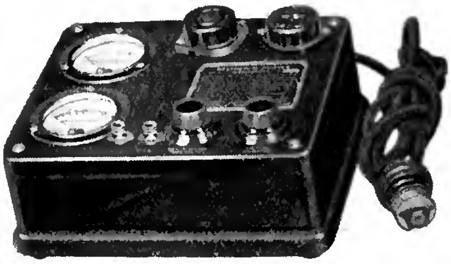
"If removing antenna and ground does not eliminate the noise the trouble is in the receiver or power supply. A defective tube may cause noise, and poor or dirty contact at tube prongs or between volume-control arm and winding may be the cause of noisy reception. A poorly soldered or broken connection in the receiver may be the cause of noise. Check the by-pass condenser for leak or intermittent short circuit.

Very often noise is picked up by the antenna system. Such noises are generally caused by line leaks, battery chargers, and static. But the fact that a noise disappears when the antenna is disconnected, or when a station is detuned, *does not necessarily mean that the noise is not in the set itself.* Noises of all kinds, set and external pick-up, are always accentuated when a signal is being received. The detection of a carrier wave sensitizes the receiver to all sound disturbances.

If it is impossible to determine whether or not the noise is arriving by way of the antenna by ordinary means, an oscillator should be coupled to the receiver, and its wave picked up. The oscillator should be so closely coupled that the pick-up is not affected through the usual antenna system. Then the change in sound intensity with the removal of the antenna is a reliable indication of conditions.

The Service Forum

A COPY of John Rider's book, *A Treatise on Testing Units for Service Men*, has found its way to "The Serviceman's Corner." This is a small book containing some fifty pages of material much of which will be of

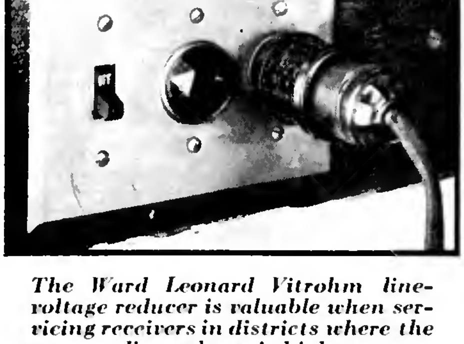


The Weston set-checker which has been designed especially for portable use

value to the radio workers to whom it is addressed. Mr. Rider has succeeded in collecting from diversified sources considerable data of interest to the serviceman. Items of probable utility to our readers are short chapters on tube reactivation, a general utility tube tester, and the section on voltmeters and ammeters with their multipliers and shunts. This book can be obtained from the Radio Treatise Company of New York City for $1.00.

ONE of the best books on the general servicing of commercial receivers that the service editor has ever seen (and certainly one of the best all around service manual published by a manufacturer for distribution to his dealers) is that circulated by the King Manufacturing Company of Buffalo, New York. This is furnished in loose-leaf form, with an attractive and durable binder. It covers many general items of interest in an altogether authentic and useful way. Such points as tube rejuvenation, a simple modulated oscillator, adding power tubes, static, test equipment are considered with no special emphasis on King receivers. Any servicemen having occasion to service King receivers should make it a point to secure a copy of these bulletins if they are not already on his radio book shelf.

THE dentist keeps a careful record of his patient's mouths by means of a chart of the teeth noting, their peculiarities and the work done upon them. The service bench might take a tip from the dentist's chair. A simple layout chart of each set serviced, with a notation of voltages, tubes used and in which sockets, along with an abbreviated history of this particular installation and the results expected from it under normal operation, would speed up the next service job on that receiver.



The Ward Leonard Vitrohm line-voltage reducer is valuable when servicing receivers in districts where the line voltage is high

SEVERAL servicemen have suggested that it would be a boon to the independent serviceman if he could buy a test set on the installment plan. Such purchase plans must generally be arranged with through the dealer rather than the manufacturer, and in such cases the serviceman loses the discount that is legitimately his.

A CALIFORNIAN serviceman, in the employ of a dealer, writes us: "In one of B. B. Alcorn's articles he stressed the necessity of good testing equipment. I had a hard time getting mine together and when I came to the Jewell Analyzer thought I never would be able to get the $97.50 together. After a little thought I went to my employer and explained to him the necessity of an analyzer, telling him that I felt our service could be improved greatly by its use. A few days later I received my outfit, getting it at cost and am paying for it $10.00 per month. Maybe some of the servicemen who are reading your magazine have been unable to obtain this equipment but have a big-hearted boss."

THE Supreme "Radio Diagnometer" can be secured from the Supreme Instrument Corporation of Greenwood, Miss., by a down payment of $38.50 followed by ten monthly payments of $10.00 each. This is a complete tool kit and test set combination, mounted in a neat carrying case. The entire equipment weighs 25 pounds.

SPEAKING of test sets call to mind a half dozen letters from servicemen requesting construction data on simple test equipment requiring only two meters, with the necessary switches and shunts. We should be glad to publish pictures and diagrams of such a job. Have you one?

MANY a serviceman can make a profitable connection with a local dealer. Not a few radio dealers have gone into the radio business via a slow evolution from furniture or kitchen stoves. They know nothing whatever of the servicing side of their business and are losing good will because of their ignorance. They would be more than happy to coöperate with a good serviceman.

The F. O. Kinnecom Electric Company (Electrical Engineering and Construction) of Providence, Rhode Island, established many profitable dealer associations by sending out the following form letter on their letterhead to radio dealers:

"Gentlemen:

"For the past 33 years the writer has been engaged in electrical engineering and construction.

"Our experience shows that fully sixty per cent. of the trouble with radio to-day is caused by crude and faulty installations. Two or three years ago the public thought that noise was associated with reception, but to-day, with the number of high-grade sets on the market and the keen competition in making sales, it is our honest belief and experience that the houses that are making proper installations so as to insure a good quality of reception are the ones that will ultimately dominate the trade.

"We are qualified to make inspections of radio installations, or to lay out or supervise the actual work. We have a fine assortment of high-grade testing instruments and we welcome an investigation as to our ability and standing in the above line of work.

"Would it not be a good sales talking point to state that all radio installations made by your house are passed on by an established engineering company, who issue an itemized report to you? May we not be of service to you?

"Yours truly,".

The First Steps For Dealer's Profit

PRACTICAL RADIO SERVICE RECORDS

By JOHN S. DUNHAM

Q R V Radio Service, Inc.

LET'S eavesdrop on the office end of a telephone conversation which runs something like this: "Jones Radio Service. Yes, Mrs. Green, we shall be glad to have a man call. What is the address, please? Which model is your radio? Are you using batteries or a power unit? About how long ago did you last have new B batteries? Thank you. When would you like to have a man call? Only in the morning? Yes, I know we've been there a number of times, Mrs. Green, but we have such a large number of calls that it is quite impossible to remember all the special details of each of them. Yes, we'll have a man call to-morrow morning. Thank you."

Now let's eavesdrop in another office. "Smith Radio Service. Yes, Mrs. Green." While Mrs. Green is speaking, the efficient young lady at the desk reaches about ten inches to her right, to the alphabetical file containing perhaps a thousand active records, and extracts therefrom—*within five seconds* —a card bearing the complete record of the last several calls made at Mrs. Green's home. The record makes questions unnecessary, and she immediately replies to Mrs. Green's statement of trouble by saying: "We shall be glad to have a man call to-morrow morning to take care of it, Mrs. Green. Thank you. Good-bye."

While the example given in the first paragraph is exaggerated—the average service concern would not ask all those questions—every bit of that advance information is of real value in servicing a radio. If complete data is not on record, then it must either be obtained from the customer each time a call is requested, or else the serviceman must approach the job "blind" and hope he'll have everything he might need. Of course, it would be possible to have a serviceman so fully equipped that he would be prepared at all times to meet extraordinary demands for any amount of supplies, but it would be neither practical nor economical. If proper records are kept, each man takes with him, each day, only the supplies he actually needs, plus a small amount for emergency calls, thus keeping the average inventory down to a figure of perhaps one-fifth of that which would otherwise be necessary.

A Card System

THE system of records we shall describe briefly has been used by one organization for the past five years and has proven itself to be very satisfactory. The 3 by 5 inch job card illustrated on this page is written up as soon as a call comes in, and is then immediately put in a numerical file under the date the work is to be done. If it is to be done the same day, it is put either into the individual job-card box of the man to whom it is assigned. or, if it is to be telephoned to him, in a special place on the desk until that is accomplished, after which it goes into his box to be written up when he comes in. At the end of each day the job-cards filed under the date of the next day are assigned to the various men, a record is made of the assignments in a day-book used only for that purpose, and they are then placed in the men's boxes. There is no waiting in the mornings for work to be assigned.

The reports written by the men on the job-cards, *before leaving each job*, are transferred practically verbatim, the next morning, to the 5 by 8 inch master-cards illustrated. These large cards, which have been filed in the "to be done" section pending completion of the work, are now put into the "to be billed" section, or if cash was paid, into the "completed" section. The "to be billed" section is removed bodily each afternoon, and after billing, the cards are filed in the "billed" section, where they remain until paid or written off. Statements are sent out monthly, and that fact is recorded on the cards. When payment has been made, the card is then placed in the "completed" section.

When the first master-card has been filled up, and card number two has been started with the record of a call made, then card number one is placed in an inactive "old" file. Every six months, the cards in the active "completed" section upon which no call have been recorded during the past twelve months, are removed, carefully tabulated in a classified record of customers gained and lost, and are then placed in a "dead" file.

Arrangement of File

THE plane of the cards is parallel to the length of the drawer, so that the person at the desk is directly in front of the cards which are in either the right- or left-hand drawers, when they are open. Each of the active alphabetical sections employs guides of a color differing from the colors of the other active sections. Each section has a special guide preceding it, with a large tab on which is printed the name of that section, and they are placed, from front to back, starting at the front end of the drawer, in the following order: "To be done", "To be billed," "Billed," "Completed." The small job-card file, and the supply of blank cards of both sizes, are kept in the upper left-hand drawer. The lower drawers on both sides are used for less active, and inactive files, arranged for accessibility in the order of their degree of activity.

QRV RADIO SERVICE Job No. 25101

Dealer CRY ... Phone ...
Customer Jones, Carl F. ... Phone ...
Address 11 E. 12 St. 4-B

Work to be done Svc. Probably needs A's, may need B's — Set Radiola 25
Tubes UX-199-120
Supply Dry A, B, C
LS Radiola 100

Service } by Hunt Date 10/30 A. M. ~~P. M.~~
Inspection by ... Date ... A. M. P. M.

Installation

Flat-top ... ft.
L. I. Outside ... ft.
Inside ... ft.
Gnd. ... ft.
Stas. hrd. & vol. ...
... Qual. ...
Remarks ...

Inspection or Service

Inst. O.K.? ...
Stas. hrd. & vol. WEAF, WJZ, WOR
good Qual. good
A 4.6 B 81-40-118 C 4.5-22.5
Report Put in A's. Cleaned and adj. rheo. Put in 3 new tubes. Rest OK Recommended p.j. meter
Furnished 6 - 6A's 3UX-199 tubes
Collected ...

Fig. I—These illustrations show a job-card and master-card of the type described by Mr. Dunham completely filled out on both sides

Bill to } Dealer } QRV (from R.C.A.) — ZONE I — CARD No. 6
Address ...
Customer Jones, Mr. Carl F. — Res. Addr. 11 East 12th Apt. 4-B — Set Radiola 25
Tubes UX-199-120
Res. Tel. ... — Supply Dry A, B, C
Bus. Tel. GRA-3200 — Bus. Addr. 30 West 23rd St. — L. S. Radiola 100

Date	Done by	Job No.	Work done. Results obtained	Date Billed	Date Pd.
10/30/26	Hunt	25101	SVC. Put in A's, Cleaned and adj. rheos. Replaced		
			3 tubes. Recommended p.j. meter. Rest OK. WEAF, WOR		
			WJZ - good vol & qual. A 4.6 - B 81-40-118 -		
			C 4.5-22.5	10/31	11/15
1/3/27	K'hof	26937	SVC. Open 1st a.f. pl cat. Brot in catacomb for		
			replacement. A's and B's needed		
1/4/27	Price	26964	SVC. Put in new cats. A's, B's, C and one tube		
			Shifted tubes. Adj. L.S. and loop contacts. Rest OK	1/6/27	3/1
			Locals - good vol & qual. A 4.6 B 92-46-138		
			C 4.5-23 Sold p.j. meter		
3/20/27	H.M.L.	29452	SVC. Put in A's. Rest OK. WEAF, WAAM, WHN - good		
			vol & qual. A 4.6 B80-40-120 C 4.5-22½	3/21	6/4
6/6/27	Pede	31004	SVC. Put in A's and replaced open L.S. coils. Fixed		
			loop wires. Replaced open vol contr cartridge. WJZ		
			good vol & qual. A 4.6 B79-38-119 C 4.5-22½	6/6	6/10

5-5M-11-26

	Date 10/30/26			Date 1/3-4/27			Date 3/20/27			Date 6/5/27			Date		
O. Inst.															
Ant. eqp.															
In. Inst.															
Loop set hukup															
Service Zone 1	6	2	50		6	00		2	50		2	50			
As:	6	3	00	6	3	00	6	3	00	6	3	00			
Bs: 10308				2	9	50									
" 2158				2	4	00									
Cs: 5156				1	1	75									
"															
Tubes: UX 199	3	6	75	1	2	25									
"															
"															
Catacomb replaced					a.	c.									
Weston pin jack meter				1	7	00									
Radiola 100 coils										1 pr	1	65			
Vol control rheostat										1		45			
Trav. Exp.															
Taxi															
	Total	12	25	Total	32	50	Total	5	50	Total	7	60	Total		

Data on Filament-Type Tubes

CHARACTERISTICS OF POWER RECTIFIERS

By ROGER WISE

Formerly, Chief Engineer, E. T. Cunningham, Inc.

> *The author of this article on the whys and wherefores of filament-type rectifier tubes and circuits was, until recently, Chief Engineer of E. T. Cunningham Inc. He is now associated with Grigsby-Grunow and actively engaged in putting into shape a tube manufacturing plant that in size will rival the largest now in existence. Mr. Wise points out the development of the present rectifier tubes of the 280 and 281 types. He shows that with certain types of filter circuits the instantaneous currents that must be supplied by the filament of the tube are much too great for the tube to have long life, and suggests another filter arrangement which increases tube life.*
>
> *It has been the experience of the Laboratory Staff that the suggested filter arrangement, whereby the first filter condenser is eliminated, produces too much hum for use with good amplifiers and good loud speakers. The Staff's lack of success may be accidental, and should be glad to hear from readers who experiment with these two filter systems.*
>
> —THE EDITOR.

THE first socket-power device sold in any quantity was the "B eliminator" which at the time these devices were first offered, some three years ago, commonly utilized the general-purpose tube, type cx-301A, as the rectifier. Some of these were single-wave rectifiers, capable of supplying 10 to 15 mA., at 90 volts, while others were full-wave rectifiers using two tubes and with an output of 20 to 30 mA. The outputs mentioned were obtainable only with tubes in which the filament was in the best of condition, and the slightest drop in filament emission became noticeable immediately in a reduction in output current and voltage.

These "B eliminators" gave good service at the time they were introduced, the conditions differing considerably from present-day requirements in several important respects, the most important one being the plate current drain of the sets then in use. Five-tube sets were just becoming popular, with six-, seven-, and eight-tube sets quite rare. The average receiver was of the three- or four-tube type, requiring from 10 to 20 milliamperes, at a maximum potential of 90 volts. The rapid increase in the number of tubes per receiver soon raised the maximum demand to 30 mA. in the case of the five-tube receiver in which the C battery was omitted altogether. Two years ago, power-amplifier tubes were introduced, the 371-type tube adding nearly 15 mA., to the total receiver current drain when operated 135 volts, and 20 mA. when operated at 180 volts. As a result of this increase the maximum current requirements became 50 to 60 mA. Other developments were the type of receiver in which the filaments of cx-299 tubes were operated in series from socket power, requiring 65 to 75 mA. and those using cx-301A in series and requiring 250 to 300 mA.

The rectifier using the cx-301A, soon became inadequate in the face of the rapidly increasing current demand, and the cx-313, a full-wave rectifier, and cx-316B, a half-wave rectifier, were introduced, the cx-313 providing an output of 65 mA., the maximum allowable transformer voltage being 220 volts a.c. per anode. The cx-316B also has a rating of 65 mA., but the design is such as to permit the use of higher transformer potentials, 550 volts. With an efficient filter the cx-313 provided a maximum voltage of 180 volts, and the cx-316B, 450 to 500 volts. These types are now being superseded by the cx-380 (full-wave) rated at 125 mA. and 350 volts a.c. transformer voltage per anode and the cx-381 (half-wave) rated at 110 mA., and 700 volts a.c. The latter two tubes have been in production only a short time, and the data presented in connection with them is subject to slight modifications.

The circuit diagram of one of the early types of rectifiers designed to use cx-301A tubes, is shown in Fig. 1. This circuit diagram also shows the placing of the oscillograph vibrators used in testing the performance of this unit as shown in the following figures.

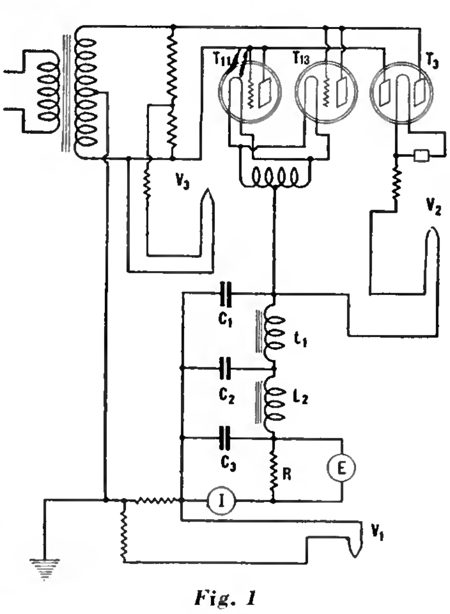


Fig. 1

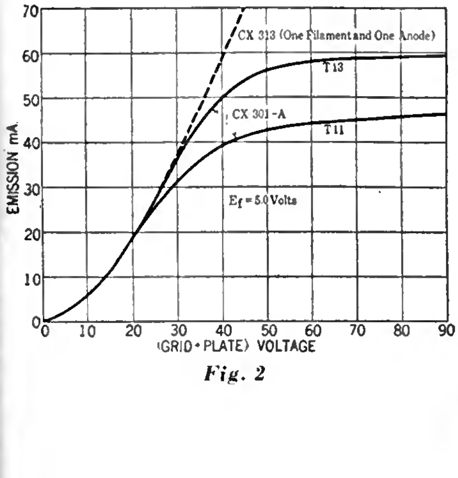


Fig. 2

Vibrator V_3 is arranged to show the transformer secondary voltage, which, with 110 volts applied to the primary, was 230 volts r.m.s., or 115 volts per tube, the applied voltage to each rectifier being one half of the total transformer voltage because of the full-wave connection. Vibrator V_1 reads the instantaneous current through the tube, while V_2 by means of a special circuit arrangement reads the voltage across the tube only during the time it is conducting current. The back voltage across each tube is blocked off by means of the auxiliary full-wave rectifier tube, T_3 in the diagram.

With this arrangement it is possible to get a complete record of the performance of each rectifier and to determine the exact point at which overloading, due to limited filament emission, begins. The power lost in the tube can also be computed, and the efficiency determined.

In taking the records, high sensitivity vibrator elements requiring about one milliampere per millimeter deflection, were used and a 10-millimeter deflection was satisfactory for most of the work. The current required, 10 mA., could not be disregarded in taking some of the voltage readings, but the effect of this current, for instance, the current flowing through the vibrator V_2, was eliminated by making an extra exposure on the film, the vibrator V_1 being opened when V_2 was being read, and *vice versa*. Tubes T_{11} and T_{13} were cx-301A's while T_3 was a cx-380 rectifier tube.

In Fig. 2 the emission characteristics of the cx-301A tubes used in the tests on this older type of socket-power device are shown. The tubes were prepared for service by an ageing treatment so that the emission would remain entirely steady during the taking of the film. A voltage of 100 volts was applied to both plate and grid, under which voltages the full emission current of 40 to 60 milliamperes was drawn over to these electrodes. Under this very severe overload the emission dropped slowly, and after the current had dropped to 20 mA. the voltage was cut off and the filament reactivated at 7.0 volts for a few minutes. After a few cycles of this treatment the emission remained steady for a long period of operation at the high voltage.

The curves show that practically the full emission current flows when a potential of 50 volts is supplied to the anode (that is, to the grid and plate connected together as an anode) and that there is very little increase as the applied voltage is raised to 90 volts or above. The dotted line gives some data for a cx-313 tube.

When a cx-313 was substituted for the two cx-301A tubes in taking the record shown in

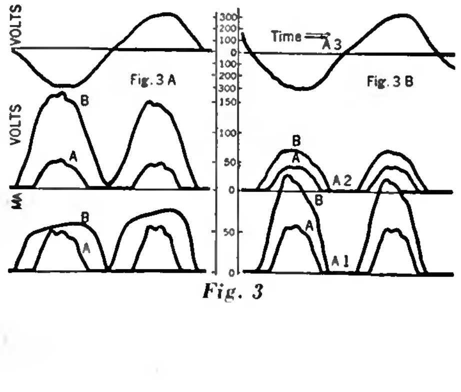


Fig. 3

Fig. 2 the emission curve of one filament and anode of this tube, shown by the dotted line, (Fig. 2) should show no evidence of saturation within the limits of the figure.

In the oscillograph record, Fig. 3, each figure contains two separate records of the performance of the socket-power unit in question. The records made by vibrators V_2 and V_1, labelled A in the figure, show in each case the performance under a load current of 20 mA. the normal maximum for this unit, while curves B show the performance at 50 mA. output. Referring to Fig. 3A, the upper record, Vibrator V_3, is that of the voltage developed across the secondary of the transformer.

Oscillograph Records

THE voltage developed across the tube is V_2 when the current indicated by V_1 is flowing. It can be noted in the curves showing the current wave form that the voltage rises rather rapidly as the current starts to flow, and then less rapidly as it reaches higher current values. This is partly due to the fact that the resistance offered by the tube to the flow of current decreases as the current increases until the full emission current flows, and partly to the less rapid increase in instantaneous transformer voltage, near the peak of the wave. The current does not begin to flow at the instant the transformer voltage increases, but lags about 40°, this lag being due to the voltage existing across the first filter condenser. In this particular case the voltage across the load was 108 volts, and the voltage across the first filter condenser was somewhat higher. At the instant the current started to flow the transformer voltage was approximately 120 volts, indicating that this value of voltage existed across this condenser. Current then flows for the next 100° of this alternation, and at the time it ceases to flow the transformer voltage is 145 volts, as a result of the charging of the condensers. During the remaining part of the alternation the rectifier is idle.

The voltage across the tube just reached the value required for full emission current, 50 volts, and the current was slightly higher than was expected from the d.c. readings, above 50 mA. On the second alternation the current reached a slightly higher value, 55 mA., but because of the higher emission given by tube, T_{13}, the peak voltage drop was 43 volts.

Conditions indicated by record B on these two vibrators were with maximum obtainable load current, 50 mA., to obtain which the output terminals were shorted except for the resistance of the vibrator.

The voltage across the tubes reached a value close to the full transformer voltage,

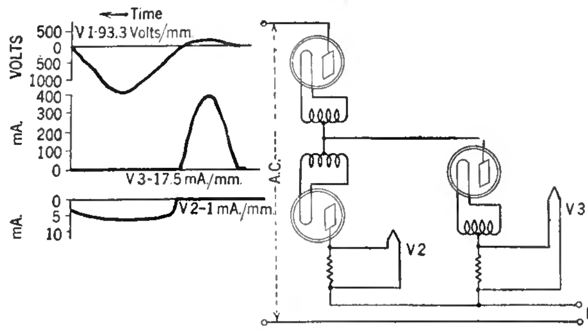


Fig. 6

the peak with tube T_{11} being 160 volts, and with T_{13} just under 150 volts. Practically all of the energy delivered by the transformer, 16 watts exclusive of the filament energy, was dissipated in the rectifier tubes, accounting for the fact that the output terminals had to be shorted to reach this current value.

At the conclusion of this test a single CX-313 was substituted for the two CX-301A's with the following results. At 20 mA. the performance is practically identical with that obtained from the CX-301A tubes, but at 50 mA., the CX-313 has ample available emission so that the saturation current is not reached, the peak value rising to 115 mA. The voltage drop across the tube is much smaller as a result, the peak being 70 volts, as compared with 160 and 150 volts, respectively, with the CX-301A tubes. Since less voltage is consumed in the tube, more power is available in the output circuit and it is no longer necessary to short the output terminals to obtain this current. The output voltage, in fact, reached 60 volts, the output current being practically the same as before, 51 mA. As a result of this increased load voltage the voltage across the first filter condenser is increased, and the current no longer starts flowing as soon as the transformer voltage begins to rise, although it does carry current earlier in the cycle than was the case with the lower load current.

The results are tabulated in Table I.

The curves shown in Figs. 4A to 4E, record the performance of a half-wave rectifier, the type used being CX-381. The transformer potential, indicated by vibrator V_3 on each record, was maintained throughout at 750 volts a.c. The load resistance was also kept constant at 5000 ohms.

Half-Wave Rectifiers

IN THE first oscillograph record, 4A, all filter elements are omitted. The peak current value was 140 mA., while a d.c. meter in the load circuit, indicating the average current, gave a reading of 47 mA. Thus, the tube's filament was called upon to supply, momentarily, three times the average load current. This is an important fact, since the filament must be made large enough to supply the emission current for the peak value. The ratio between peak and average current will be noted for each figure, in order to determine the relative load imposed by each circuit upon the tube's filament.

The second exposure, Fig. 4B, was taken after adding a 4-mfd. condenser across the load. The charging of this condenser permitted a much larger current to flow through the tube, because of the reduced load impedance and the output current not only increased greatly in value to 102 mA., but continued to flow during the alternation when the rectifier was idle. The back voltage developed across this condenser reduced the time during which the tube carried current, thus further increasing the peak current demand upon the tube which, as indicated by V_2, rose to the value of 535 mA. The ratio of peak to average current was thus increased to $\frac{535}{102}$ or 5.2:1.

In Fig. 4C, a 20-henry choke was placed in series with the load. The effect of the self inductance of the choke in causing the current to lag behind the voltage is quite evident on this film, and it also caused a marked decrease in the peak current to 70 mA., as well as in the average current (26 mA.). The current flowed for a longer portion of the cycle, however, and the ratio of peak tube current to average load current was reduced to the more favorable value of 2.8:1. A transient voltage was developed at the moment the current ceased to flow through the tube, caused by the self-inductance of the choke.

In the next figure of the series, 4D, the usual filter system was added, the performance being similar to that obtained with a condenser alone, except for the improved filtering of the output current. The peak tube current was practically the same as in 4B, 540 mA., the output current 102 mA., a ratio of 5.3 to 1.

In the fifth figure, 4E, the usual input condenser was omitted, resulting in greatly reduced demand on the tube and also in a marked reduction in output. The results are similar to those of Fig. 4C. except that the choke was smaller, 10 henries, and, therefore, had a smaller effect in reducing both peak and *load* current. The peak tube current was 130 mA., and output 45 mA., a ratio of 2.9:1. The transient voltage which appeared in Fig. 4C was again present, and was sufficiently severe to result in an appreciable ripple in the output current.

This series shows quite clearly that omission of the first filter condenser in a half-wave rec-

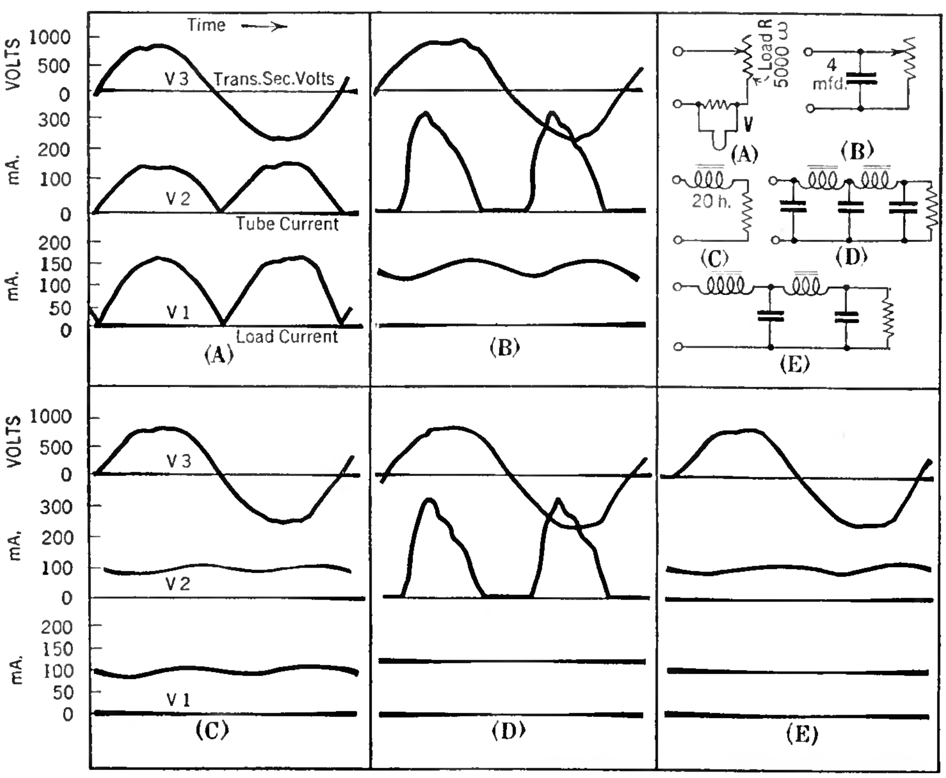


Fig. 4

tifier circuit causes an undue drop in output voltage, because of the reactive drop in the choke, to compensate which the transformer voltage would have to be greatly increased. The filter action was also impaired. The favorable factor was that this connection did result in a much lower ratio of peak tube current to average load current, reducing the maximum required emission to a low value. (See Table II)

Determining Efficiency

IN DETERMINING the overall efficiency, the transformer, the tube, and filter losses were included, but the power supplied to the filament was omitted because it remained constant and if included would have affected the readings taken with low load current, 4C and 4E, disproportionately. The reduced efficiency in these two cases was caused by the fact that the internal resistance of the tube rises rather rapidly at small plate current values. Had the transformer voltage been increased to maintain the load current at a higher value, much higher efficiency would have been obtained. It should be noted that in Figs. 4A to 4C, the power delivered to the load could not be determined from the average reading of output current and voltage because of the performance of the full-wave rectifier's irregular wave form.

Fig. 5, shows the more favorable results obtained with a full-wave rectifier tube in the same circuit combinations covered in Fig. 4. The rectifier tube was a cx-380, operating at 600 volts, or 300 volts per anode.

In Fig. 5A, with a resistance load, the load current flows during nearly the entire cycle since current is flowing through one or the other of the two tubes except at the time the transformer voltage passes through zero. The ratio of peak to average current is, therefore, reduced 50 per cent. as compared with the half-wave rectifier, being 150 and 103 mA., respectively, a ratio of 1.4:1.

In Fig. 5B, the 4-mfd. condenser is added, the increase in load current being much less marked than with the half-wave circuit, rising 19 mA., to 122 mA. The peak current through the tubes rises to 310 mA., ratio 2.4:1.

The next, Fig. 5C, shows the effect of the choke placed in series with the load. In this case it is interesting to note that the choke has quite a different effect from the condenser, since it reduces the peak current carried by the tube while it also keeps current flowing through one anode or the other during the entire cycle. The ratio of peak to load current is very low, 105 mA., to 97 mA., or 1.1:1.

Fig. 5D, shows the performance of the full-wave rectifier with the usual filter. The ratio of peak to average current is again high, 290 mA., to 118 mA., or 2.5:1.

Fig. 5E shows the performance with the first filter condenser of Fig. 4 removed. The peak current is now only 110 mA., or only 1.15 times larger than the average load current, which is 96 mA. The output voltage was only 45 volts, or 18 per cent. lower than that obtained with the usual filter, Fig. 5D, the readings being, Fig. 5D, 250 volts, Fig. 5E, 205 volts.

The various readings including, power output and efficiency, are tabulated in Table III

The ripple voltages present at the outputs of the filter arrangements shown in Figs. 4 and 5 have not been measured, but a few tests indicated that there was not a marked difference, especially if the condenser omitted at the input was added across the output of the filter. The only disadvantage noted in using the arrangement shown in Fig. 5 was the fact that the transformer voltage had to be increased 22 per cent. to obtain a load voltage equal to that obtained with the usual filter.

The very greatly reduced peak current demand on the rectifier tubes makes the use of this circuit arrangement highly desirable. Furthermore, the efficiency improves rapidly as the load current is increased, and with equal current outputs it was found that the energy dissipated in the tube was lower and the efficiency slightly higher with the filter arrangement shown in 5E than with that of 5D. The possibilities of this arrangement were called to our attention by Mr. J. C. Warner of the General Electric Research Laboratory, and these tests have shown clearly the advantages obtained in the full-wave rectifier circuit, Fig. 4, indicating that the arrangement is not suitable for half-wave rectifiers.

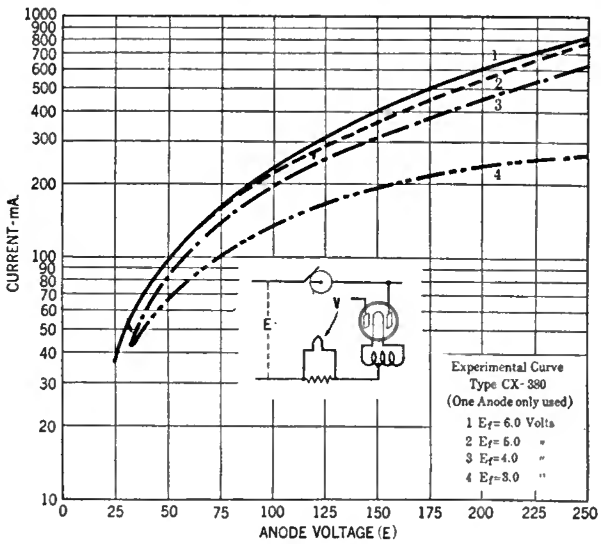


Fig. 7

Effect of Revised Filter Circuit

THE remarks made in discussing the lower emission requirements with the revised filter arrangements shown in Fig. 4E, might lead the experimenter to believe that this change would permit much higher load currents to be obtained from the rectifier. However, the amount of energy dissipated in the tube must be considered, as that is one of the important factors limiting the output obtainable from a rectifier. Fig. 6, shows a condition which may occur if an excessive load is placed on the tube, the tube used being a cx-381.

Vibrator 1 on this figure reads the full voltage across the tube both in the conducting and in the nonconducting direction. The transformer voltage was 750 volts, and the peak approximately 1050 volts. It will be noted that the peak voltage across the tube reached a much higher value, 1400 volts, due to the fact that the voltage across the first filter condenser is added to the voltage across the tube. In the conducting direction the voltage was quite low, as would be expected, 185 volts. Vibrator V_3, shows the current through the tube, which reached a peak value of 450 milliamperes. The load current is not shown on the film, but it was 140 mA., an overload of 37 per cent. on this type tube, a value which resulted in excessive heating of the plate. As a result of the heat developed by the excessive current, the plate reached a temperature at which a slight amount of electron emission occurred which is shown on an exaggerated scale by vibrator V_1. The average value of this reversed current was 4.5 mA., and the peak value 6.8 mA. The fact that during a portion of the cycle this emission was drawn across to the filament at an instantaneous voltage of 1400 volts means that considerable energy was dissipated on the filament and the overheating of the filament became evident in a visible increase in brightness in the center. The circuit arrangement and placing of the vibrators in obtaining this record are shown in the circuit diagram, the double rectifier arranged in series with the tube under test being necessary to separate the two components of the current through the rectifier tube. A small biasing voltage, not shown in the diagram was added to prevent a circulating current between these two rectifier tubes. In taking the voltage across the

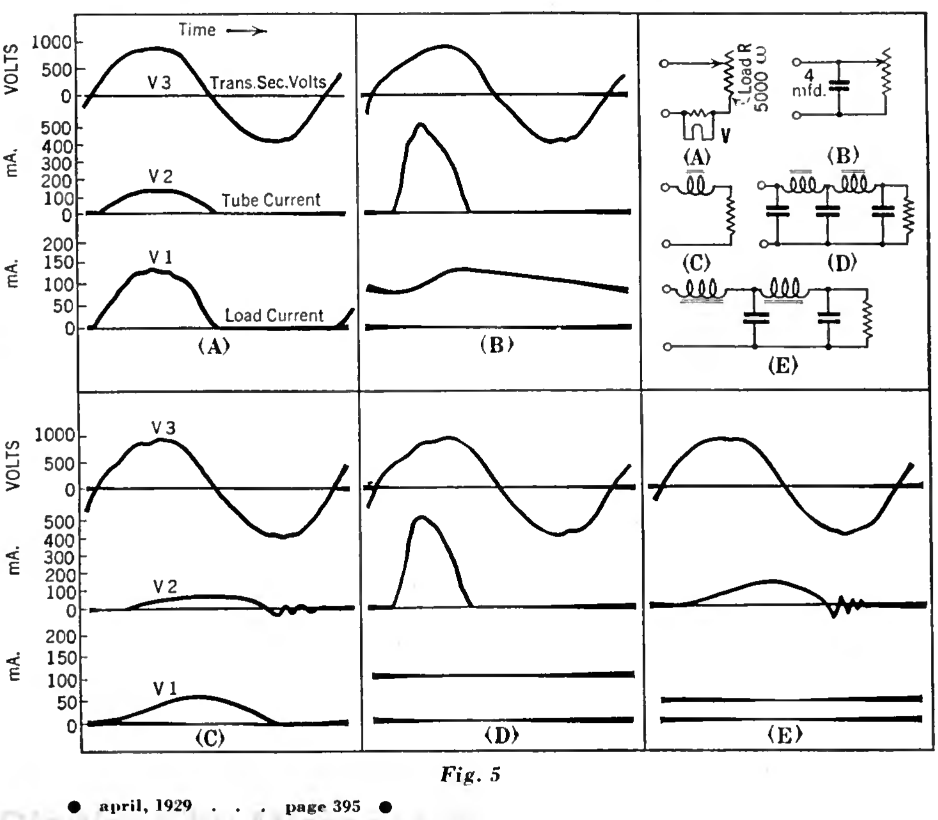


Fig. 5

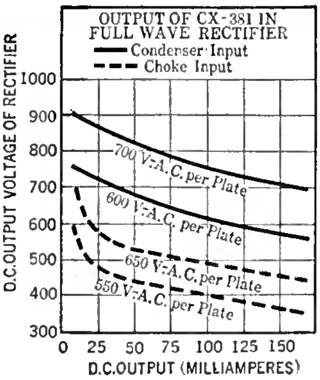


Fig. 8A

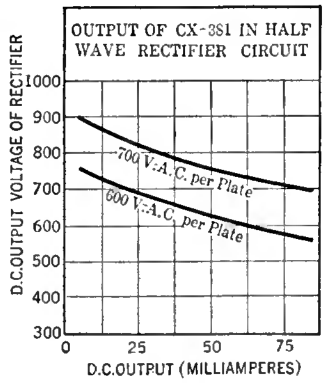


Fig. 8B

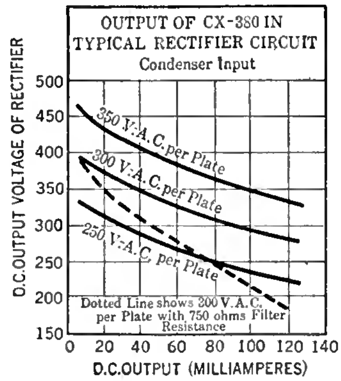


Fig. 8C

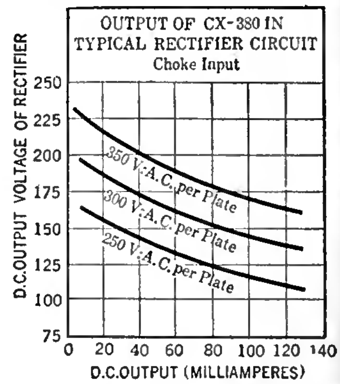


Fig. 8D

tube the vibrators recording the current through the tube were opened, as the current flowing through the voltage vibrator would have otherwise added to the reversed current. Similarly the voltage vibrator was open when the current values were being recorded.

Since the heating through the tube would be nearly as great with the improved type of filter connection, it will probably not be possible to increase the current rating of this tube to any extent when used under such conditions, even though the maximum current required is much decreased.

In Fig. 7, an experimental emission curve taken on one anode of a cx-380 tube is shown. It is not possible to read the full emission current of the tube on a d.c. test without damaging the tube as is the case with all tubes in which a large filament is used. In taking this film, voltages up to 250 volts were applied directly to the anode for a very short time at the proper intervals by means of a synchronous contact mounted on the oscillograph motor. In this way a current peak occurred at the same instant each cycle and gave a deflection on the oscillograph vibrator at a fixed point on the screen. In this way the amount of energy dissipated in the tube was kept low, and by calibrating the oscillograph vibrator the current readings were determined. The curves taken showed clearly the very satisfactory characteristics of the oxide-coated filament developed for this tube. Curve 1 shows the performance with a filament voltage of 6 volts, giving a slightly higher anode current than that obtained at 5 volts. The current was still increasing rapidly as the applied voltage was increased to the maximum used, 250 volts d.c. The filament voltage of 6 volts is not of course the normal operating voltage, and Curve 2 shows the emission obtained at the rated voltage of 5 volts, the current reaching the high value of 800 mA. with 250 volts applied. Curve 3 shows the performance at the reduced voltage of 4 volts. Even at this voltage the current was still increasing rapidly at 250 volts and was 620 mA. Curve 4 was taken with the filament voltage reduced to 3 volts, and this curve shows more definite evidence of saturation. The emission current still reached the surprisingly high value of 270 mA.

The fact that the oxide-coated filament does not give a definite saturation current is well known, and has been pointed out by many experimenters.

Performance curves of the cx-381 tube as a half- and full-wave rectifier are shown in Figs. 8A and 8B. In taking these data a large transformer having good regulation was used. The voltage was measured at the input to the filter, hence in using these data, proper allowance must be made for transformer regulation and for the IR drop in the chokes in estimating the transformer voltage required to obtain the desired voltage at the output terminals of the filter in any given case. Fig. 8B also shows in dotted lines the output voltage obtained when the first filter condenser is omitted.

Similar data is shown for type cx-380 in Figs. 8C and 8D. In these figures the latest recommendations regarding transformer voltage and rectified current output are shown. Maximum values for the cx-380 and cx-381 (Jan. 1, 1929) are:

	Rectified output	125 mA.
	Transformer voltage, per plate	350 volts
For type cx-381:		
	Rectified output	85 mA.
	Transformer voltage	700 volts

In using these values the experimenter and engineer should regard them as the limiting values rather than as the average working values, as has been done at times in the past. If, for instance, it is anticipated that an over voltage of 10 per cent., due perhaps to line voltage fluctuations, will be encountered frequently in practice, the working voltages and currents should be reduced to such an extent that the above values will not be exceeded when the higher voltage is applied to the primary of the power transformer in the equipment in question.

Note: The chokes used were rated at 10 henries, 300 mA. When used with load currents up to 125 mA. the inductance was approximately 20 henries. This difference in inductance values had only a minor effect on the results obtained.

Table I

Rectifier Tube	*Line Voltage*	*Load Resistance Ohms.*	*Load Current mA.*	*Load Volts*	*Power Delivered to load Watts.*	*Remarks*
2cx-301A	110	5400	20	108	2.2	*Max. filament emission required*
" "	"	0	50	0	0	*Tubes severely overloaded.*
1cx-313	"	5400	20	108	2.2	*Tube lightly loaded.*
1cx-313	"	1200	51	60	3.1	*Tube load 78 % of maximum.*

Table II

Circuit Connection	*Transformer Input Watts*	*Load Volts*	*Load Current mA.*	*Peak Tube Current mA.*	*Output Watts*	*Ratio Peak to Average Current*	*Overall Efficiency percent.*
4A	43.	225	47	140	25.5	3:1	59
4B	90.	525	102	535	54.5	5.2:1	60+
4C	19.5	132	26	70	5.9	1.5:1	30
4D	90.	525	102	540	54.5	5.3:1	60
4E	25.	225	45	130	10.1	2.9:1	40

Summary of Fig. 4

Circuit Conditions:

Line Volts	110 a.c.
Transformer Volts	750 a.c.
Filter Chokes	10 Henries
Filter Condensers	4 mfd.
Load Resistance	5000 Ohms.

Table III

Circuit Connection	*Transformer Input Watts*	*Load volts*	*Load Current mA.*	*Peak Tube Current mA.*	*Output Watts*	*Ratio Peak to Average Current*	*Overall Efficiency per cent.*
5A	45.	219	103	150	23.6	1.4:1	52.5
5B	59	258	122	310	33.5	2.5:1	56.5
5C	38	204	97	105	21.2	1.1:1	55
5D	57	276	118	290	33.1	2.5:1	58
5E	38	215	96	110	20.8	1.15:1	55

Summary of Fig. 5

Circuit Conditions:

Line Volts	110 a.c.
Transformer Volts	600 a.c.
Filter Chokes	10 Henries
Filter Condensers	4 mfd.
Load Resistance	2350 ohms.

No. 19 *Radio Broadcast's Home-Study Sheets* April 1929

Fundamental Radio Theory

THERE is a simple formula that must be used very generally if one is going to plan or experiment in a quantitative way with radio circuits. Its use need not involve any tedious mathematical reductions, as the results of this formula have been reduced to tabular form. The application of this formula is so fundamental that every student of the subject should have a clear understanding of the simple manner in which it is derived. It is, in fact, the connecting link, so to speak, between two very different electrical manifestations—the alternating current that lights our homes and the faint radio waves that find their way to the antenna.

It is assumed that the reader is already possessed of an elementary knowledge of electricity and is familiar with the fundamental units involved in expressing such quantities, as voltage (E), current (I), resistance (R), capacity (C), and inductance (L). The last term is the only one that usually presents any difficulty, but it will become clear as the work proceeds.

Ohm's law, $I = \frac{E}{R}$, (See Home Study Sheet No. 3) expresses the relation of current, voltage, and

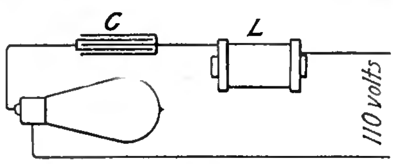


Fig. 1—Tuning 60-cycle 110-volt supply

resistance in a direct-current circuit. The corresponding formula for an alternating-current circuit is:

$$I = \frac{E}{\sqrt{R^2 + \left(2\pi fL - \frac{1}{2\pi fC}\right)^2}}$$

in which f is the frequency of the alternations. Now it requires scarcely an elementary knowledge of algebra to see that if the two terms inclosed within the brackets in the denominator can be made to equal one another, their difference will be zero, and the equation becomes,

$$I = \frac{E}{\sqrt{R^2 + 0}} = \frac{E}{R}$$

which is Ohm's law. When this condition exists the circuit is said to be *tuned*. The essential point to be observed is the fact that the denominator of the equation will be a minimum, and therefore the value of the current is maximum, *only* when

$$2\pi fL = \frac{1}{2\pi fC} \text{ or when } f = \frac{1}{2\pi\sqrt{LC}}.$$

An experimental application of this important formula may be had readily if there are at hand one or two coils wound with fine wire on iron cores—the primary of an old high-ratio audio transformer, for example—and some condensers, such as are used as part of filters or by-pass equipment. Connect a ten- or fifteen-watt lamp to the 110-volt alternating-current house supply in series with a coil and a condenser, as indicated in Fig. 1. When approximately the proper values for L and C for a 60-cycle current are secured, it will be found that when the condenser is short-circuited the lamp will burn less brightly, thus indicating that less current is flowing. To arrive at appropriate values of L and C for striking results, it may be necessary to use two coils in series, or two condensers in parallel, all depending on the equipment at hand. But the experiment is quite worth while, particularly to one whose experience has been largely with direct current, as it demonstrates so clearly that a condenser, which is a non-conductor in the case of direct current, is not only a conductor for alternating current, but may actually increase the flow of current.

To apply our formula to this experiment, let it be supposed that a 1-mfd. filter condenser is used. This is one-millionth of a farad, which is the primary unit. A simple calculation will then show that for the usual frequency of 60 cycles per second an inductance of approximately 7 henries will be required to tune the circuit to produce the maximum current flow.

No matter how different it may seem, radio is simply a manifestation of an alternating current of high frequency, the difference being purely one of degree and not of kind.

The velocity at which a disturbance, say sound or light, travels depends on the medium through which it is transmitted. Thus, sound has one velocity in water (about 4900 feet per second) and another in air (about 1100 feet per second), but for either medium the velocity of all sounds is equal. That is, a note from the upper end of a piano will reach a distant observer as soon as one from the lower end. As both light and radio are dependent for their transmission on the same medium called the ether, they, in accordance with all other observed wave phenomena, travel at the same velocity. This velocity, is approximately 300,000,000 meters a second.

As the velocity of propagation is constant, and as this velocity is equal to the length of one wave multiplied by the number of waves per second, or the frequency, f, it necessarily follows that $f = \frac{300,000,000}{\text{wavelength}}$ and if $f = \frac{1}{2\pi\sqrt{LC}}$, wavelength $= 2\pi\sqrt{CL} \times 300,000,000$ or if microhenries and microfarads are used wavelength $= 1884\sqrt{LC}$ frequency in kc. $= \frac{159.2}{\sqrt{LC}}$

These relations have been worked out for a great many wavelengths, and a few are presented in the following table. Its value to the experimenter will be evident. With a given coil and condenser, it is only necessary to multiply the inductance of one by the capacity of the other, to find the wavelength to which they will respond. If a condenser of a certain capacity is at hand, a simple division will tell us what the inductance must be to tune to a given wavelength. As the experimenter begins to get his laboratory together, he will soon find himself determining the inductances and capacities of his various coils and condensers, and, with the table at hand, he may always keep informed as to the wavelength or frequency of the current he is handling.

Meters	f	L × C
100	3,000,000	0.00282
200	1,500,000	0.01126
300	1,000,000	0.0253
400	750,000	0.0450
500	600,000	0.0704
600	500,000	0.1013
700	429,000	0.1379
800	375,000	0.1801
900	333,000	0.228
1000	300,000	0.282

The experimenter will find a complete table of L C products in *Principles Underlying Radio Communication*, the Signal Corps book, and he should either get such a table or work out one for himself. The following rule will be helpful: For smaller values, divide meters by 10 and L×C by 100; for larger values, multiply meters by 10 and L×C by 100.

Mechanial Analogies

The following mechanical analogy may aid in giving a little clearer view of the phenomena involved. The weight, L, in Fig. 2 is mounted on the upper end of an arm, the lower end of which is pivoted at the floor. A spring, C, is connected to the weight and to a rigid support, and is of such a length that the weight stands directly over the pivot when the spring is neither compressed nor extended. If the weight is pulled to one side and released it will vibrate back and forth at a certain definite frequency, depending on the size of the weight and the nature of the spring. The same frequency can be obtained by making the weight heavier and shortening the spring, or by reducing the weight and lengthening the spring.

In the above example the frequency depends on the product of two factors, and this is precisely the case in radio oscillations. We can continue to tune to a certain wavelength by increasing the inductance and reducing the capacity, or *vice versa*.

The spring is a rather apt analogy for a condenser, for the reason that when the latter is charged, the electrons are supposed to be displaced from their normal positions, to which they rebound when the condenser is discharged. Similarly appropriate is weight or mass in representing inductance, which may be considered as electrical inertia. Just as mass tends to retard the beginning of motion and to continue the motion when the applied force is withdrawn, so inductance opposes a sudden increase of current after the applied voltage ceases. The analogy may be carried further by considering the resistance of the air on the weight as corresponding to electrical resistance. Let it be supposed that the spring and weight were set up in a room from which the air has been exhausted, and that a fine thread attached to the weight is intermittently pulled exactly in tune with the natural period of oscillation. After a little time the oscillations will become very violent, and if the spring were of highly elastic material, it is quite possible that the repetition of a very minute force would finally break it. In other words, the internal forces generated within the spring may many times exceed the applied force, and this is exactly what occurs in a tuned electrical circuit when the resistance is greatly reduced, the voltage across the condenser being many times the impressed voltage. Hence it is that often a condenser tested to withstand a high voltage will break down in a resonant circuit, although no high voltage was outwardly applied.

The voltage across a coil in a resonant circuit is $2\pi fL$ times the current, but, as has already been pointed out, the current in a tuned circuit is $\frac{E}{R}$, in consequence of which the voltage across the coil will be $\frac{2\pi fEL}{R}$. That is, under given conditions, the voltage developed across the coil will be greater as the ratio $\frac{L}{R}$ is increased. In other words, the desirable thing in a radio coil is to secure the most inductance per ohm of resistance.

Another point in the analogy may be mentioned. The ability of a minute force to generate oscillations in the weight and spring would obviously disappear if the resistance were greatly increased by immersing the system in water or molasses, for example. As the resistance of an electrical circuit is increased, not only will the amplitude of the oscillations diminish, but the variations due to moderate changes on the frequency of the applied force will become less and less. In other words, with increasing resistance the system loses its selectivity, precisely as in electrical circuits.

Our analogy also illustrates a point that puzzles many beginners, and that is how the current in a condenser can be said to be 90°, that is one-quarter cycle, out of phase with the voltage (see "Home Study Sheets No. 7 and 8"). It will be observed that when the weight is at the point of maximum velocity, that is at the midpoint of its path, the spring is idle, that is, it is neither extended nor compressed. And when the weight is completely at rest at either end of its path, the spring is at that moment under its greatest stress. Similarly, when the current is at its greatest value, the condenser is at the instant of changing from one polarity to the other and so has no voltage, but when the current has just ceased flowing in, the electrons in the dielectric are under their greatest stress, so that when there is no current flowing the voltage is a maximum.

Finally, it may be pointed out, the action of the weight and spring exemplifies what is referred to in radio as *damping*. Suppose the weight was quite heavy and the spring rather short. If the weight were given an initial impulse the oscillations would continue for some time, though gradually diminishing in amplitude. Now suppose the weight were made

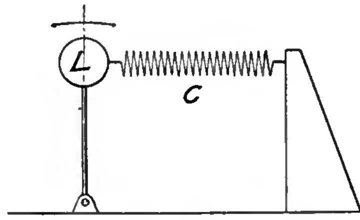


Fig. 2—Mechanical analogy of an oscillating current

very light and the spring lengthened considerably so that the frequency remained the same. Then the air resistance would increase in importance and the oscillations would die out very quickly. The corresponding change in a radio circuit would be to reduce the inductance and increase the capacity, the resistance remaining constant, and when this is done an oscillation once started is quickly damped.

To recapitulate: We have learned that the current in a radio circuit reaches its greatest value when the wavelength equals $1884\sqrt{LC}$.

That this fact is readily derivable from the fundamental equation for alternating-current circuits.

That when this condition exists, Ohm's law is applicable to the circuit.

That the voltage across the coil or condenser in a resonant circuit may very greatly exceed the applied voltage.

That the most efficient radio coil is that which has the greatest inductance per ohm resistance.

That the sharpness of tuning increases as the resistance is reduced.

No. 20 — *Radio Broadcast's Home-Study Sheets* — April 1929

Inductance Standards

THE applications of the principles in "Home-Study Sheet No. 19" are far-reaching and will afford an interesting field for experiment, but before this may be undertaken, certain standards must be acquired, as one cannot measure without some sort of a yardstick. This will, however, require many hours at the workbench, but before rolling up our sleeves, it would be well to dispose of the inductance standards, for the reason that for the value of these we are dependent on calculation.

Function of Inductance

The inductance of a coil has the same function in regard to the motion of the electrons that constitute an electric current, as weight has in regard to the motion of a material body. When the current is uniform, as in the case of direct current, inductance has no effect, just as the mass of a body is without effect in a mechanical motion of constant velocity. On the other hand, any change in the strength of an electric current, whether it be an increase or decrease, is opposed by inductance, and, as radio currents are continually changing with extreme rapidity from a maximum strength in one direction to a maximum in the other, inductance becomes a very important item.

A circuit is said to have an inductance of one henry when a current changing at the rate of one ampere per second induces therein an e.m.f. of one volt. In such a coil, there being no iron core, a current variation of two amperes would induce an e.m.f. of two volts. Inductance may therefore be considered as the ratio of the e.m.f. induced to current variation per second. The reason for this e.m.f. lies in the fundamental fact that a conductor has a voltage induced in it when it cuts the lines of force of a magnetic field. When the current is started

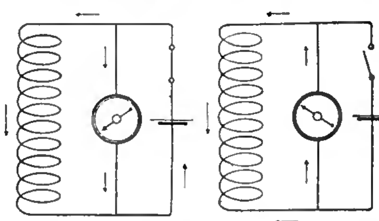


Fig. 1—Demonstrating the counter direction of the e.m.f. of self-induction.

in a coil the magnetic lines radiate outward from the center, thus cutting the turns of wire and inducing therein an e.m.f., which is always in such a direction, that it tends to delay the applied current in reaching its maximum value. Similarly, when the applied current ceases, the magnetic lines collapse towards the center, inducing an e.m.f. which now tends to maintain the current flow in the coil. By coiling a length of wire, the resulting magnetic field will be concentrated into a smaller space and, as a consequence, this counter e.m.f. increases. Inductance is a property which depends on the number of turns, size, and shape of a coil.

Laboratory Demonstrations

The counter direction of the induced current may be demonstrated by connecting up a coil, galvanometer, or compass and dry-cell battery as illustrated in Fig. 1. When the switch is closed the current will flow as indicated by the arrows in the diagram on the left. If the galvanometer needle is now restored to the zero point and held there with a pin or small weight, it will be deflected in the reverse direction when the switch is opened. This indicates a reversal of current through the galvanometer, and demonstrates the important fact that the current induced in the coil after breaking the circuit passed in the same direction through the coil as did the battery current. Obviously the reverse must have been the case when the connection was first made, as the magnetic lines proceeded outward instead of collapsing toward the center.

That the direction of a current induced when a circuit is closed is opposite to that induced when the circuit is opened may be demonstrated easily by connecting up an audio transformer to a galvanometer and dry-cell battery as illustrated in Fig. 2. When the circuit is closed the galvanometer will show a brief deflection, returning to zero when the primary current has reached its full value. When the circuit is opened, the deflection will be in the opposite direction, again returning to zero after the magnetic field has completely disappeared.

Inductance formulas have been developed for coils of a great many forms, but as our present

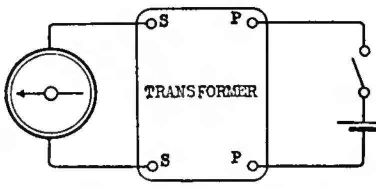


Fig. 2—Closing and opening the circuit induces two opposite currents

purpose is to acquire certain suitable standards, attention will be confined to the single-layer cylindrical form called the solenoid. The inductance of any coil of more complex winding may then be determined by comparison.

Coil Formulas

For a single-layer winding the Bureau of Standards gives the following simple formula. The significance of the terms a and b are illustrated in Fig. 3. N is the number of turns and K is a factor depending on the ratio of diameter to length, and is given in Table I.

$$L = \frac{0.03948a^2N^2K}{b} \text{ microhenries}$$

All dimensions are in centimeters, and while they may be made in inches by changing the formula to

$$L = \frac{1.0028\ a^2N^2K}{b} \text{ microhenries}$$

such a change is not advised for the reason that the metric system is now used so generally in scientific work that the experimenter should aim to acquire some familiarity with it. If a centimeter scale is available, it is just as easy to measure in centimeters as in inches, and in any subsequent computations, there will be less chance of error in handling the decimals of the metric system than with the awkward fractions of the inch.

In planning a coil for a standard, procure a tube of durable material, as near a perfect cylinder as possible, two or three inches in diameter and about twice as long. Apply one layer of number 18 d.c.c. wire. If a winding jig is not available, attach one end of the wire securely to the wall and stretch it out full length, removing all kinks and bends by pulling it tightly through a towel held in the hands. When the free end has been fastened to the tube, the process of winding may be accomplished quickly by turning the tube with the hands, always keeping the wire under tension. Before beginning the winding, however, provide suitable means for securing the two ends of the wire in place. A satisfactory way of doing this is to bore two small holes in the tube for each end and to pass the wire through in the manner indicated in Fig. 4. Place these holes so that the winding will have a whole number of turns —no fractions. If binding posts are desired, they should be very small, as large ones will add to the distributed capacity of the coil.

Measuring Coils

In counting the turns, be careful not to start counting until after the completion of the first turn is reached. Care must also be exercised in determining the length b, which, it will be noted in Fig. 3, is not the exact physical length of the coil but the

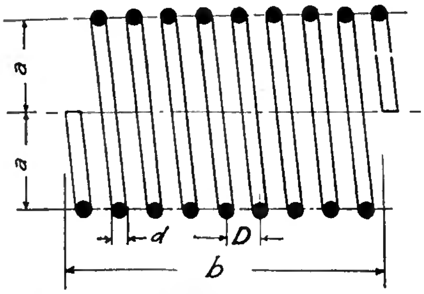


Fig. 3—Essential coil dimensions

length plus one turn, or the number of complete turns multiplied by the distance between the turns, that is b-N × D

For an inductance standard based on computation it is usually best to have the coil long rather than short, although the inductance will not be quite so great. The reason for this is that the formula may be applied more accurately, and the distributed capacity will not be as large. For this latter reason also, the coil should not be coated with any liquid preparation.

Usually the experimenter will have on hand one or more single-layer coils, and by applying the formula to these their inductance may be readily determined. These will then serve as standards until one's requirements become known more definitely through further experiment.

Accuracy

It must be borne in mind that the accuracy of the determination cannot be greater than that with which the physical measurements of the coil are taken, and among these the diameter will probably present the greatest trouble, particularly if the tube is not truly cylindrical. Under these conditions it is a good plan to wrap a strip of smooth thin paper tightly around the tube until the ends overlap. A sharp knife point should then be made to pierce the two overlapping ends, after which the strip may be laid flat and the distance between the two marks made may be measured accurately. By repeating the process after the tube is wound, the outside circumference may be determined, and then by taking an average of the two, the required diameter may be computed.

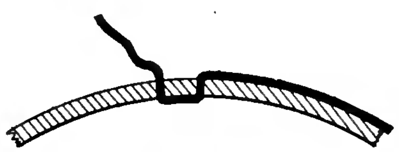


Fig. 4—Securing the end of the wire

Spaced Turns

It is sometimes desirable to reduce the distributed capacity to a minimum by using a spaced winding, which may be accomplished by cutting a shallow thread on the cylinder or by winding a string between the turns. If a high degree of accuracy is desired in the computation of the inductance of a spaced winding, a slight correction may be made for the spacing by adjusting the value calculated by the formula given above by an amount equal to —.01257Na (A + B) the proper values of A and B are given on page 284 of the Bureau of Standards Circular Number 74, *Radio Instruments and Measurements*.

In planning a coil, the experimenter will now be in a position to calculate the inductance quite closely in advance. If the wire is already at hand, estimate the total number of turns by counting the number that can be wound on one inch of the length of a lead pencil. If the size of wire has been determined, the number of turns that will go into a certain space may be estimated by referring to a wire table. Estimates obtained from wire tables are necessarily approximate as there are slight variations in the specified sizes of bare wire and in the thickness of the insulation, and further differences may result according to the tension under which the wire is wound.

Conclusion

Before leaving the present subject, the reader should be impressed with the necessity of maintaining a laboratory notebook in which to enter his calculations and observations in a clear and orderly manner. As the work proceeds, two facts will become evident: one will frequently have occasion to refer to some earlier record, and that memory cannot be trusted to retain experimental data.

Table I—Values of K

Diameter / length	K	Diameter / length	K
0.1	0.9588	0.7	0.7609
0.2	0.9201	0.8	0.8351
0.3	0.8838	0.9	0.7710
0.4	0.8499	1.0	0.6884
0.5	0.8181	1.5	0.5950
0.6	0.7885	2.0	0.5255

An Engineer's Explanation

REAL VERSUS APPARENT SELECTIVITY

By KENNETH W. JARVIS

Engineer, Crosley Radio Corporation

> *This article by Mr. Jarvis, a member of the engineering staff of the Crosley Radio Corporation, attempts to interpret the real meaning of selectivity in the light of our present-day reception problems. How much selectivity is desirable, what compromises in set design must be made to attain optimum selectivity at reasonable cost, and how the problem is solved in the design of present-day sets—all this Mr. Jarvis covers. To dealers, attempting to answer customer-questions this analysis should be useful as well as to many others of our readers desiring to follow a general investigation of the subject.*
>
> —THE EDITOR.

A RADIO set without selectivity is like a ship without a rudder, buffetted by every wind, and heeding the strongest wave and current. Some sets are selective—some are not; and broadcast transmitters and guileless amateurs are reviled alike. There is wailing and gnashing of teeth because of the radio engineers' inability to bring about the near impossible, and all because most of us do not quite understand what "selectivity" really means.

Imagine the conglomerate mess of the radiated energy of all the broadcasting stations on earth, all of the commercial transmitters, all of the amateurs, and all of the natural and man-made static, swirling, fading, crossing and recrossing the bare wire of your antenna, each inducing a voltage therein. You sit down below, more or less patiently attempting to hear the beautiful strains of the "Serenade" originating a thousand miles away, all uninterrupted and unimpeded by the myriad of unwanted impulses in your antenna. The selectivity is that property of your receiver which makes for order out of this chaos.

As we are interested in the usual broadcast reception, we need to consider only a comparatively small range of the frequencies in the whole spectrum, that is the band between 550 kc. and 1500 kc. Stations broadcasting in this range are known by their "carrier," i.e., the fundamental frequency of their radiation. Due to the frequencies needed on either side of the carrier for proper transmission, each carrier is spaced 10 kc. apart. Thus there is room for only 96 stations in the allotted broadcast-frequency range. In the new allocation plan, various stations either divide time or are located geographically so that they can use the same frequency without interference. For our purpose we can, therefore, consider that there are only 96 stations, one on each 10-kc. band of the broadcast range.

In explaining the mechanism of transmission, use is made of the "side-band theory" which says that in addition to the carrier frequencies, a broadcasting station radiates additional frequencies corresponding to the audio tones. If, as is approximately true, the frequency distribution and percentage modulation as based on these side bands is the same for all stations, we can neglect the side waves and consider only the relations of the various carrier frequencies.

What is Selectivity?

OBVIOUSLY, we are interested in selecting the energy of some one carrier frequency out of all the number present at the antenna. The strength of the signal (or carrier) at the antenna will influence the degree of selectivity. This strength is measured in microvolts (millionths of a volt). The bigger the antenna, the more microvolts it will pick up. The field strength of the signal is, therefore, rated in microvolts per meter, and the field strength, multiplied by the effective height of the antenna in meters, gives the actual voltage induced in the antenna. Thus a signal of 100 microvolts per meter acting on a four-meter antenna will produce an input voltage to the set of 400 millionths of a volt.

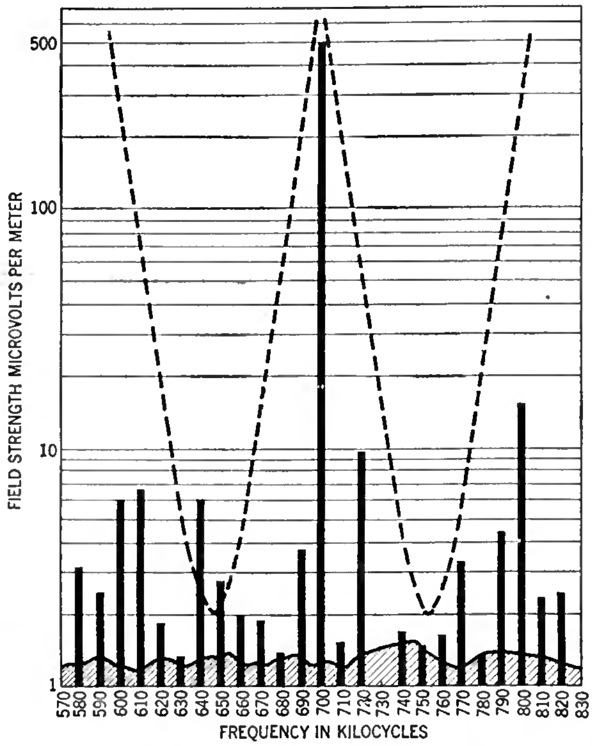


Fig. 1—A powerful local broadcasting station often presents a peculiar selectivity problem. In the case illustrated above, it is impossible to receive stations between 650 kc. and 750 kc. without interference from the powerful local

Before making use of this relation of field strength, a brief view of the nature of selectivity is necessary. Fundamentally, selectivity means a greater response to one frequency than to any other. This leads to the idea of resonance. If a circuit or system is quite responsive to some one frequency, it is said to be resonant to that frequency. Forms of mechanical resonance are familiar to everyone. The piano and violin strings tuned to the same note are in resonance. If the piano note is sounded, the sound waves will travel through the air and start the violin string vibrating and emitting sound. The pendulum of a clock oscillates back and forth at a definite frequency. The pendulum system is resonant to that frequency.

Sometimes a road has small ripples at regular intervals. If an automobile is driven at the proper speed over these little ripples, the car will begin to surge up and down with greatly increasing movement. If the car be driven faster, the springs take up the movement of the wheels and the chassis stays almost still. Driving slower allows the car slowly to follow up and down the ripples without any great movement. But at some particular speed, the weight of the car and the elasticity of the springs are "resonant" at the frequency of the ripples of the road surface and a terrific movement results.

Obviously the bigger the ripples, the greater will be the car movement. This is equivalent to increasing the force applied. The nearer the car runs at the "resonant" speed, the greater will be the movement. If there are "snubbers" on the car or there is a lot of resistance to the motion, the amplitude will not be so great.

Electrical circuits exhibit the same sort of resonance to electrical forces as the mechanical systems show. The condensers in the circuit correspond to the elasticity of the springs while the inductance corresponds to the mass of the car. Therefore it follows that a similar relation is obtained between the force and resistance in electrical circuits as in mechanical systems.

Electrical Equivalent

THIS may be illustrated in curve A of Fig. 2 where the height of the curve at any particular point represents the current flowing in the circuit at the frequency applied, the voltage remaining constant. It is obvious that this circuit has the property of "selectivity" and gives the greatest response at some particular frequency. Usually a single circuit does not have sufficient selectivity and two or more such resonant circuits are needed. The amplification might be adjusted to give the same maximum current in the last resonant circuit and then the system would have a curve like B, of Fig. 1.

Having obtained some idea of why a receiver is selective, a little different viewpoint is now necessary. A receiver should be sufficiently selective just *not* to hear any interfering station. Obviously this depends on the strength and frequency of this would-be interfering station. Therefore, the usual selectivity curve is drawn as in Fig. 3. Here the height represents the field strength in microvolts per meter necessary to apply to the receiver an output just loud enough to be heard. The receiver is tuned to 1000 kc. and obviously it takes less voltage to hear an output at this frequency, only 2 microvolts. At 10 kilocycles off resonance, the input would have to be 3.5 microvolts, while at 20 kilocycles off resonance, the input must be about 10 microvolts, or five times as much as at resonance.

In Fig. 4 is shown the field strength pattern at a particular antenna, where the heights of the lines represent the amplitudes of the "carriers" on each channel frequency. The wavy shaded portion represents the "static level," or the voltages introduced in the antenna due to static and unwanted noise.

This graph also contains the curve of Fig. 3 (curve A). The stations heard will be the one at 1000 kc., at which the set is tuned, and also the station on the adjacent channel, 1010 kc. The relative strengths of the signals will be about in proportion to the height of the field-strength lines *above the selectivity curve*. Thus the station on 1000 kc. will be about 4 times as loud as that at 1010 kc. The field strength of the station at 980 kc. is even greater than that at 1000 kc., but due to the selectivity of the circuit it cannot even be heard. The station at 990 kc. could never be heard with this set even if it were tuned right on 990 kc. A more sensitive set would be necessary, and even then the reception might not be good, due to the static and interfering signals.

Now assume that the receiver used had poorer selectivity as shown in Fig. 5. (Hereafter only the superimposed diagrams are given.) It is apparent that three stations are heard at once quite strongly and a fourth, at 1020 kilocycles, can just barely be heard. A simple way to visualize this is to imagine the selectivity curve, such as in Fig. 3, is cut down into a sheet of cardboard, and then laid over top of the field strength picture. Sliding this cardboard horizontally along the frequency scale corresponds to tuning the receiver, and the stations you can see projecting up above the slot in the cardboard are those which you will hear. If you cut out such a cardboard cover having the selectivity curve shown in Fig. 1, and slide it back and forth as suggested, you will see that it will be impossible to get any one station without interference from some other station. This is too often true with many radio receivers.

Effect of Tuning

A VIEW of the selectivity field strength charts will show a well-known fact. Detuning the receiver will reduce the output, and therefore, this method is often used to control the volume of a set. There are several objections to this practice. The resonance response to some interfering frequency is increased greatly, thus decreasing the selectivity and increasing the noise. In addition this detuning invariably changes the quality of reception. The receiver should be tuned directly on the station desired and the output regulated with the volume control.

There are many other peculiar cases of selectivity, some of which are illustrated here.

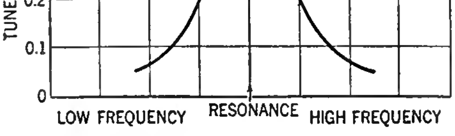


Fig. 2—Selectivity is improved by connecting two or more resonant circuits in series. Curve A shows the selectivity of a single circuit, curve B of a series of circuits

Take as an example the case of a strong local station. Such a station may have a field strength of as much as 10,000 microvolts, per meter, which is far beyond the range of the cross-section sheets used here. For illustration, take the curve of Fig. 1. Notice that the horizontal scale of frequencies is smaller than before. The selectivity is the same as in Fig. 5. Assuming we are using the cardboard covers again, they must be placed in the positions shown in order to avoid hearing the strong local station. This means that no station between 650 and 750 kc. can be heard without interference from the local.

It may be that before the local station raised its power, the radio set could satisfactorily receive the station on 720 kc. Therefore, when such reception can no longer be obtained, the local transmitter is blamed. The transmitter is "broad" and it "spreads all over the dial" and many are the protests against the design. However, the only crime of which the station can be accused rightfully is that of attempting to increase its service area and providing the benefits of static-free reception to a greater number. Investigation of such complaints has shown almost always that they have originated with the owners of obsolete receivers, at least from the selectivity standpoint. As bigger and better transmitters are built, receiver design must necessarily conform. It is unfortunate that advancement in radio service must render obsolete the inefficient type of receiver and act to the

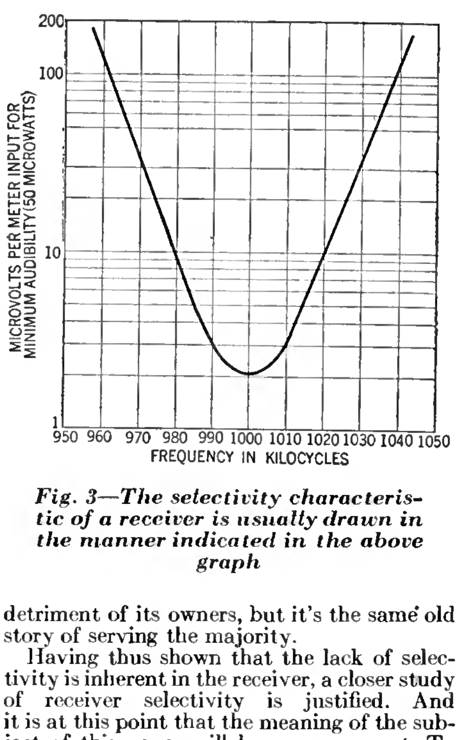


Fig. 3—The selectivity characteristic of a receiver is usually drawn in the manner indicated in the above graph

detriment of its owners, but it's the same old story of serving the majority.

Having thus shown that the lack of selectivity is inherent in the receiver, a closer study of receiver selectivity is justified. And it is at this point that the meaning of the subject of this paper will become apparent. To an engineer, *selectivity is represented by the curve shape, and the ratio of the signal field strength needed at any frequency to that needed at resonance to produce an audible signal.* This is a very real thing, expressible in numbers, and is a factor which can be calculated as a ratio. To the user, the selectivity of a receiver is apparently the way in which stations can be separated. The relation can best be shown by the use of our cardboard covers and a field-strength diagram. This is shown in Fig. 6.

The selectivity curves of two sets, A and B, are drawn. The *real* selectivity of the two sets is exactly the same. For simplicity, the field strengths of five adjacent stations are shown having equal amplitude. By sliding the cover marked A, it is obvious that any one station, to the exclusion of all others, may be selected. By sliding B along the frequency scale, it is apparent that at least three stations will

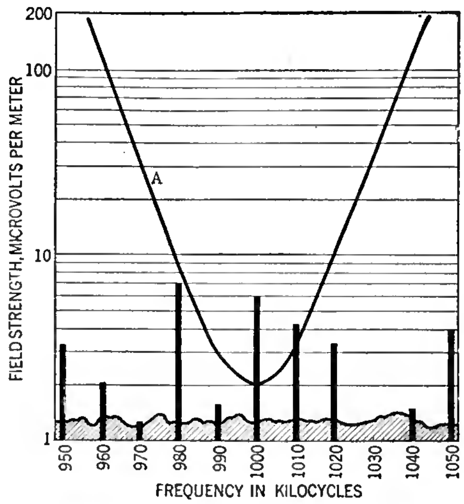


Fig. 4—In this graph the selectivity curve (Fig. 3) is superimposed over the field-strength pattern at a particular antenna. Vertical lines indicate amplitudes of carriers and shaded area indicates the "static level"

be heard at all times! The difference between real selectivity and apparent selectivity is quite clear!

Selectivity vs. Sensitivity

PROPERLY understood, this fact is no detriment. By backing off the volume control on the more sensitive set until the two sets have equal sensitivity, the apparent selectivity will be equal. In general it may be said that *the greater the sensitivity of a radio receiver, the less will be the apparent selectivity.* (Notice that this *does not* say that the set having the least apparent selectivity will be the most sensitive.) In demonstrating a very sensitive receiver, a salesman will often turn the volume control full on, showing how many stations can be received. While not saying "Yes, all at once," the prospective customer may react against the set due to the apparent lack of selectivity. It is so simple to reduce the volume control and thus increase the apparent selectivity that all this discussion seems out of place. Yet so many operators of good radio receivers will unhesitatingly blame the poor selectivity of his receiver upon conditions entirely irrevelant, when a proper consideration of the true factors will clear up a lot of trouble. Ask any radio dealer how much trouble has been caused and how many radio sets have "suddenly gone wrong" due to a change in power, frequency, or location of the customary vendor of entertainment. Before leaving this point, it is well to drop a word of warning to any prospective purchasers. In the demonstrations of selectivity *make sure the fine apparent selectivity of a set is due to the real selectivity of the circuits and not due to simply a lack of sensitivity.*

The selectivity of a receiver depends on the size of the coils and condensers, the resistance, circuit coupling, and many other circuit factors. As the set is tuned from one end of the broadcast-frequency range by changing the condensers or the inductance of the coils, the real selectivity changes.

Fig. 7 shows three selectivity curves taken on the same receiver. (The sensitivity in each case was adjusted to interference output with two microvolts per meter input.) The selectivity at 550 kc. is quite good, while that at 1500 kc. is poor. This means that instead of having a constant selectivity, and thus a cardboard shield of constant shape, the gap must open up gradually as the set is tuned to a high frequency.

As the usual receiver varies greatly in

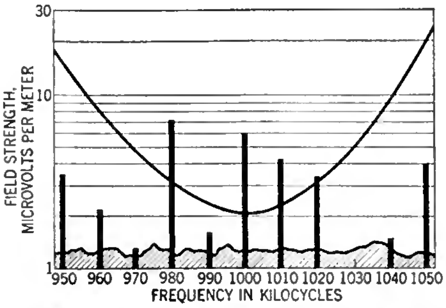


Fig. 5—The selectivity curve of Fig. 2A superimposed over the field-strength pattern of Fig. 4. Note that the signals of four stations are heard at once due to the poor selectivity of the circuit

sensitivity in different parts of the frequency range, and as the real selectivity (as per Fig. 7) also varies greatly, the apparent selectivity is quite a complicated result. This elementary discussion should help considerably, however, in understanding the action of the receiver.

Other Considerations

THE real and apparent selectivity so far have been considered only on the electrical basis on which they operate. To the user of a particular set, there are mechanical factors contributing to the apparent selectivity almost as important as the electrical characteristics. A large frequency-control knob tends to make tuning easier and increases the apparent selectivity. The vernier drive and the large illuminated drum dials are contributors to the same idea. To the operator, who cannot "see" the field strength pattern at his antenna, the selectivity is estimated by the dial movement necessary to eliminate any particular station. This basis for judging selectivity is as inaccurate as it is common. The "results" obtained depend upon the frequency range covered by the entire dial movement and the rate of frequency change at any operating point. Assume two sets, both having a dial movement of half way around, one tuning from 540 kc. to 1520 kc., and the other tuning from 570 kc. to 1350 kc. It is evident that the apparent selectivity would be greater on the first set as a given movement would shift the resonance frequency faster.

The shape of the condenser blades greatly influences the apparent selectivity. If the blades are semi-circular, a given angular rotation will cause a greater change in resonance frequency at the high frequencies than at the low frequencies. This results (as based on dial movement) in the apparent selectivity being greater at high frequencies, and thereby (to the user's mind) compensates the decrease in real selectivity as indicated in Fig. 7. If the condenser blades are shaped so as to give uniform change in frequency with uniform rotation (so called straight-line-frequency type) the apparent selectivity will be the same as the real selectivity.

One more factor is responsible for a huge misunderstanding in judging the sensitivity of a radio receiver. That is distribution of the broadcasting stations themselves. The new allocation has placed a great number of small stations on the same, or closely adjacent bands. A sensitive receiver will pick up a great many of these stations, and owing to their proximity, several stations may be heard at once. Such stations are usually so close together that they interfere or "beat" with each other and produce a strong continuous audio note. This note is not due to the modulation of either station, but is the "beat" of the two carriers. Such interference is quite common and is usually understood by those who have a technical knowledge of the reasons why, but to a novice or to one who doesn't care to know why, such interference is charged against the receiver's selectivity. Most radio users know that the selectivity of a receiver enables them to eliminate those signals they do not want, and they automatically class those cases of station interference against the receiver also.

Another type of station interference which occurs in some receivers is that obtained due to modulation in the receiver. Two signals may be heard at once, but only when tuned to either one of the stations. The signals of the two stations "modulate" each other in the r.f. end of the set and both modulation frequencies are superimposed on each carrier frequency. Obviously "selectivity" can do nothing to help such cases. Fortunately such cases are rare as they occur only when the volume control is in the audio end of the set, or where extremely strong signals are impressed on an untuned input. This kind of "cross talk" can best be eliminated by using a wave trap tuned to one of the two stations interfering. This may be an important point in selectivity demonstrations and the real selectivity impaired because of this fact.

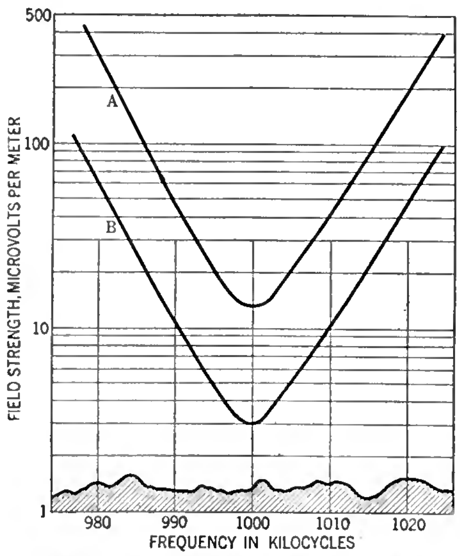


Fig. 6—The real selectivity of the two curves above is exactly the same, but the apparent selectivity of A is much greater

Conclusions

WHAT conclusions of value to the set user may be drawn from the above discussion? First, and probably the most important, is the fact that the apparent selectivity can be increased greatly by decreasing the sensitivity of the receiver, and then tuning accurately on to the frequency of the station desired. Try it. You will be surprised at the big improvement in selectivity when the volume control is reduced just enough to eliminate the undesired station.

Another valuable conclusion is in regard to the size of the antenna. With higher-powered transmitters rapidly coming on the air and "interference" reports on the increase, it is standard practice for the radio editors and engineers to say "Use a smaller antenna." It is obvious that this accomplishes the result. In Fig. 6, the apparent selectivity of set B will increase just as much by reducing the input to 7 microvolts, as it will by changing the sensitivity to correspond to the set A. However, reducing the size of the antenna to improve the selectivity *decreases* the distance-getting ability of the set. As previously shown, intelligent use of the volume control gives the same control of the apparent selectivity without permanently reducing the efficiency of the set. Here's one more vote for longer and higher antennas. On clear, cold nights you can use the extra sensitivity a little brain work will provide.

How selective should a set be? An ideal set should have sharp cut-off and a flat response the width of one broadcast band. To date no commercial set of this type has been built, and the problems involved indicate that such a receiver will not be available for some time to come. Just remember, in demanding "knife-edge selectivity," that, like lots of other things in life, selectivity is a compromise. Too broad a selectivity curve, and interference results. Too sharp a selectivity curve and the quality is impaired greatly by the loss of the high notes. A good engineering compromise, plus a little intelligent operation, will provide for many hours of interference-free entertainment.

WARD LEONARD'S AUTOMATIC VOLTAGE REGULATOR

UNSATISFACTORY receiver performance, and short tube life due to excessive line voltage—this has been one of the most pressing problems associated with the a.c. receiver and has probably been one of the major causes of consumer dissatisfaction with sets of this type. It appears, however, that the problem has now been solved completely and in a very satisfactory manner by the Ward Leonard Company. This company has perfected a new device (that many manufacturers will probably include in their receivers this fall) which performs the double function of power transformer and line-voltage regulator. This device makes the operation of the set independent of ordinary variations in line voltage. It takes the place of the power transformer ordinarily used in a receiver and it functions, not only to supply all the voltages required for the set's operation, but also to compensate variations in line voltage. With this new device in the set the line voltage can vary from say 90 to 150 volts and the actual voltages applied to the tubes in the set will vary a negligible amount.

We were present when the Ward Leonard Company demonstrated this device which was installed in a Crosley set. By means of an auto transformer connected to the a.c. line, the engineers varied the line potential from 90 to 150 volts. The voltage applied to the filaments of the tubes varied less than a tenth of a volt! The device works entirely on magnetic principles—it contains no moving parts, resistors, thermal units, etc. The Ward Leonard engineer responsible for the design is H. K. Kouyoumjian. H. E. R.

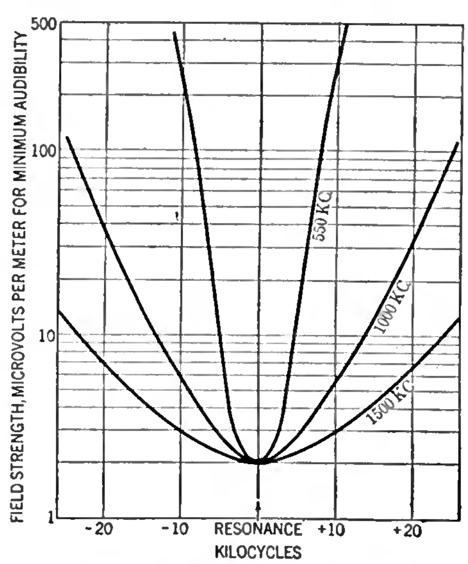
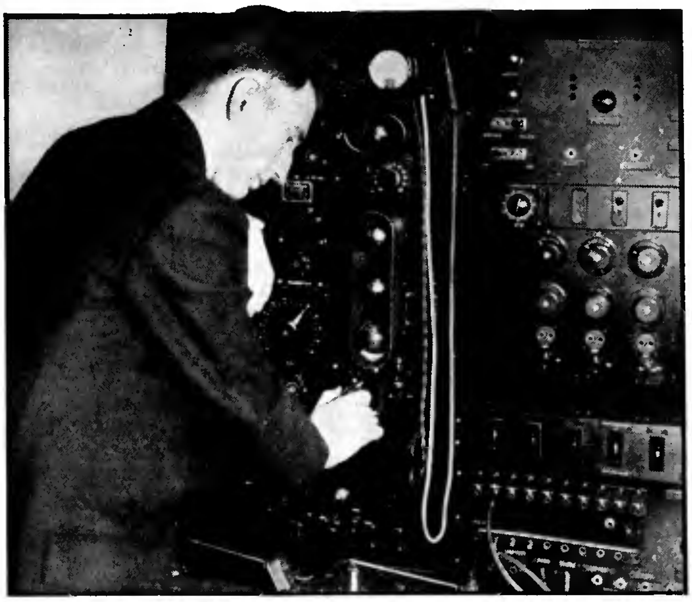


Fig. 7—The selectivity of the usual receiver varies with the frequency to which the circuits are tuned as illustrated in the above curves

BROADCAST ENGINEERING

BY CARL DREHER

Loud Speaker Frequency Peak Correction



Clarence R. Clark, chief engineer for KJR, is pictured above at the controls of KJR's new 5000-watt transmitter

SOMETIMES, in broadcast monitoring or other operations involving judgment of quality, loud speakers are encountered which would be suitable for the purpose except for a marked peak in response somewhere in the audio-frequency range. This undesired sensitiveness may readily be reduced to any desired degree by the application of an audio-frequency filter, which, in the form described below, is simply the familiar radio-frequency "rejector" designed to function at a lower frequency, i.e., an audio frequency, the alternating-current principles remaining the same.

Fig. 1 shows a radio-frequency rejector circuit intended to eliminate interference at a given frequency, f, to which the combination of inductance and capacity, $L_r C_r$, is tuned. This path then presents a minimum impedance to incoming waves of frequency f, and the receiver tuning elements, $L_a C_a$, may be set for some other desired frequency without interference, the currents of frequency f passing to earth by way of the rejector path and hence causing no interference.

Fig. 2 shows a loud-speaker characteristic, assumed to have been secured by such methods as those described by Wolff and Ringel: "Loud Speaker Testing Methods," *Proc.* I.R.E., Vol. 15, No. 5, May 1927; or Bostwick: "Acoustic Considerations Involved in Steady State Loud-Speaker Measurements," *Bell System Technical Journal*, Vol. 8, No. 1, January, 1929, and in numerous other articles. At 1000 cycles, it will be noted, there is a peak about 10 DB above the general level of response at other frequencies. By an audio-frequency filter circuit such as that represented by the elements L_f, C_f, and R_f in Fig. 3, connected in parallel with the audio coil of the loud speaker, such a peak in response may be smoothed out. The constants assumed are given only for purposes of illustration, although they are in the general range encountered in practice.

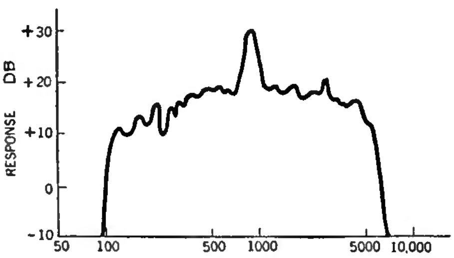


Fig. 2

The decrease in loud-speaker current required at 1000 cycles is first calculated from

$$\text{Response}_{\text{DB}} = 20 \log \frac{I_1}{I_2}$$

It is found that for a 10 DB decrease the ratio between the two currents must be 3.16, or, approximately, the initial current should be

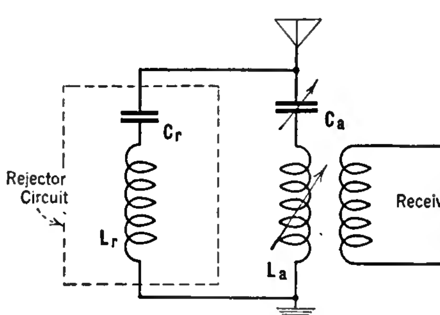


Fig. 1

reduced to one-third. This means that in the filter branch of Fig. 3 the current at 1000 cycles must be twice the current through the loud speaker voice coil. It is known that if the loud speaker impedance at 1000 cycles is Z_s, and the filter impedance Z_f, the current from the amplifier will divide in the ratio

$$\frac{I_s}{I_f} = \frac{Z_f}{Z_s} \qquad (2)$$

It follows that at 1000 cycles, for the purpose in question, the filter circuit in Fig. 3 should have only half the impedance of the loud speaker.

The latter quantity is determined by measurement on an inductance bridge, or by some other standard method (see, for example, Ramsey: *Experimental Radio*), in which, however, care must be taken to feed the measurement circuit from a 1000-cycle source and to adjust the current through the loud speaker so that it will have substantially the same constants as under normal operating conditions. If we assume that the 1000-cycle impedance is found to be 20 ohms, then the filter must have an impedance of 10 ohms at the same frequency. Part of this 10 ohms will be in the coil L_f, the resistance of which may be measured with d.c. on a Wheatstone Bridge; the remainder is made up in the separate resistance R_f.

All that remains is to calculate L_f and C_f to resonate at 1000 cycles. The formula used is

$$f = \frac{5033}{\sqrt{LC}} \qquad (3)$$

where f is in cycles per second, L in millihenries, and C in microfarads. The conditions will be satisfied approximately by a mica condenser with a capacity of 2.5 microfarad, and a 10-millihenry coil of the honeycomb type, or by a 1.0-microfarad condenser and a 25-millihenry coil. The resistance of the coil being measured, as outlined above, the proper series resistance may be added to smooth out the 10 BD peak in the loud-speaker response.

Generally speaking, the sharpness of tuning of such audio-frequency rejectors matches the sharpness of peaks in the loud-speaker response curve, so that there is not much chance of doing damage to the frequency characteristic of the loud speaker by introducing troughs on either side of the peak which is eliminated. Above the resonant frequency the filter has an inductive reactance, which soon rises to several hundred ohms as the frequency is increased, while below the resonant frequency the same effect takes place with a capacitive reactance. Thus the filter serves to cut off the peak at the frequency for which it is designed, and has little effect on the response at other points in the band.

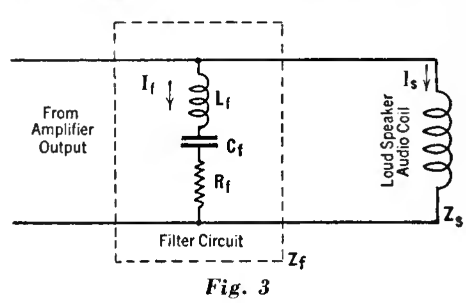
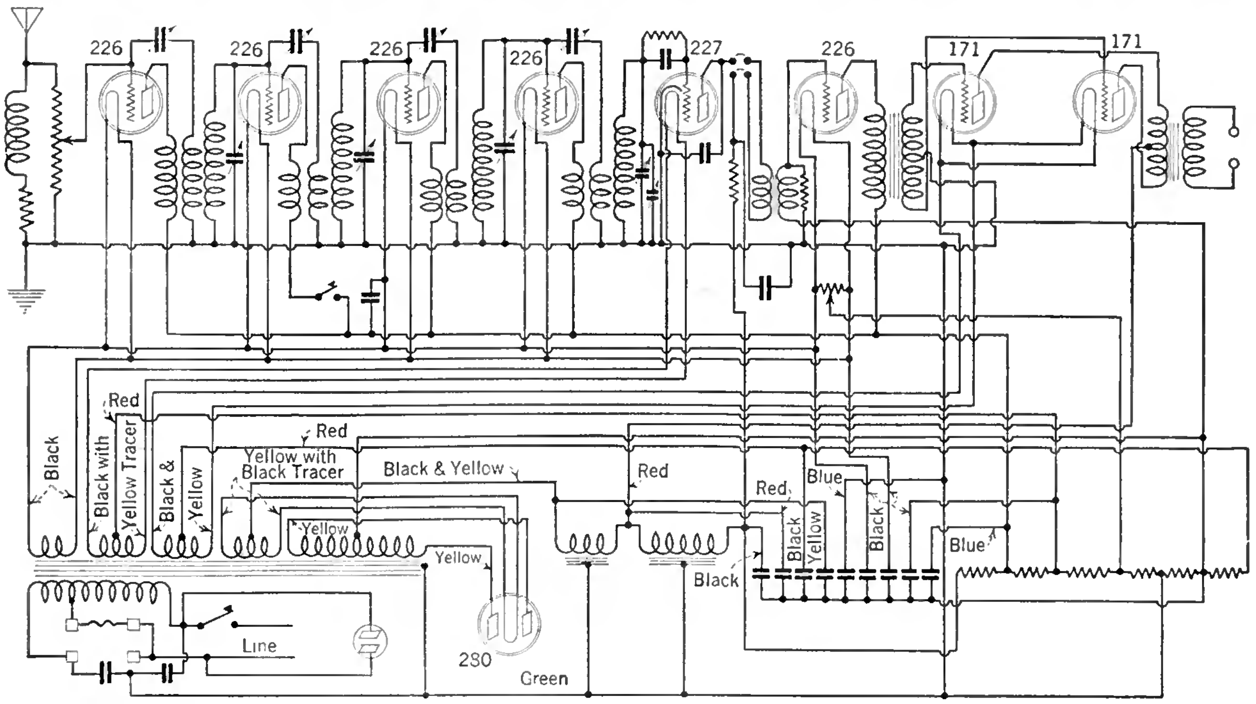


Fig. 3

No. 21 *Radio Broadcast's Set Data Sheets* April, 1929

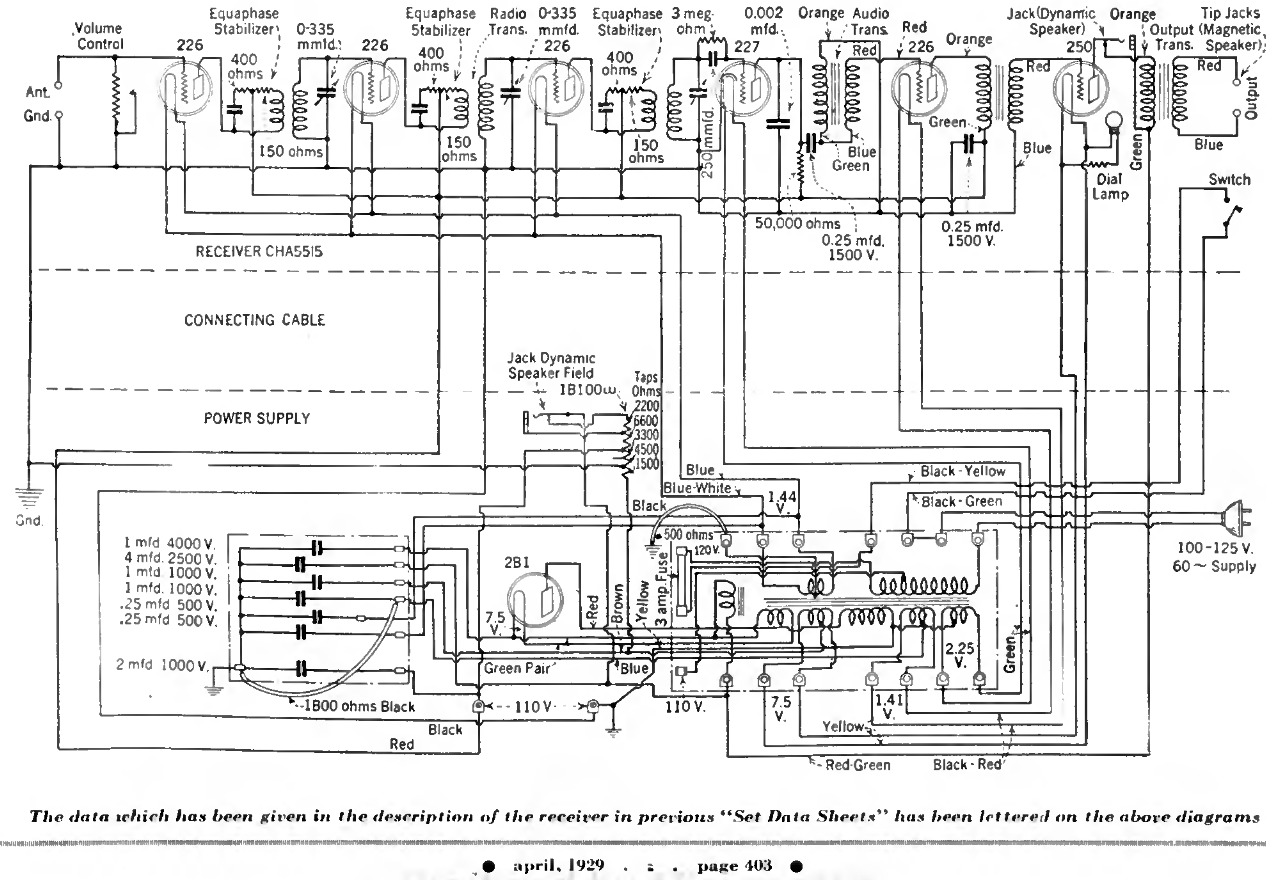
THE DAY-FAN 8-AC POWER SET

This receiver is completely light-socket operated and uses five 226-type tubes, one 227-type tube and two 171A-type tubes. It should be noted that each r.f. transformer contains three coils, the third winding being used for neutralizing purposes to prevent the amplifier from oscillating. A jack in the plate circuit of the detector permits the use of a phonograph pick-up unit.



THE FRESHMAN MODEL 2N-12 RECEIVER

This Freshman receiver utilizes the Equaphase circuit in which an Equaphase stabilizer is used in each plate circuit of the r.f. amplifier tubes. These stabilizers tend to make the plate circuit non-reactive, thus making it impossible for the tubes to oscillate. The output circuit of the set has been arranged to permit the use of either ordinary cone loud speakers or moving-coil loud speakers.

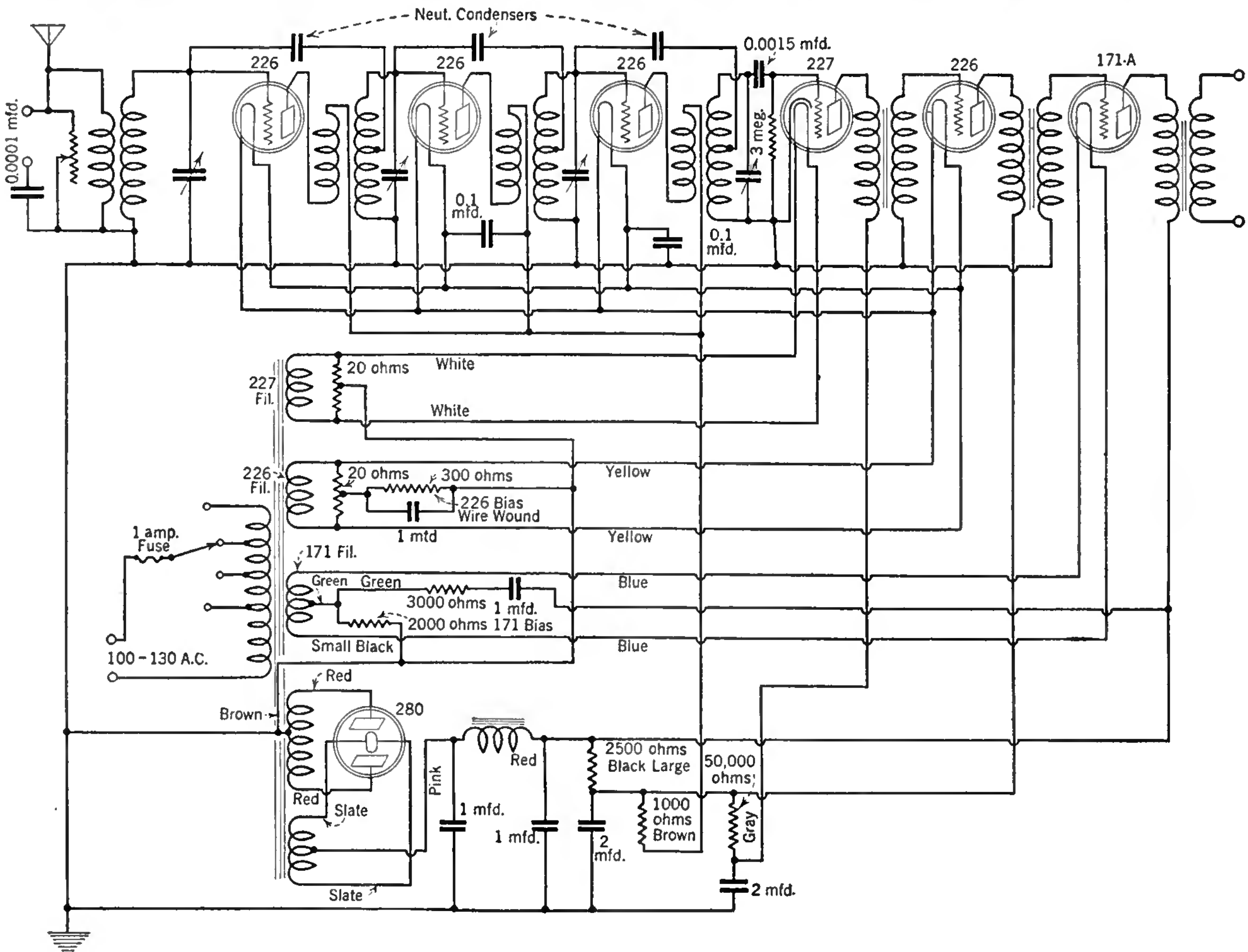


The data which has been given in the description of the receiver in previous "Set Data Sheets" has been lettered on the above diagrams

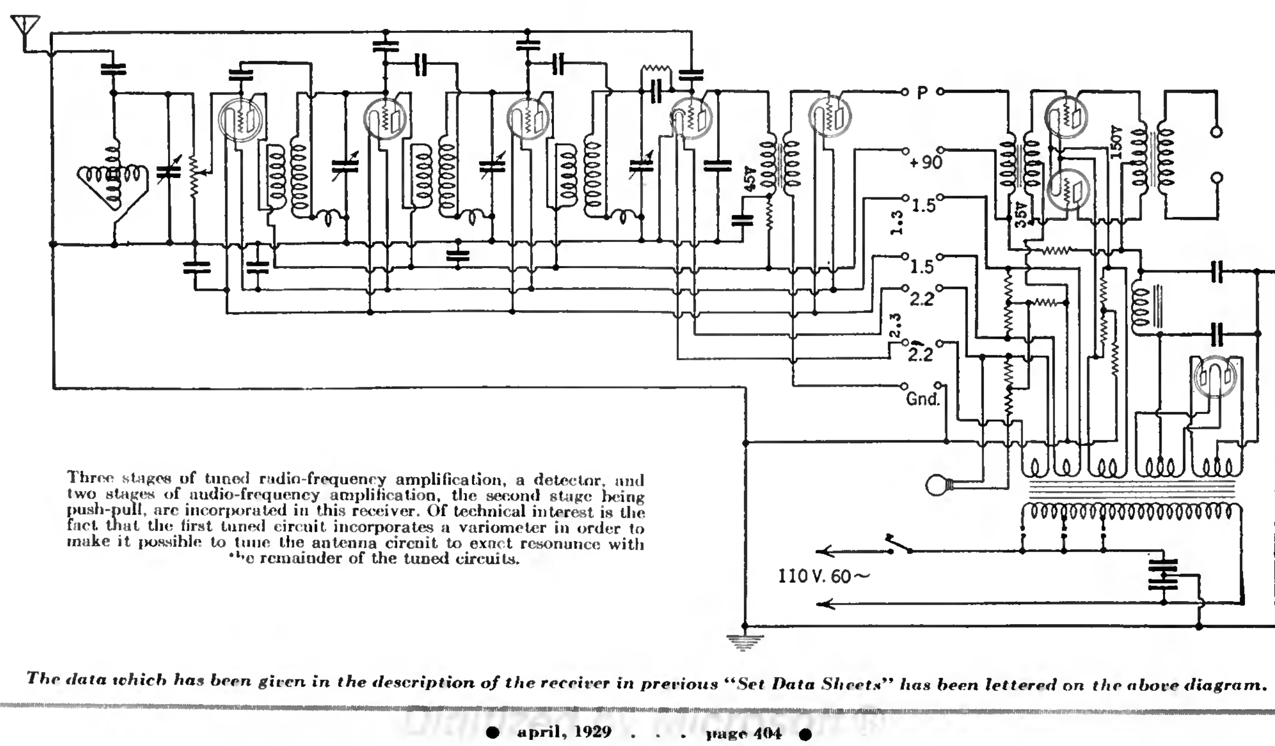
No. 22 — *Radio Broadcast's Set Data Sheets* — April, 1929

THE KING MODEL H RECEIVER

This receiver utilizes a conventional circuit consisting of two stages of r.f., detector, and two stages of a.f. amplification. The volume control consists of a variable resistor connected between antenna and ground. It should be noted that the power transformer contains four taps to permit the use of the set on any line voltages between 100 and 130 volts a.c. The rectifier is a 280-type tube.



THE BOSCH MODEL 28 RECEIVER



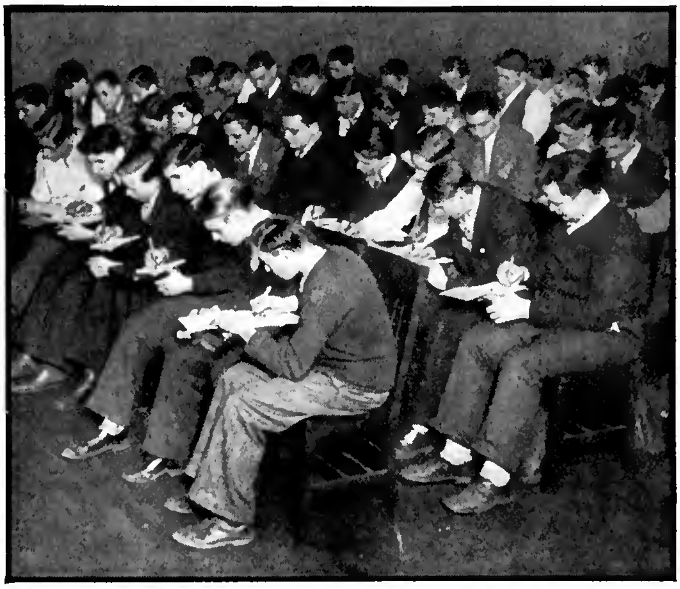
Three stages of tuned radio-frequency amplification, a detector, and two stages of audio-frequency amplification, the second stage being push-pull, are incorporated in this receiver. Of technical interest is the fact that the first tuned circuit incorporates a variometer in order to make it possible to tune the antenna circuit to exact resonance with the remainder of the tuned circuits.

The data which has been given in the description of the receiver in previous "Set Data Sheets" has been lettered on the above diagram.

Solving an Employer's Problem

AN EXAMINATION FOR RADIO SERVICEMEN

By J. F. B. MEACHAM



Employers of radio servicemen have found that the most satisfactory means of selecting highly trained men is by submitting all applicants to a written examination

RADIO dealers and others who regularly engage new men for their service staffs must cull out the good men from the poor and how to do it well is a problem that has not been generally solved. Many men charged with the task of hiring and firing have learned to their sorrow that not all who call themselves "radio experts" are really qualified. The first requisite for a good serviceman is that he have a good practical background of electrical and radio knowledge. One excellent way to find out if the applicant has this knowledge is to set an inclusive and formal examination which he must pass.

The sample examination for servicemen which appears below is one which has been used with excellent results by the Q R V Radio Service, Inc., of New York. This examination attempts to determine the general knowledge of the applicant and does not go into all the problems which arise in the servicing of a.c. receivers. It has been found that men who can pass an examination of the scope of this one are usually quite capable of intelligently solving most service problems which they meet in the field.

We present this sample examination with the suggestion that it may be helpful as a guide to other organizations who hire servicemen. We should like to hear from our readers who are using formal examinations of this type and would be glad to see copies of similar examinations which they are using.

Section I—Fundamentals
(TEN CREDITS)

(Give the formula in each case and show your arithmetic.)

1. (a) If you desire to furnish a current of 3.5 amperes to a load through a resistance of 8 ohms, what must be the voltage drop across the resistance? (b) How much power is consumed in the resistance, in watts?

2. (a) If a voltage of 7 volts is impressed across a resistance of 125 ohms, what current will flow, in amperes? (b) In milliamperes?

3. (a) If a potential of 20 volts causes a current of 5 amperes to flow through a circuit, what is the resistance of the circuit, in ohms? (b) If a potential of 200 volts causes a current of 0.5 milliampere to flow through a grid-leak, what is the resistance of the leak, in megohms?

4. (a) What is the total resistance in ohms of three rheostats whose separate resistances are 3, 5, and 9 ohms, when connected in series? (b) When connected in parallel?

5. (a) What is the total capacity in microfarads of three condensers whose separate capacities are 0.5, 2 and 8 mfd. when connected in series? (b) When connected in parallel?

Section III—Tubes
(FOUR CREDITS)

1. (a) What is the important difference between a 199-type tube and a 120-type tube? (b) Between a 201A and a 112? (c) Between a 112 and a 171? (d) Between a 171 and a 210?

Section IV—Batteries
(TEN CREDITS)

1. (a) Is it better to test the voltage of a dry cell under no load or under load? (b) Why? (c) What should be the no load voltage of a fresh dry cell? (d) Of a fresh 45-volt B battery? (e) How long may the average 45-volt battery be satisfactorily used? (f) Why can it not be satisfactorily used longer than that?

2. (Questions under 2 apply only to lead cells) (a) Is a voltage reading a sufficient indication of the condition of a storage battery? (b) Why? (c) Is a hydrometer reading sufficient? (d) Why? (e) If you know only the voltage and the ampere hour capacity of a storage battery, how would you compute the normal discharge and initial charging rate? (f) Of what is the electrolyte of a lead cell composed? (g) Why does the specific gravity of the electrolyte change during charge and discharge? (h) At what height should the surface of the electrolyte in a lead cell be maintained? (i) What trickle charge rate would be approximately correct for a set using five 201A tubes and one 112 tube which is operated for an average of four hours per day, the charger operating 20 hours?

Section V—A.C. Power Units
(TEN CREDITS)

1. (a) Can the voltage delivered to a set by a B-power unit be accurately measured by the ordinary battery-testing voltmeter? (b) Why? (c) Name an exception to your answer to (a). (d) What effect would be produced on the terminal voltage of the average B-power unit by the substitution of a 171-type tube for a 112-type tube in a set to which the power unit is connected? (e) Why?

Section VI—Servicing
(FIFTY CREDITS)

(In those of the following questions which refer to broadcast receivers, when no particular set is mentioned you may assume it to be an average five-tube factory-built set.)

1. In what order would you conduct a routine test of a broadcast receiver, assuming the entire pick-up system to be ok.? Answer briefly. Letter your answers as: (a), (b), etc.

2. If a set is noisy, and you do not recognize its source by the character of the sound, how can you determine readily whether it is in the set itself or is being picked up by the antenna-ground system?

3. (a) Which is most liable to open, the secondary winding or the primary winding of an audio-frequency transformer? (b) Why?

4. (a) What would be the effect on the output of an open in the grid circuit of the second r.f. tube in a broadcast receiver? (b) Of the first a.f.?

5. If one of the leads to a tuning condenser in a broadcast set is open, what is the effect?

6. (a) How would you determine the total plate current drain of a broadcast receiver? (b) Approximately what would the drain be of a set using four 201A's and one 112 tube, with the correct plate potentials and grid potentials applied? (c) If a test shows half the current you would expect under the conditions of (b) what is the most probable trouble, assuming the batteries ok.?

7. (a) When a low-pitched steady hum or howl is set up in a set, regardless of tuning condenser settings, what is the most probable trouble? (b) What is the cause of that trouble? (c) Name two remedies.

8. (a) If, in a broadcast receiver, one of the audio tubes appears to be burning with a brilliancy much greater than normal, what is the trouble? (b) Would the same condition produce the same brilliancy in an r.f. tube? (c) Why?

9. If the signal strength of a receiver was far below normal, but you could not find any trouble in the set itself, or the tubes or batteries, or loud speaker, what would be the sequence of your next tests, in detail? Let your answers be lettered as: (a), (b), etc.

10. If, with the tuned circuits of a set all out of resonance, an intermittent hissing and frying noise is audible in the loud speaker, what is the most probable trouble?

11. (a) If you find the plate potentials furnished to a set by a B-power unit to be very low, with the plate current to the set also very low, and you notice that the plate of the power-unit rectifier is running red hot, what it the most probable trouble? (b) If you found the plate voltages very low, but the plate current, measured in the minus B lead between the power unit and set terminals, abnormally high, what is the most probable trouble?

12. With the filaments of a set at normal brilliancy, approximately what potential should 90 volts of B battery produce at the plate of the first a.f. tube?

13. If a test shows normal potential from the B post of an audio transformer to filament, but none from the plate—of the tube whose output goes to that transformer—to filament, what is the trouble?

Section VII—Diagrams
(TEN CREDITS)

1. Draw a circuit diagram of a five-tube set, tuned and neutralized r.f., with detector regeneration, transformer-coupled audio, 171-type tube in last stage, with storage A, a. c. trickle charger, B-power unit, and automatic relay. Power-unit rectifier may be either thermionic or gaseous type.

2. Draw a circuit diagram of a super-heterodyne having two stages of "intermediate" r.f., omitting the a.f. stages.

Section II—Tubes
(SIX CREDITS)

1. Give data for the following tubes, for normal operation.

TYPE	USE	FIL. V.	PLATE V.	GRID V.	FIL. CURRENT	PLATE CURRENT	Plate RES.	AMPL. CONSTANT
199	amplifier	....	....	....	....	....	....	....
199	detector	omit....	....	....	....	....	....	....
120	amplifier	omit	....	....	....	....	....	....
201A	amplifier	....	....	....	....	....	....	....
201A	detector	omit	....	....	....	....	....	....
200A	detector	....	....	....	....	....	....	....
112	amplifier	....	....	....	....	....	....	....
171	a.f ampl.	....	....	....	....	....	....	....
210	n.f. ampl.	....	....	....	....	....	....	....

IN THE RADIO MARKETPLACE

News, Useful Data, and Information on the Offerings of the Manufacturer

New Receivers Announced

THE Crosley Radio Corporation has announced two new receivers; the Gemchest and the Showchest. The Showchest is a console model with a built-in Dynacone loud speaker. The receiver itself is an eight-tube a.c. set employing three stages of tuned r.f., detector, and two stages of audio, the output stage of which is push-pull using two 171A-type tubes. The Gemchest utilizes two stages of r.f., a regenerative detector, and two stages of a.f.

THE ATWATER-KENT COMPANY has announced two new receivers. One is the table model 46 set using seven a.c. tubes and one rectifier. This set is priced at $83.

The second receiver is the console model 53, priced at $117. The chassis is housed in a metal console together with the new Atwater Kent dynamic-type loud speaker. The price of the new dynamic loud speaker when sold separately is $34.

THE COLUMBIA PHONOGRAPH COMPANY'S latest product is the model 950 phonograph-radio combination. This combination includes a Columbia electrical phonograph and a Kolster radio receiver. The price is $450.

THE SPARKS-WITHINGTON COMPANY has announced a new Sparton console receiver, type 930, priced at $189.50. This new receiver utilizes the same band-selector circuit used in previous Sparton Equasonne receivers. In the console is also included a Magnavox dynamic-type loud speaker. Tubes are included as standard equipment without added cost. According to Captain Sparks, president of the company, production during the past season was nearly three times as great as during the preceding season.

AN A.C.-222-TYPE TUBE is used in the new Series K receivers produced by the Federal Radio Corporation. This set will be available in both table and console models. The lowest priced model will cost $127.50. A 227-type tube is used in the first r.f. stage and in the second r.f. stage a new 222-type a.c. tube is used. In the detector and first-audio stages 227-type tubes are used and in the output there are two 171A-type tubes.

Miscellaneous New Products

THE new Y-227-type detector tube manufactured by the Sonatron Tube Company reaches its proper operating temperature within five to seven seconds after the power has been turned on. This time lag is quite short in comparison with the 15- to 30-second lapse for most other heater-type tubes. This company also has a new type 171-AC. tube selling at $3.50.

THE C. E. JACOBS MANUFACTURING COMPANY, of 2802–10 N. Kedzie Avenue, Chicago, has developed a new product, the "Repleno" rectifier for use as a replacement unit in electrolytic rectifiers. The list price is $1.00 per jar. These rectifiers are said to be suitable for use in the electrolytic B-power units made by Philco, Willard, Exide, Vesta, etc.

THE R. C. BURT SCIENTIFIC LABORATORIES, of Pasadena, California, are the manufacturers of two devices useful in radio engineering. One is the standard Burt Photo-Cell, which, according to the makers, is a highly sensitive photo-electric cell giving a current of 1 microampere per 100 foot candle and a linear relation between 0.1 and 1000 foot candles. The Burt cell is not affected by fatigue.

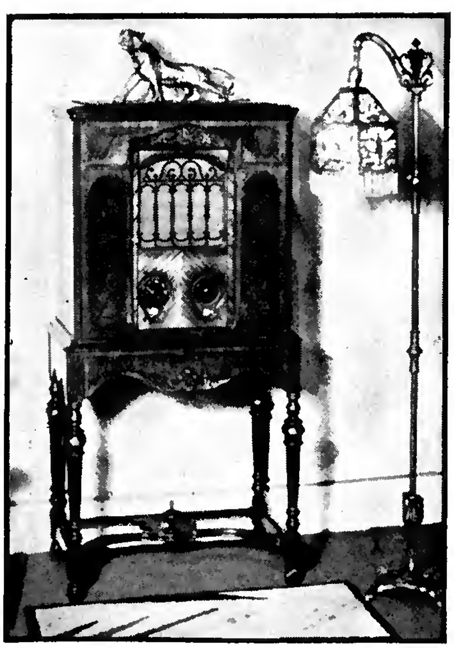
The second device is the Bedell-Reich Stabilized Oscilloscope. The oscilloscope may be used in the varied fields of investigation in which the vibrating mirror or cathode-ray oscillograph is used.

THE TRUTONE RADIO SALES COMPANY, 114–116 Worth Street, New York City, has placed on the market the "Si-len-ser," a device for use between the light socket and the radio set to eliminate line noises.

A NEW DYNAMIC loud speaker switch is being made by the Therm-A-trol Manufacturing Company. This device is designed for use in conjunction with a.c. receivers which are being operated in conjunction with a separate a.c. dynamic loud speaker. By the use of this special switch the power input to both the set and the dynamic loud speaker can be controlled by means of the single switch on the receiver.

FERRANTI, INCORPORATED, makes two output transformers designed to connect between the moving coil of a dynamic loud speaker and a power tube. The type OP-2C is designed for use with single tubes of all types and the OP-4C is for use in push-pull circuits. An article telling how and when to use such transformers will be found on page 194 of RADIO BROADCAST for January, 1929.

PROBABLY THE SIMPLEST way to make it posible to get more output from a radio set without overloading the last tube is to place two power tubes in parallel in the output stage. A device to permit this to be accomplished readily is being manufactured by Arthur H. Lynch, Inc., and is called the Lynch Tubadapta. It consists of two tube sockets mounted in a convenient holder that can be plugged into the power-tube socket of any receiver.



The new Atwater Kent receiver in a console cabinet with built-in loud speaker

NEW LOUD SPEAKERS known by the trade name of Conamic are being made by the Operadio Manufacturing Company. Various models are available ranging in price from $28.00 to $32.50. Special loud speaker chassis are available for use in manufactured receivers.

THE EXCELLO PRODUCTS CORPORATION, of 4820 West 16th Street, Cicero, Illinois, are manufacturers of Excello cabinets for use with all types of radio receivers. There are available also special cabinets designed especially for well-known receivers such as the Atwater Kent, Crosley, Radiola, etc.

THE NEW S-M dynamic loud speaker units are being offered in two models; the type 850 for a.c., and the type 851 for d.c. field excitation. Hum in the a.c. model has been eliminated by supplying the field with 120 volts from a 280-type full-wave rectifier. Across the output of the rectifier is connected a 2-mfd. filter condenser which, in conjunction with the field coil, completely filters the output so that only pure d.c. flows through the field winding. The loud speaker is equipped with a 229-type coupling transformer so that the loud speaker may be used with all types of tubes. The 850-type a.c. unit is priced at $58.50 and the 851-type d.c. unit at $48.50. Only the loud speaker unit itself can be obtained, i.e., they are not sold in cabinets.

Radio Industry Briefs

WITH the sale of station WABC to the Columbia Broadcasting chain, the New York offices of A. H. Grebe and Co. have been moved from West 57th Street, New York, where they were combined with the offices and studio of WABC. The Grebe executive offices are now at the factory in Richmond Hill, Long Island, New York.

HAL P. SHEARER, formerly general manager of the Splitdorf Radio Corp., of Newark, N. J., has been chosen vice-president and general manager of the new Sleeper Radio and Mfg. Corp., Long Island City, N. Y. A. N. Clifton, formerly sales manager of the Alden Manufacturing Company, is sales manager of the reorganized Sleeper Company.

GUY C. KOWFELDT, 529 South 7th Street, Minneapolis, Minn., and E. F. Coughlin, 10 High Street, Boston, Mass., were recently appointed district managers for the deForest Radio Company. They will coöperate with jobbers and dealers in their territories.

ALBERT L. SCOTT, formerly with the Girard Phonograph Company, Edison distributor in Philadelphia, has been appointed manager of the Atlanta, Ga., branch of the Edison Distributing Corp.

MERWYN HEALD is the new chief engineer of the Thordarson Mfg. Co., of Chicago. Mr. Heald was formerly chief engineer of the Robertson-Davis Co., of Chicago. The new Thordarson executive was graduated in E. E. from Northwestern where he was a member of both Sigma Xi and Phi Beta Kappa. Thordarson has also announced an increase in their factory space and additional research and production is now contemplated.

THE GENERAL CONTRACT PURCHASE CORP., New York, has issued the third edition of their catalog of R. C. A.

licensed receivers, prices, and number and type of tubes employed. Among the licensed sets listed, the following companies not themselves holding an R.C.A. license are shown to supply sets: Brunswick Phonograph Co., Buckingham Radio Corp., Bush & Lane Piano Co., S. Freshman, Graybar Electric Co., National Carbon Co., Sonora Phonograph Co., and Victor Talking Machine Co.

THE SPRING MEETING of the National Electrical Manufacturers Association will be held at the Homestead, Hot Springs, Va., May 20–25, 1929.

A CLEVELAND BRANCH of the Thordarson Manufacturing Co., has been opened at 520 Citizens Bldg., with C. M. Hendricks in charge.

THE MANUFACTURING activities of the Chas. Freshman Co. and the Freed-Eisemann Radio Corp., will be combined in a new factory to be located in Clifton, N. J., 12 miles from New York, according to a recent announcement of C. A. Earl, head of the two concerns.

THE KELLOGG SWITCHBOARD AND SUPPLY CO., of Chicago is now licensed under the patents of the Radio Corporation to make receivers. The license was granted as of January 1, 1929. A complete list of RCA set licensees will appear in a subsequent issue of this magazine.

THE BREMER-TULLY MANFACTURING CO., has just received a receiver license under the Hazletine and LaTour patents.

THE NEW RECEIVER manufacturing plant of the Temple-Sleeper Corp., is located at 5253 West 65th Street, Chicago. A. Marchev is president of the new company.

THE FACTORY OF Colin B. Kennedy, Inc., is being moved from Highland, Ill., to South Bend, Ind. It is said that the Kennedy company has merged with the Studebaker Co., of South Bend and plans to market sets through mail order channels.

THE EBERT FURNITURE CO, Red Lion, Pa., is now offering a line of high-quality cabinets at popular prices. A. Irving Witz and M. J. Polikoff have been appointed national sales agents. Mr. Witz was formerly eastern representative for Bremer-Tully and the Webster Co., of Chicago, and the Fidelity Radio Corp., of Salt Lake City. He is now also vice president and sales manager of the Argon Tube Corporation, Newark N. J.

PRICE reductions on ten types of R.C.A. tubes were announced on February 15th by the Radio Corporation of America. Radiotron UX-226 is reduced to $2.00, UY-227 to $3.00, UX-280 to $3.50, UX-281 to $7.25, UX-112A to $2.50, UX-250 to $11.00, UX-199 to $2.00, UX-171A to $2.50, UX-200A to $3.50, and UX-201A to $1.40.

Technical Notes

VARIABLE condensers of all types for use in the manufacture of receivers are made by the Precise Products, Inc. Single or gang condensers can be obtained with maximum capacities of 0.0005, 0.00035, or 0.00025 mfd. Relative to the accuracy of these condensers, the following data was received from A. deFord, sales manager.

"We hold the accuracy of our condenser to within three mmfd. plus or minus over the entire range. All of our production condensers are calibrated in five different positions using the resonance method. The tolerance we have specified above is closer than some manufacturers demand.

"We are building group condensers with as many as 5 to a gang, and the returns on these condensers have been less than one half of one per cent."

PRODUCTION TESTS ON Durham Metallized Resistors have been made more severe to make certain that the units have an ample safety factor, According to a recent release from the International Resistance Company, all Durham Metallized Resistors are "flash" tested for five minutes at a load of twice the normal rating of the unit.

The Radio Dealer's Note Book—No. 2 Voltage-Control Devices

ACCURATE summaries of useful information are constantly of value to those radio folk who deal with the public. This sheet, one of many such on various subjects to follow, sets down collected information on voltage-control devices. The dealer or serviceman can remove this part of the page for his notebook or he can have it photostated in any number of copies.

A.C. line voltages throughout the country are not constant. When an a.c. set is installed the dealer must make whatever adjustments are necessary to permit the set to operate at maximum efficiency at the particular value of voltage at the socket to which the set is connected.

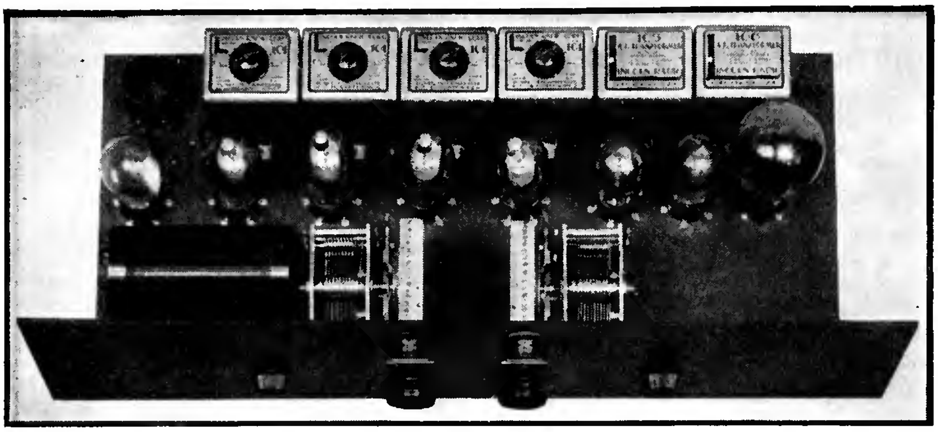
This adjustment may be accomplished readily with those sets supplied with several taps on the power transformer. In such a case the proper procedure is to make measurements with an a.c. voltmeter to determine the maximum voltage at the light socket. The tap on the transformer is then adjusted for operation at this voltage.

All receivers are not supplied with taps on the power transformer and in other cases it may be found that the taps available do not in some instances permit a wide enough adjustment; for example, a set might have taps to permit operation on line voltages up to 115 volts but by test it may be found that the line voltage is at times as high as 125 volts. In such a case it is necessary to install some device to reduce the line voltage to 115 volts. A complete list of the adjustable line voltage control devices made for this purpose is given in the table below.

These devices which are either fixed or variable resistors are generally mounted in some convenient manner so that they may be connected readily between the light socket and the power lead from the set. Whether a fixed or variable resistor is used depends upon various factors. Most radio owners are not particularly interested in the mechanics of the set and don't want to be bothered by having to adjust a line voltage control device from time to time. For this reason a fixed resistance of the proper value should be used whenever possible. This is quite satisfactory where the voltmeter test of the line voltage shows the supply to be high but uniform. If the test shows that the voltage varies over wide limits, sometimes being high, sometimes normal and at other times quite low, it is best to install one of the devices containing a variable resistance so that the amount of line-voltage compensation can be adjusted as necessary by the owner of the set. The second thing to do if the line voltage is found to undergo wide variations is to write a good stiff complaint to the power company.

Space limitations do not permit us to go into detail regarding how to determine what size resistance to use under different conditions but fortunately the various companies manufacturing these devices can supply excellent charts showing just what resistance to use. This information should be in the hands of all dealers and servicemen. A note to RADIO BROADCAST written on your business stationery will bring to you complete data on all the devices listed in the following table.

Mfgr.	Type No.	Price	Characteristics				Remarks
			Fixed Resistor		Variable Resistor		
			Ohms	Wattage	Ohms	Wattage	
Aerovox	997	1.50	3 to 75	60			
Central Radio Laboratories	Control Box	3.00					Mounted in a metal box with socket and input power lead
Clarostat Mfg. Co.	Power Clarostat	3.50			0–10 25 to 500	40 40	
DeJur-Amsco Corp.	Voltage Regulator No. 360	12.50					Mounted in a metal box with socket, input lead, and a.c. voltmeter to permit accurate adjustment to 110 volts
Insuline Corp. of America	Resistovolt Light-Duty Resistovolt Heavy-Duty	1.75		125 250			
Thermatrol Mfg. Co.	Voltage Control	1.75			30	75	Consists of small device to plug into light socket. Four adjustments for voltages from 110 to 125 volts
Ward Leonard Mfg. Co.	507–63 507–59 507–83 507–96 507–39 507–41 507–43 507–44 507–45 507–97 507–98 507–99 507–100 507–101	5.50 5.50 5.50 2.00 2.00 2.00 2.00 2.00 2.00 2.00 2.00 2.00 2.00 2.00	 2.5 3.5 5.0 7.0 10 12.5 15.0 22 31 45 62	 60 60 60 60 60 60 60 60 60 60 60	50 20 12.5	60 60 60	Which size resistor is used depends upon the line voltage and the current drawn by the set. A complete chart is available indicating what resistor to use.
Wirt Company	No. 211 No. 211-a	2.25 3.25				65 150	Mounted in a convenient unit to plug into the light socket
X-L Radio Labs.	X-L Link	5.75					Mounted in a metal box with socket and input power lead



Interior view of the new Hollister a.c.-operated super-heterodyne

Licensees of the Technidyne Corporation

THE Technidyne Corporation, 644 Broadway, New York, headed by Lester Jones, has informed RADIO BROADCAST of the following licensees under their patents:

RECEIVER CIRCUITS

Continental Radio Corporation, Fort Wayne, Ind., makers of Slagle Receivers. Sets made by this company embody the so-called "feed-forward" Technidyne circuit.

Sparks-Withington Company, Jackson, Michigan, makers of the Sparton Receiver. Sets made by this company employ the Jones "Equase" circuit.

The A-C Dayton Company, Dayton, Ohio. A new Technidyne licensee who plan to market a set with the "Equase" circuit during 1929.

OTHER LICENSEES

Electrad, Inc., New York, manufacturers of the "Royalty" variable resistor under Technidyne patents. A new type of variable resistor developed by the Technidyne Corp. will be marketed by Electrad also.

Electro-Motive Engineering Corp., New York, makers of Elmenco fixed resistors.

De Jur-Amsco Corporation, New York, makers of fixed resistors under Jones patents.

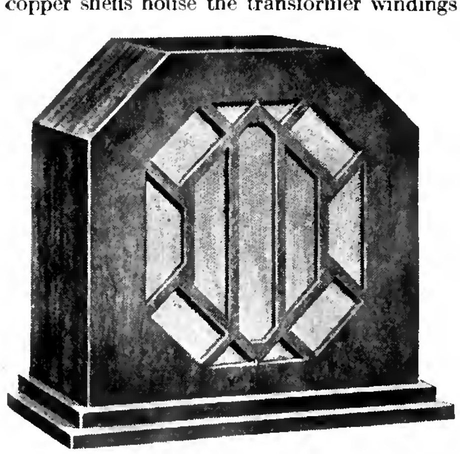
The Hollister AC8 Super-Heterodyne Kit Receiver

IN CIRCUIT and general layout the Lincoln Radio Corporation's new kit, the Hollister AC8, is similar to the former Lincoln 8-80 except that the new kit is designed for complete a.c. operation, the original 8-80 being a d.c.-operated set. The Lincoln Corporation advises us that they have obtained excellent results from this set, finding it possible from their location in Chicago to tune-in a station at practically every degree on the dial. A description of the new AC8 has been received from the Lincoln Corporation and the essential details of the circuit are given below.

The receiver is tuned by variable condensers independently operated by two illuminated drum dials. All wiring is done beneath sub-base, which is composed of bakelite, eliminating possible shorts, and creating good insulation for all component parts. Substantial double-contact sockets are assembled in bakelite base ready for wiring.

The tubes employed are as follows: oscillator, 227-type; first detector, a.c. screen-grid tube, 222 a.c.-type; three intermediate stages, a.c. screen-grid tubes, 222 a.c.-type; second detector, 227-type; first audio, 227-type; second audio, 210- or 250-type.

The type-101 tunable intermediate transformers are used in the a.f. stages. Heavy copper shells house the transformer windings and variable condenser. The Clough system is used in the audio amplifier.



The new Conamic loud speaker manufactured by the Operadio Manufacturing Co.

An output transformer—Lincoln No. 107—may be mounted at right-hand side of base when the set is used with a loud speaker that is not equipped with an output transformer. The output transformer is not included in the standard kit, as the majority of dynamic loud speakers already have an output transformer incorporated in them.

The power equipment for the Hollister AC8 is in a very compact crystalline-finished case and it supplies 45 volts, 135 volts, and 450 volts B; 7½ volts a.c., and 2¼ volts a.c. One 281-type tube is used as rectifier.

The operation of the set is simple. The two dials track evenly throughout the broadcast range. A single volume control, composed of a 3000-ohm potentiometer controlling the 45 volts applied to the screen-grid tubes, is the only other adjustment necessary for tuning.

List of Parts

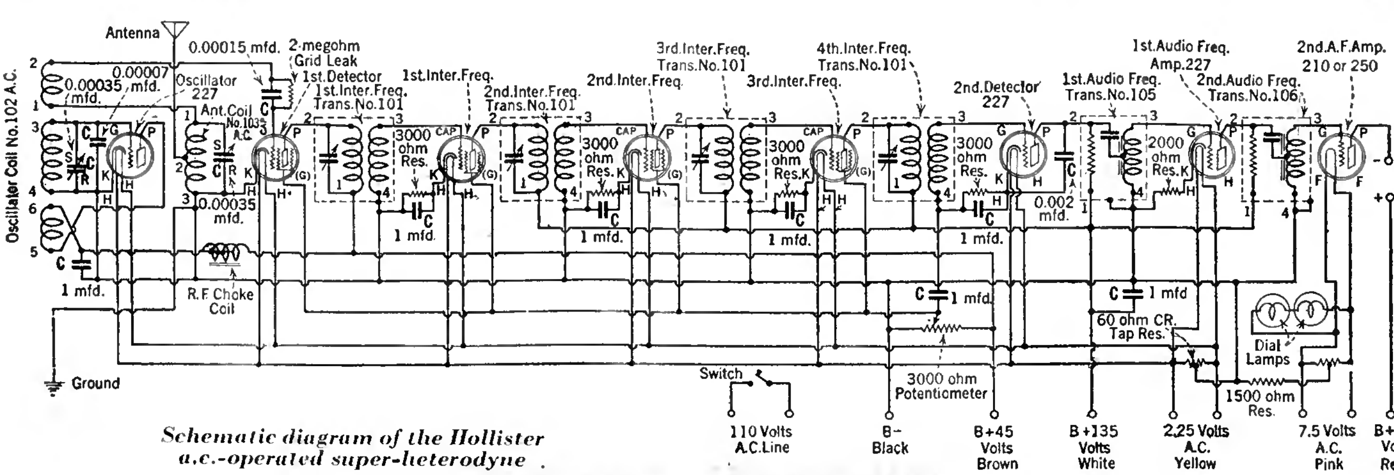
One No. 102AC oscillator;
One No. 103AC antenna;
Four No. 101 i.f. transformers;
One No. 105 a.f. transformer;
One No. 106 a.f. transformer;
Two .00035-mfd. condenser, Precise;
One Sub-base and socket assembly, completely drilled;
Two Sub-base supports;
Two Illuminated drum dials and windows;
One Front Lithographed panel;
Two Binding posts;
Seven 1-mfd. condensers;
One TP-3-M 3000-ohm potentiometer, Carter;
Four 3000-Ohm resistors, Electrad;
One 2000-Ohm resistors, Electrad;
One 1500-Ohm resistor, Yaxley;
Two CU60 center-tapped resistors, Carter;
One S-M No. 275 choke;
One .00015-mfd. condenser with clips, Aerovox;
One 2-Megohm grid leak, Aerovox;
One Sangamo .00007-mfd. condenser;
One .002-mfd. by-pass condenser, Aerovox;
One Carter 110-volt a.c. switch;
Two Tip Jacks;
One Terminal strip, Jones;
One Battery cable, Jones;
Two Knobs for potentiometer and switch;
One Set hardware and wire;
One Set of blueprints;
One Small panel for console (optional).

The kit of parts for the Hollister AC8 list at $110. The power unit for the set lists at $60.

The S-M Screen-Grid A.C. Kit Receiver

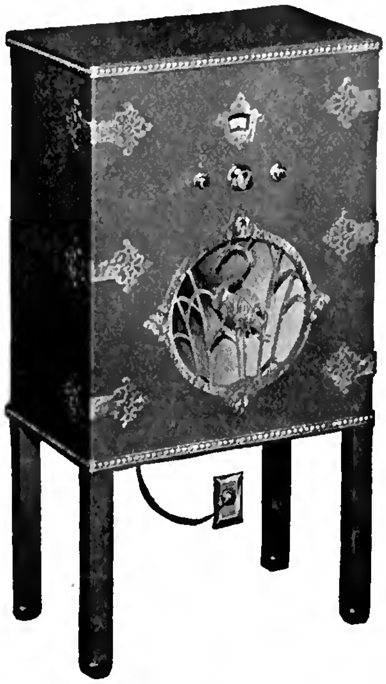
THE S-M model 720AC Screen-Grid Six is the newest kit being manufactured by the Silver-Marshall Company. H. R. Randall of this company has supplied us with the following details regarding this new receiver.

The model 720 AC is a six-tube a.c.-operated screen-grid receiver, available either as a kit for home assembly or as a custom-built set. It employs three r.f. stages, each using one of the new 224-type a.c. screen-grid tubes, a 227-type detector tube, and two stages of Clough-system a.f. amplification. In the second a.f. stage is found the new 245-type power tube delivering over 1.6 watts of undistorted power output. Four tuned circuits, effectively shielded, and controlled by two tuning dials (the antenna-stage condenser is separate from the three-gang condenser tuning the second, third, and detector stages) enables all tubes to be operated at full efficiency and eliminates the loss (or, at best, small gain) attendant upon the usual untuned "dummy" r.f. stage used to permit single-control operation. As both dials track very closely, the two dial feature is not a drawback to simple operation, while it is a very great



Schematic diagram of the Hollister a.c.-operated super-heterodyne

THE NEW CROSLEY GEMCHEST



Chinese Chippendale Cabinet design in three colors, Mandarin Red, Manchu Black and Nanking Green. Contains seven-tube Gembox shielded receiver (three tubes radio amplification, detector, two audio tubes and rectifier) and the dynamic Crosley Dynacone power speaker (built on a different principle of armature actuation.) Without tubes $94.

THE CROSLEY RADIO CORP.
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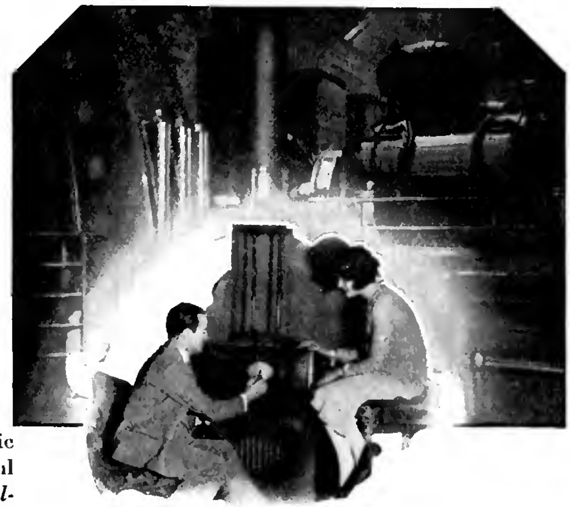

THE radio listening public is entitled to powerful volume plus undistorted *quality* output. Radio engineers and radio set manufacturers have worked steadily toward this result, constantly endeavoring to simplify radio construction. Simplicity without the loss of effectiveness is the keynote of engineering progress.

Now Arcturus announces two new tubes that definitely improve both volume and tone quality. They add new power to any A-C set, yet keep the reproduction clear and undistorted.

These two tubes are the No. 122 Shield Grid Tube and the No. 145 Power Tube. Both operate from a 2.5 volt a.c. filament heater potential. A specially prepared technical bulletin on these new tubes will be sent on request.

[Engineering Facts Have a Utility Significance to the Broadcast Listener]

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ARCTURUS RADIO TUBE COMPANY ~ Newark, N. J.

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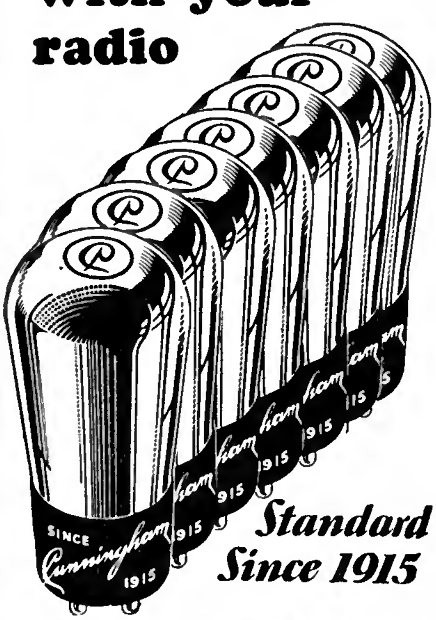

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The Type 320 Test Oscillator supplies a modulated signal at 1,400 and 640 kilocycles in the broadcast band and at 180 kilocycles for testing of an intermediate-frequency amplifier.

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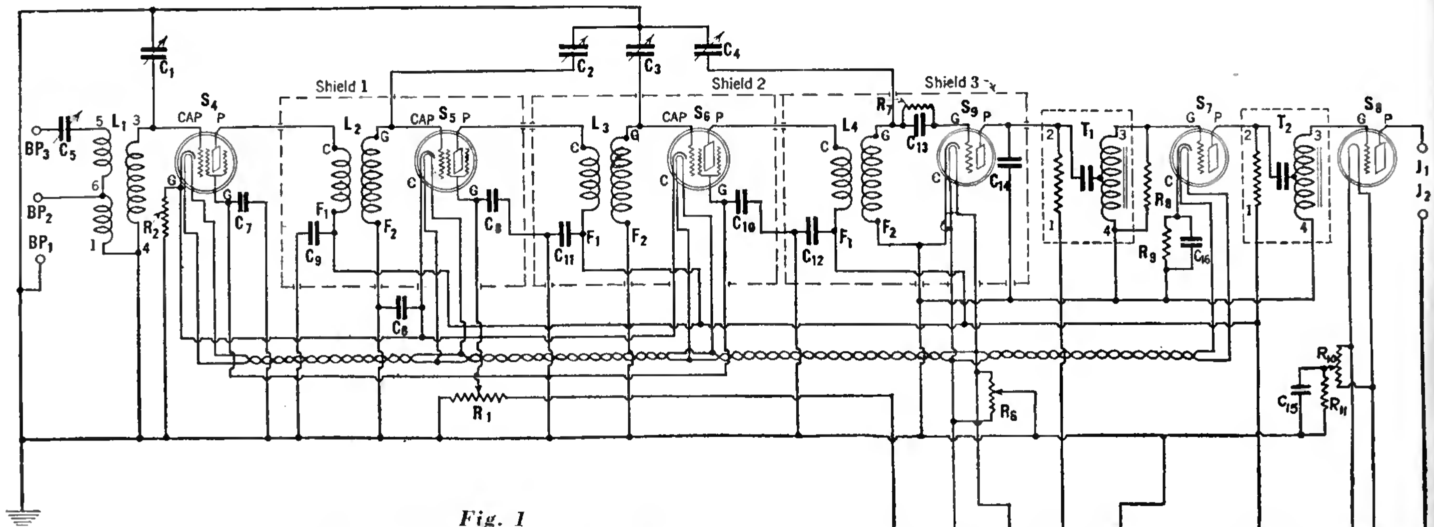


Fig. 1

Schematic diagram of the new S-M. six-tube a.c.-operated screen-grid receiver

aid in obtaining maximum results in the way of sensitivity and selectivity.

Actual measurements on a single r.f. stage show a gain of about 14 at 550 kc. and about 28 at 1500 kc. Each r.f. stage employs one 224-type a.c. screen-grid tube, together with an r.f. transformer consisting of a secondary of 98½ turns of No. 29 enamelled wire wound upon a threaded moulded-bakelite form 1½" in diameter and 1½" long, with a primary consisting of 35 turns of No. 38 enamelled wire upon a 1¼" tube located at the filament end of the secondary. From the antenna coupling system a voltage gain of about 60 is obtained.

From the picture, the r.f. amplifier section is seen to consist of a large antenna coil tuned by a single .00035-mfd. condenser and provided with a tapped primary and with a 75-mmfd. antenna series condenser for selectivity control. This coupler feeds the grid circuit of the first screen-grid r.f. amplifier which, in turn, feeds into three almost identical shielded r.f. circuits, each housed in a small copper can. Each of these stages employs the small r.f. transformer described above which is tuned by a section (equipped with individual compensator) of the three-gang die-cast condenser. In the two left-hand shields are the second and third screen-grid r.f. amplifiers, and in the right-hand shield the 227-type detector. By-pass condensers are contained in each stage shield to localize r.f. current paths. Volume control for the receiver is affected by means of a 3000-ohm potentiometer arranged to control the screen-grid potential of the three 224-type r.f. amplifier tubes.

The heaters of screen-grid and detector tubes are operated in parallel and are fed from a 2.5-volt winding of the transformer contained in the power supply for the receiver, and which furnishes A, B, and C power to the entire set.

The audio amplifier employs the well-known Clough audio system in two stages with a 227-type tube in the first stage, and a 245-type tube in the output stage. In its frequency-versus-amplification curve, as given on this page, it will be seen that it is extremely satisfactory over the frequency range involved in reproduction of music and speech.

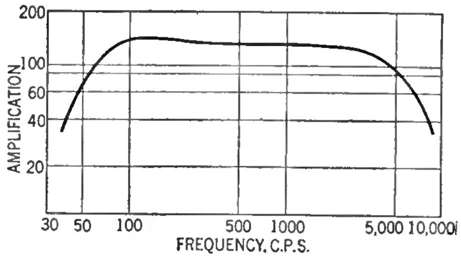


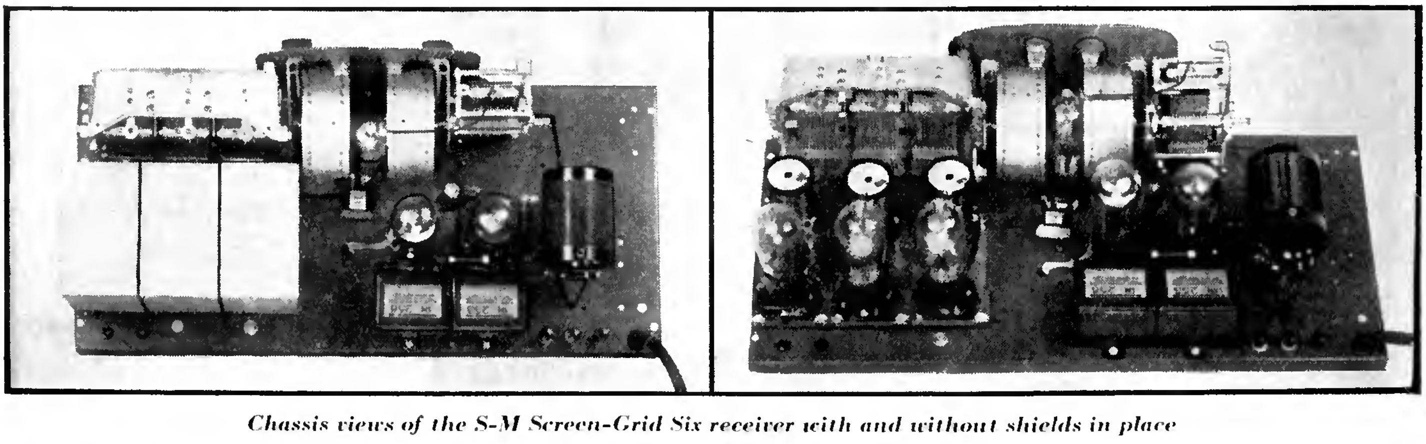
Fig. 2

No output transformer is supplied in the receiver, though space is left for the inclusion of such a device. This omission is justified on the ground that the builder will generally employ one of the better types of dynamic loud speakers, and such loud speakers are ordinarily equipped with output transformers. Should this not be the case, and should a magnetic loud speaker, or other type not equipped with output transformer, be used with the set, an output-coupling device, such as a transformer or choke and condenser filter, must be connected between set and loud speaker to prevent the high plate current of the 245-type power tube from damaging the loud-speaker windings. The undistorted power output of 1.6 watts is sufficient to provide adequate fidelity and sufficient volume.

Inasmuch as complete constructional data for this receiver may be had from the manufacturer offering the kit, space will not be taken to present it here. Constructional pamphlets may be had upon application directly to this magazine. The parts required for the construction of the receiver are as follows:

List of Parts

C_1 One S-M condenser, 0.00035-mfd., type 320R;
C_2, C_3, C_4 One S-M three-gang condenser, 0.00035-mfd., type 323;
C_5 One S-M midget condenser, 0.000075-mfd., type 342 B;
C_6, C_{15} Two Potter condensers, 1-mfd., type 104;
C_7-C_{12}, C_{16} Seven Sprague condensers, 0.25-mfd.;
C_{13}, One Polymet grid condenser, 0.00015-mfd.;
C_{14} One Polymet by-pass condenser, 0.002-mfd.;
L_1 One S-M antenna coil, type 140;
L_2, L_3, L_4 Three S-M plug-in r.f. transformers, type 132A;
S_1- S_7, S_9 Eight S-M tube sockets, five-prong, type 512;
S_8 One S-M tube socket, four-prong, type 511;
T_1 One S-M a.f. transformer, first-stage, type 255;
T_2 One S-M a.f. transformer, second-stage, type 256;
J_1, J_2 Two Yaxley tip jacks, insulated, type 420;
R_1 One Yaxley midget potentiometer, 3000-ohm, type 53000;
R_2 One Yaxley resistor, 150-ohm;
R_6 One Carter sub-base rheostat, type A6;
R_7 One Polymet grid leak, 2-megohm;
R_8 One Durham resistor, 0.15-megohm;
R_9 One Yaxley resistor, 1500-ohm;
R_{10} One Yaxley resistor, center-tapped, type 840C;
R_{11} One Ohmite resistor, 1500-ohm;
One S-M universal pierced chassis, type 701;
One S-M dual-control escutcheon, type 809;
Two S-M vernier drum dials (one left and one right), type 806;
Three S-M copper stage shields, type 132A;
Three moulded binding posts;
Miscellaneous hardware, battery cable, hook-up wire, etc.



Chassis views of the S-M Screen-Grid Six receiver with and without shields in place

The *Radio Broadcast* LABORATORY INFORMATION SHEETS

By HOWARD E. RHODES

THE aim of the Radio Broadcast Laboratory Information Sheets is to present, in a convenient form, concise and accurate information in the field of radio and closely allied sciences. It is not the purpose of the Sheets to include only new information, but to present practical data, whether new or old, that may be of value to the experimenter, engineer, or serviceman. In order to make the Sheets easier to refer to, they are arranged so that they may be cut from the magazine and preserved, either in a blank book or on 4" x 6" filing cards. The cards should be arranged in numerical order.

Since they began, in June, 1926, the popularity of the Information Sheets has increased so greatly that it has been decided to reprint the first one hundred and ninety of them (June, 1926-May, 1928) in a single substantially bound volume. This volume, "Radio Broadcast's Data Sheets," may now be bought on the newsstands, or from the Circulation Department, Doubleday, Doran & Company, Inc., Garden City, New York, for $1.00. Inside each volume is a credit coupon which is worth $1.00 toward the subscription price of this magazine. In other words, a year's subscription to RADIO BROADCAST, accompanied by this $1.00 credit coupon, gives you RADIO BROADCAST for one year for $3.00, instead of the usual subscription price of $4.00.

—THE EDITOR.

No. 273 RADIO BROADCAST Laboratory Information Sheet **April, 1929**

Neutralizing and Compensating R. F. Circuits

PROBABLY two of the most common tasks which servicemen are called upon to perform are the adjustment of the neutralizing and compensating condensers in tuned r.f. receivers. These tasks are exceedingly important although not especially difficult.

If a set is not neutralized properly it will oscillate on some wavelengths, especially down around 200 or 300 meters. Therefore, if a set does oscillate it is necessary to reneutralize the various stages. This should be done in an orderly fashion, starting with the stage nearest the antenna and following with the other stages in order. Also, all servicemen should be equipped to perform these adjustments quickly on all receivers, and in this connection specially prepared tubes of the types used in r.f. amplifiers, the 201A, 226, and 227, are a great aid. These tubes are prepared by cutting off as close to the base as possible one of the filament prongs, in the case of a 201A- or 226-type tube, and one of the heater prongs in the case of the 227-type tube.

In adjusting a receiver tune-in a strong local station broadcasting on some wavelength between 200 and 300 meters, carefully tuning the dials to exact resonance. Then, with the prepared tube placed in the first r.f. socket in place of the good tube, carefully adjust the first neutralizing condenser to that position which gives the minimum signal from the loud speaker. Then remove the prepared tube, and replace the good tube. Now put the prepared tube in the second r.f. stage and repeat the operation, etc.

The compensating condensers in a receiver are placed across the main tuning condensers and function to compensate the slight differences in capacity between the various stages so that all the tuned circuits will be in exact resonance. Compensation should also be done with the set tuned to some station around 250 meters. When compensating a set it is best to tune-in some weak station, since slight changes in volume will then be noticeable more readily. The exact procedure is as follows. First tune-in a weak signal to maximum volume and then adjust all the compensating condensers to give the maximum signal strength. Retune the main dial to the point of maximum volume and then readjust the compensating condensers again.

No. 274 RADIO BROADCAST Laboratory Information Sheet **April, 1929**

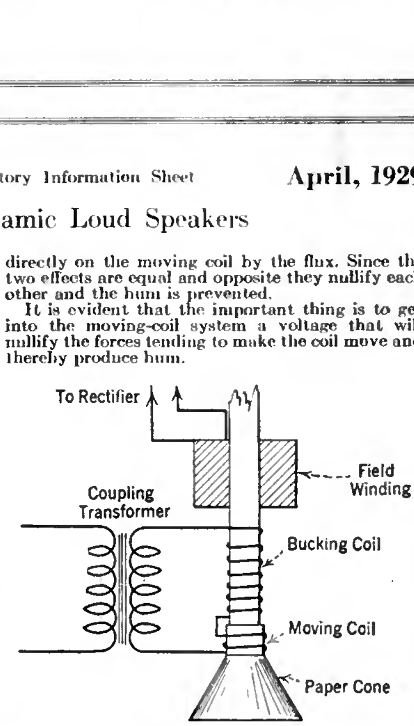
Bucking Coils in Dynamic Loud Speakers

MANY a.c. dynamic loud speakers use "bucking coils" to reduce the hum due to the use of rectified but poorly filtered a.c. to supply the field current. This bucking coil functions as follows.

Referring to the diagram, the bucking coil is connected in series with the moving coil and the secondary of the coupling transformer. The moving coil is, of course, fastened to the diaphragm. The bucking coil is wound around the pole piece of the electro magnet.

Now, since the rectifier supplies to the field a pulsating current, it follows that the magnetic flux produced by this current will also fluctuate. Since the moving coil is in the field of this flux, there will be a reaction between it and the varying magnetic flux and the coil will tend to move—and its movements would have the same frequency as that of the field current. If the diaphragm moves, sound is produced and as a result we would get an audible hum. The effect of the pulsating field current is, however, nullified (more or less) by the bucking coil. The coil is also in the magnetic field and it, therefore, has induced in it a voltage corresponding in frequency to that of the pulsating field current. This voltage induced in the bucking coil sends a current around the circuit consisting of the transformer, the moving coil, and the bucking coil. The magnitude of this current is such that its effect on the moving coil is equal and opposite to that produced directly on the moving coil by the flux. Since the two effects are equal and opposite they nullify each other and the hum is prevented.

It is evident that the important thing is to get into the moving-coil system a voltage that will nullify the forces tending to make the coil move and thereby produce hum.



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ROBERT S. KRUSE

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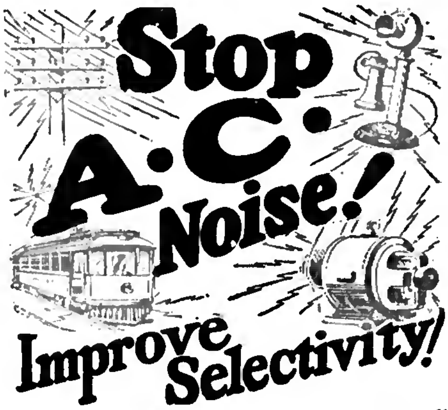
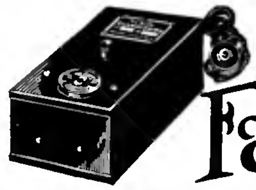


PLUG in a Falck Claroceptor between wall socket and radio set and eliminate "static" from motors, street cars, telephones and electrical appliances. This new improvement by a pioneer radio parts manufacturer grounds and thus blocks out line interference noise and radio frequency disturbances. *Also improves selectivity and distance.* Requires no changes in set. Measures just 3½ x 5½ x 2½ inches. Thousands now all over America use the Claroceptor for clearer A. C. reception. Get one right away—at radio parts dealers. Write for descriptive folder.



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type .06 (5x6½x7½)	20.00
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MICROPHONE TRANSFORMER (3x3x3½)	18.00
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P.M.S. portable (12x32x22)	225.00
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We furnish the complete installation or any part of the equipment as desired.

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The Sign of Enduring Quality

No. 275 Radio Broadcast Laboratory Information Sheet April, 1929

Obtaining Grid Bias from B-Power Units

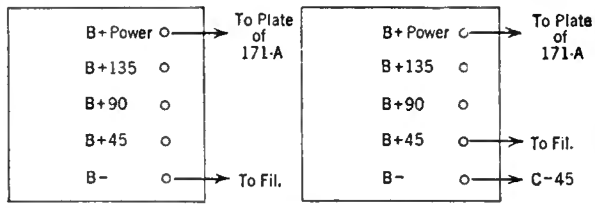
BOTH B and C potentials for a 171A tube may be obtained readily from a simple B-power unit without adding any resistors or condensers to the circuit; it is simply necessary to change a few connections.

Sketch A on the sheet shows an ordinary B-power unit and the connections which would be made to it if it were to supply only plate potential to the 171A power tube. Sketch B shows the connections if it is to supply C potential as well.

In these diagrams it should be noted that the connection of negative filament from the regular B-minus terminal on the power unit has been changed to the + 45-volt terminal. With this arrangement the + 45-volt terminal then becomes B minus, the plus 90 volt terminal becomes plus 45 and so on, each terminal supplying 45 volts less than it is marked. The regular B-minus terminal is now 45 volts lower in potential than the new B-minus terminal, and, therefore, from the regular B-minus terminal we are able to secure a negative potential of 45 volts which we can apply to the grid of the 171A-type tube. In this way we have, by a simple circuit change, made it possible to obtain C bias for the power tube.

Forty-five volts is slightly higher than normal, but not sufficiently so to affect seriously the output from the tube. This slightly higher than normal bias will help to lengthen the life of the tube.

The arrangement described above can be applied only to those B-power units capable of supplying under load a maximum of about 225 volts. This much voltage is necessary because 180 volts are required on the plate and 45 volts are used to supply C bias. With this arrangement 45 volts are obtained from the tap that normally supplied 90 volts and 90 volts are obtained from the tap that ordinarily supplied 135 volts.



(A) (B)

No. 276 Radio Broadcast Laboratory Information Sheet April, 1929

Simple Two-Way Telephone Set

IN THE country friends who live some miles apart often wish to establish a telephone communication channel without the expense of installing a regular pole line. Lieutenant W. H. Wenstrom, U. S. A., suggests the following simple method of building such a communication system.

As can be seen from the diagram given in Laboratory Sheet No. 277 the set is simplicity itself. It is essentially a radio receiving tube (a 199-type tube is satisfactory) provided with input and output transformers. The best ratios are somewhere around 1:6 for the input and 3:1 for the output. The microphone may be an old, discarded telephone "mike."

Two sets are, of course, required for one communication channel. Due to the economy of apparatus, radiophone practice must be used in operation. A definite time for communication is arranged in advance. At this time "A" calls and "B" listens. When "A" finishes calling, both operators throw their switches, and "B" then answers "A." The procedure might be compared to two unusual people carrying on a conversation where each one politely waits until the other has finished before he himself begins.

Because two stages of audio-frequency amplification are used in the talking circuit, one at the sending end and one at the receiving end, the connecting wire line may be very much poorer than a standard telephone line. Continuous fence wire, or any medium-resistance metal circuit fairly well insulated from the ground may serve as one conductor, with the ground as the other conductor.

Parts Required

1 Audio transformer, 6:1-ratio
1 Audio transformer, 3:1-ratio. (connected reversed)
1 Four-pole double-throw switch
1 Microphone, telephone-type
1 Pair of headphones
1 199-type tube and socket
A battery, fil. ballast and fil. switch
B battery, 45 volts

The four-pole double-throw switch changes the set from "send" to "receive." It saves expense by permitting the use of the same tube and transformers for both operations.

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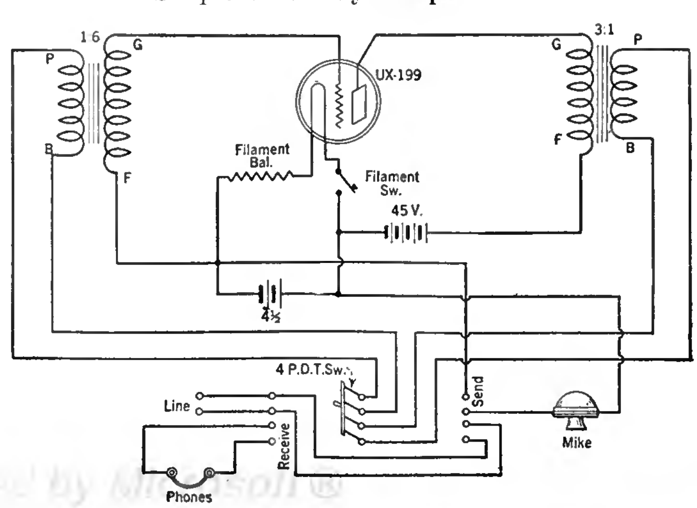

PAM 16 or 17. List Price without tubes, $125.00

The installation, the dealer and the PRODUCT

Foreseeing the business possibilities of educational broadcasts, Harold Batchelder, proprietor of the Garden City Radio Company, Newtonville, Massachusetts, installed in the Frank A. Day Junior High School, Newtonville, a receiving set and "PAM" amplifier, which proved to be the forerunner of many other school installations he has made.

Other radio dealers have foreseen the possibilities of "PAM" amplifiers not only for this use, but for many other purposes, and are working hard on this *profit-making non seasonal item.*

What do you foresee?

The PAM-17 is identical with the PAM-16 except that it furnishes in addition field current for a dynamic speaker designed to have its field energized by 90 to 165 volts direct current. For all other types of speakers, including dynamics, having their field energized from storage battery or AC 110-volt, 60-cycle, use the PAM-16. Both amplifiers are designed to operate from 105 to 120 volts, 50 or 60 cycles AC.

Write for handsome folder R B-6 describing the above and other PAM Amplifiers which are also a "Sound Investment."

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